Irish Science Teachers' Association

Eol-Oidí na hÉireann

Report presented to the Minister for Education and NCCA in response to the 2023 draft specifications (syllabi) in Leaving Certificate Biology, Chemistry and Physics

Report prepared by the Biology, Chemistry and Physics Committees of the Irish Science Teachers' Association

February 2024

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Foreword

As President of the Irish Science Teachers' Association I am acutely aware of the important role that the ISTA plays in science education in Ireland. As the professional body representing science teachers in Ireland, the ISTA represents over 1,200 teachers throughout the country. In my role as ISTA President I have witnessed at first hand the enormous dedication and commitment shown by ISTA members who, in a voluntary capacity, work to help their fellow science teachers. All ISTA activities are carried out in somebody's spare time and this is one of the great strengths of the ISTA.

We are now at an important stage in the development of science education in Ireland as three new draft syllabi or specifications in Biology, Chemistry and Physics have recently been published by the NCCA for discussion and feedback. The ISTA has been to the forefront of the consultation process of its members and has run three very successful continuing professional development online seminars attended by 648 science teachers. These seminars helped to obtain feedback from the teachers "on the ground" who will be tasked with the challenge of ensuring that these three new syllabi will be successfully implemented in the classroom and in school science laboratories throughout Ireland.

In addition to the online seminars, the ISTA has also issued a detailed questionnaire to its members in order to obtain feedback on the draft syllabi. A total of 320 questionnaires have been completed by science teachers to date. This report contains an analysis of all feedback gathered from teachers who participated in the online seminars and those who completed the questionnaire. This report summarises and synthesises the feedback from these teachers.

I commend the initiative of the ISTA in carrying out this comprehensive process to ensure that the voice of science teachers is clearly heard. It is vital that the Leaving Certificate subjects of Biology, Chemistry and Physics continue to attract the best students in the country. Therefore, it is important that the new syllabi are of the highest standard and are designed according to international best practice in curriculum design. I hope that the voice of ISTA is listened to when finalising the draft syllabi and that the recommendations in this report are put into practice when the syllabi are finalised.

I wish the ISTA continued success in its important role in science education in Ireland

Luke O'Neill

Professor Luke O'Neill

ISTA President

Executive Summary

This report summarises the response of the Irish Science Teachers' Association to the Leaving Certificate Physics, Chemistry and Biology Draft Specifications (syllabi) published by NCCA in December 2023. In this report, the term "syllabus" and "specification" will be used interchangeably as the term "syllabus" has greater clarity and is the more commonly used term at international level.

Chapter 1 gives a short introduction to the ISTA and explains how data were gathered for this report.

Chapter 2 addresses curriculum and syllabus design in Ireland in the past decade. The ISTA is fully supportive of the concept of learning outcomes and of designing syllabi within a learning outcomes framework. However, in Ireland, problems have arisen as a result of a "learning outcomes only" approach adopted by NCCA in syllabus design over the past decade. This "learning outcomes only" approach has caused problems in the classroom due to the lack of clarity for teachers on what subject content should be taught to the students and the depth to which the content should be taught. As a result, different teachers interpret the learning outcomes differently (and may have been encouraged to do so in some CPD programmes) – and the interpretation of learning outcomes by the State Examinations Commission may differ from that of some teachers. This has led to a situation where for some students and teachers there is a lack of alignment between the syllabus as they interpret it, and the questions on the Junior Cycle or Leaving Certificate examination papers.

Learning outcomes are a valuable tool for identifying what learners should know, understand and be able to do at the end of a lesson or programme. However, it is not appropriate to use learning outcomes alone to define a syllabus and its assessment, especially for a nationally assessed curriculum. Learning outcomes are statements of essential learning, and as such they are written at minimum acceptable or threshold (pass / fail) standard. If teachers focus only on learning outcomes, there is a real risk that the teaching and learning targets will be at a minimum rather than a maximum level, that the bar will not be set high enough for student learning, and that as a result, standards will fall. This "dumbing down" of standards has been referred to by teachers across many subjects at Junior Cycle level.

Teachers do not see it as their role to interpret or "unpack" learning outcomes as was recommended to teachers in the provision of CPD programmes at Junior Cycle level. It is the role of the NCCA to ensure that learning outcomes are clearly defined in published syllabi so that it is clear to teachers what students must be able to do in order to successfully achieve each learning outcome. The Leaving Certificate Physics, Chemistry and Biology syllabi currently being taught in our secondary schools have great clarity and are held in high esteem by teachers, students and third-level academics. The views of teachers on the need to ensure that the new Physics, Chemistry and Biology Specifications are of a similar high standard has been supported by two Oireachtas Committees in the publications *Learning for Life* and *The Future of Science, Technology, Engineering and Maths (STEM) in Irish Education* as discussed in Chapter 2 of this report:

> *The Department of Education should publish revised specifications for Physics, Chemistry and Biology at Senior Cycle by the end of 2023. A key priority should be that the revised syllabus for each subject is far more detailed with comprehensive instructions for teachers. The Committee recommends that the National Council for Curriculum and Assessment (NCCA) reviews the proposed design of the new specifications to ensure teachers are properly supported and students are taught to the highest professional standards.*
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> *(Oireachtas Committee, 2023 p.19)*

Chapter 3 discusses the Leaving Certificate Physics Draft Specification. An analysis of the draft specification has been carried out by the ISTA Physics Committee in consultation with ISTA members. Arising from this analysis, it is clear that one of the main problems with the Leaving Certificate Physics draft specification is the lack of clarity in a significant number of learning outcomes. Of the 101 learning outcomes in the "contextual" (subject specific) strands of the specification, a total of 69 learning outcomes (68.3%) are unclear. Due to this lack of clarity, it is impossible for teachers to ensure that their students achieve these learning outcomes – and impossible for students to know if they have achieved them. Recommendations to bring clarity to each vague learning outcome are made in Chapter 3. All of the learning outcomes in the contextual strands of the Physics draft specification are listed in Appendix 1 with relevant comments made on each Learning Outcome.

An analysis of time to teach each individual specification has been carried out and it is felt that the learning outcomes in the contextual strands cannot be achieved within 160 hours of teaching the specification.

Of the 101 learning outcomes in the specification, 10 contain reference to Higher Level material. It is recommended that this balance needs to be discussed at an NCCA Subject Development Group meeting as no detailed discussion has been held to date on this topic.

An analysis of the unclear learning outcomes shows that they fell into various categories:

(i) Learning outcomes that make no sense in the context in which they are being used.

(ii) Learning outcomes that are so vague and so broad that it is impossible to know what students must be able to do in order to achieve the learning outcomes.

(iii) Learning outcomes that use the term "primary data" when it is not necessary to use it.

(iv) Learning outcomes that use the term "secondary data" when it is not necessary to use it.

(v) Learning outcomes that are vague and ill defined.

(vi) Learning outcomes that do not clarify what laboratory practical work should be carried out in order to achieve the learning outcome.

(vii) Learning outcomes that overlap

In addition to lack of clarity in 69 learning outcomes, there is also a lack of clarity in the laboratory practical investigations that are mandatory in order to achieve the appropriate learning outcomes. The ISTA Physics Committee has analysed the draft specification and provided a list of 23 Laboratory Practical Investigations that are considered to be mandatory in order to successfully implement the specification in the classroom.

Chapter 4 discusses the Leaving Certificate Chemistry draft specification. An analysis of the draft specification has been carried out by the ISTA Chemistry Committee in consultation with ISTA members. Arising from this analysis, it is clear that one of the main problems with the Leaving Certificate Chemistry draft specification is the lack of clarity in a significant number of learning outcomes. Of the 127 learning outcomes in the contextual strands, a total of 40 learning outcomes (31.5%) are unclear. Due to this lack of clarity, it is impossible for teachers to ensure that their students achieve these learning outcomes – and impossible for students to know if they have achieved them. Recommendations to bring clarity to each vague learning outcome are made in Chapter 4. All of the learning outcomes in the contextual strands of the Chemistry Draft Specification are listed in Appendix 2 with relevant comments made on each learning outcome.

An analysis of time to teach each individual specification has been carried out and, in general, it is felt that the learning outcomes in the contextual strands can be achieved within 160 hours of teaching provided that the Unifying Strand is deleted from the specification. Since this strand deals with the Nature of Science, it is felt that this has been adequately covered at Junior Cycle level.

Of the 127 learning outcomes in the specification, 35 contain reference to Higher Level material. It is recommended that this balance needs to be discussed at an NCCA Subject Development Group meeting as no detailed discussion has been held to date on this topic.

An analysis of the unclear learning outcomes shows that they fell into various categories:

- (i) Learning outcomes that do not contain active verbs.
- (ii) Learning outcomes that make no sense in the context in which they are being used.
- (iii) Learning outcomes that are so vague and so broad that it is impossible to know what students must be able to do in order to achieve the learning outcomes.
- (iv) Learning outcomes that use the term "primary data" when it is not necessary to use it.
- (v) Learning outcomes that use the term "secondary data" when it is not necessary to use it.
- (vi) Learning outcomes that are vague and ill defined.
- (vii) Learning outcomes that use broad terms such as "range of" without any further clarification.
- (viii) Learning outcomes that do not clarify what laboratory practical work should be carried out in order to achieve the learning outcome.
- (ix) Learning outcomes that include unsuitable active verbs.

In addition to lack of clarity in 40 learning outcomes, there is also a lack of clarity in the laboratory practical investigations that are mandatory in order to achieve the appropriate learning outcomes. The ISTA Chemistry Committee has analysed the draft specification and provided a list of 26 Laboratory Practical Investigations that are considered to be mandatory in order to successfully implement the specification in the classroom.

Chapter 5 discusses the Leaving Certificate Biology Draft Specification. An analysis of the draft specification has been carried out by the ISTA Biology Committee in consultation with ISTA members. Arising from this analysis, it is clear that one of the main problems with the Leaving Certificate Biology Draft Specification is the lack of clarity in a significant number of learning outcomes. Of the 99 learning outcomes in the contextual strands, a total of 66 learning outcomes (66.7%) are unclear. Due to this lack of clarity, it is impossible for teachers to ensure that their students achieve these learning outcomes – and impossible for students to know if they have achieved them. Recommendations to bring clarity to each vague learning outcome have been made in Chapter 5. All of the learning outcomes in the contextual strands of the Biology Draft Specification are listed in Appendix 3 with relevant comments made on each learning outcome.

An analysis of time to teach each individual specification has been carried out and, in general, it is felt that the learning outcomes in the contextual strands can be achieved within 160 hours of teaching provided that the Unifying Strand is deleted from the specification. Since this strand deals with the Nature of Science, it is felt that this has been adequately covered at Junior Cycle level.

Of the 99 learning outcomes in the specification, 17 contain reference to Higher Level material. It is recommended that this balance needs to be discussed at an NCCA Subject Development Group meeting as no detailed discussion has been held to date on this topic.

An analysis of the unclear learning outcomes shows that they fell into various categories:

(i) Learning outcomes that do not contain active verbs.

(ii) Learning outcomes that are so vague and so broad that it is impossible to know what students must be able to do in order to achieve the learning outcomes.

(iii) Learning outcomes that use the term "primary data" when it is not necessary to use it.

(iv) Learning outcomes that use the term "secondary data" when it is not necessary to use it.

(v) Learning outcomes that are vague and ill defined.

(vi) Learning outcomes that use broad terms such as "range of" without any further clarification.

(vii) Learning outcomes that do not clarify what laboratory practical work should be carried out in order to achieve the learning outcome.

(viii) Learning outcomes that include unsuitable active verbs.

In addition to lack of clarity in 66 learning outcomes, there is also a lack of clarity in the laboratory practical investigations that are mandatory in order to achieve the appropriate learning outcomes. The ISTA Biology Committee has analysed the draft specification and provided a list of 13 Laboratory Practical Investigations that are considered to be mandatory in order to successfully implement the specification in the classroom.

Chapter 6 discusses the Unifying Strand which is located in the introductory material to the Physics, Chemistry and Biology Draft Specifications. It is a strand that deals with the Nature of Science and consists of 11-12 learning outcomes according to the individual specification. Most of the learning outcomes are identical in all three specifications.

Analysis of the learning outcomes in the Unifying Strand show that they consists of a list of very broad learning outcomes that have inserted into the introductory section of the Physics, Chemistry and Biology Draft Specifications. The Unifying Strand adds little or nothing to the three specifications. On the contrary, teachers feel that the broad learning outcomes in the Unifying Strand have the potential to be a source of confusion and stress to teachers who fear that what has happened in the examining of Agricultural Science will also apply to the new Physics, Chemistry and Biology Specifications when introduced into the classroom. Problems reported by teachers that they have encountered with the vague Leaving Certificate Agricultural Science syllabus are discussed in Chapter 6 and Chapter 7.

In addition to the broad nature of the Unifying Strand, there is no attempt in any of the three draft specifications to link these broad learning outcomes to the learning outcomes in the contextual strands. This is one of the key aspects of constructive alignment in curriculum design. Without this constructive alignment, the Unifying Strand is meaningless as the strand simply consists of a list of broad learning outcomes that have been cut and pasted into the introductory section as a stand-alone strand with no effort made to link these learning outcomes to those in the contextual strands. Since constructive alignment is an essential component in all syllabi designed within a learning outcomes framework, we recommend that either the Unifying Strand be deleted from all three specifications or that a clear constructive alignment strategy be drawn up to link the broad learning outcomes in the Unifying Strand to the appropriate learning outcomes in the contextual strands.

Chapter 7 analyses the data obtained from science teachers via the online questionnaire and the three national online CPD events to discuss the draft specifications. The online questionnaire was completed by 320 science teachers and the CPD events were attended by a total of 648 science teachers (Physics = 106, Chemistry = 224 and Biology = 318)

Over 90% of teachers expressed dissatisfaction with the allocation of 40% of the marks to the research investigation component. The most popular choice was 20% mark allocation with the next most popular option being 10% mark allocation for coursework.

When asked about the level of laboratory equipment / resources, only a small percentage (7%) described their laboratories as being very well equipped. Over 40% of laboratories were described as being either poorly equipped or very poorly equipped. The majority of teachers (82%) do not feel that they have sufficient resources to support the additional assessment component Research Investigation in their schools.

The additional assessment component will seriously impact on the availability of school laboratories and laboratory resources to other classes such as Junior Cycle and Transition Year, e.g. less practical work having to be carried out at Junior Cycle and Transition Year level, students having to be moved out of laboratories to facilitate Leaving Certificate project work, implications of teacher availability for students who wish to participate in BT Young Scientists' Exhibition and Scifest Exhibition. The perceived rush to introduce the new specifications in schools in 2025 without schools being adequately equipped was also of concern to teachers.

Teachers identified that the proposed model of assessment of Leaving Certificate biology chemistry and physics "additional assessment component" by means of a laboratory-based Investigation in sixth year as outlined in the draft specifications would have a number of effects

- Additional stress on teachers and students
- Adverse effect on uptake of Leaving Certificate Physics, Chemistry and Biology.
- Cheating associated with proposed model and alternative models to give credit to students for practical work should be considered.
- Widening of the social divide.
- Timing in sixth year and timescale of introduction were identified as problematic.
- Similar negative consequences as experienced in the Agricultural Science research projects.
- Importance of provision of laboratory technicians.
- Importance of making School Management aware of implications of research investigations in Physics, Chemistry and Biology.

Teachers identified major problems with the clarity of learning outcomes in the Physics, Chemistry and Biology draft specifications. These problems will greatly add to the stress on teachers and students working towards a high-stakes examination such as the Leaving Certificate.

Some suggestions for topics which could be included in the draft specifications and excluded from the draft specifications were also made by teachers.

On average, almost 90% of teachers reported that they were unclear on what mandatory laboratory investigations should be carried out by students in school laboratories. An average of 96% of teachers was in favour of a list of mandatory student laboratory investigations being included in the final draft of the Physics, Chemistry and Biology specifications. Among the advantages of mandatory student practical work that emerged from the data were:

1. Mandatory investigations ensure that all students acquired basic key skills in laboratory practical work.
2. Once the basic laboratory skills were acquired, students are then in a position to carry out scientific investigations as required in the second mode of assessment.
3. The list of specified mandatory investigations on the current Leaving Certificate Physics, Chemistry and Biology syllabi help teachers to obtain funding from school principals.
4. Mandatory investigations were liked by students who enjoyed practical work as they were rewarded on the examination paper for carrying out these mandatory investigations.
5. Mandatory experiments allowed student to develop the skill of following a written set of instructions as is demanded in standard operating procedure of industries such as the biopharmachemical and electronics industries.
6. Mandatory experiments are good from a Health and Safety perspective as a risk assessment can be carried out easily for each experiment to be carried out by students.
7. Mandatory investigations assist with lab organisations and management as stock taking is made easier.
8. Mandatory investigations help to have a "level playing pitch" between schools with ample funding and schools with minimum funding.

In final comments made by teachers, issues highlighted were: increased stress on students and teachers caused by the research investigations, potential for damage to uptake of science subjects at Leaving Certificate level, lack of clarity of learning outcomes, the need to pilot the research investigation model due to the huge pressure of having approximately 50,000 students carrying out research investigations across Physics, Chemistry and Biology, widening of social inequality and the need to have sample examination papers, marking schemes and other documentation available prior to any specification being implemented.

Chapter 8 summarises the main conclusions and recommendations as shown in the following table:

No.	Conclusion	Recommendation
1	One of the main problems in the Leaving Certificate Physics, Chemistry and Biology Draft Specification is the lack of clarity in a significant percentage of learning outcomes in each specification - Physics (68.3%), Chemistry (31.5%) and Biology (66.7%).	Work needs to be initiated by the three NCCA Subject Development Groups to bring the draft specifications up to international standard. This work involves writing into the draft specifications the detail required in order to clarify the learning outcomes highlighted in this report.
2	There is a lack of clarity about the time required to implement the new specifications in Physics, Chemistry and Biology. The time allocated to teach each specification as described in this report involves a lot of estimations due to lack of clarity associated with many learning outcomes.	When the detail described in section 1 above is written into the draft specifications, an audit should be carried out by the practising teachers who serve on the NCCA Subject Development Groups to calculate the time needed to implement each learning outcome in the classroom to ensure that the total time is within the 160 hours of class contact time.

3.	There is a lack of clarity in the laboratory practical investigations that are mandatory in order to achieve the appropriate learning outcomes. Eight reasons for having clear lists of mandatory student investigations emerged from the data analysis (Chapter 7). The fact that 96% of teachers across Physics, Chemistry and Biology requested that clear lists of mandatory practical investigations be provided shows the strength of opinion on this matter.	Clear lists of mandatory student investigations need to be provided – as exist in the Leaving Certificate Physics, Chemistry and Biology syllabi being taught in our schools. These lists should be drawn up by the NCCA Subject Development groups and embedded into each of the three specifications. The lists provided by the ISTA Physics, Chemistry and Biology committees, based on their own teaching experience and feedback from colleagues, included in this report could be used as starting points for working towards the final lists.
4.	It is clear from the analysis of data in Chapter 7 that teachers require more information on assessment. The draft specifications have been published as "bare" documents without any information on how the learning outcomes will be assessed and no information on the structure or format of the examination papers or types of questions that will be given on the Leaving Certificate examination papers in Physics Chemistry and Biology. This is in direct conflict with international best practice where sample examination papers, Teacher Guidelines, sample marking schemes and details of student laboratory practical work are provided in addition to the detailed published syllabi. At the moment the implementation of new specifications is rather haphazard and takes a "make it up as we go along" approach. Teachers cannot effectively prepare and assess students for an examination whose structure they have no idea about until the specification has been largely taught in sixth year.	The ISTA supports the motion passed at the ASTI and TUI Annual Conferences in 2023 that *That the ASTI / TUI demand that, for all future Leaving Certificate syllabi (specifications), the Department of Education, the NCCA and SEC publish the full range of syllabus documentation concurrently and not less than 12 months prior to implementation of the syllabus. The syllabus documentation to include: a detailed syllabus which embeds depth of treatment and comprehensive teacher guidelines into the syllabus, sample examination papers, sample marking schemes, rationale and research-based evidence that underpin the changes to / for introduction of syllabi*
5.	As noted in Chapters 3, 4 and 5, the ISTA is concerned about the imbalance between Ordinary Level and Higher Level in some areas of the specifications. No detailed discussions have been held at NCCA Subject Development Groups about the balance between Higher Level and Ordinary Level topics in the Physics, Chemistry and Biology draft specifications.	To ensure the correct balance between Higher Level and Ordinary Level topics and also balance across teaching times, discussions need to be held at NCCA Subject Development group meetings as part of the review process and appropriate adjustments made in the specifications.

5.	Teachers will be under a lot of stress trying to cover the learning outcomes in the contextual strands of the Physics, Chemistry and Biology specifications without the added stress of having to make sense of the very broad and general learning outcomes in the Unifying Strand.	It is recommended that either the Unifying Strand be deleted from all three specifications or that a clear constructive alignment strategy be drawn up to link the very broad learning outcomes in the Unifying Strand to the appropriate learning outcomes in the contextual strands
6	Additional Assessment Component - Percentage Allocation of marks. It is clear from the data in Chapter 7 that the vast majority of teachers (91%) are unhappy with the allocation of 40% of the marks to the Additional Assessment Component (AAC).	The allocation of marks should be reduced to either 20% or 10%. This could be introduced provisionally for an initial number of years on a trial basis.
7	Additional Assessment Component - Resource Implications. It is clear from the data in Chapter 7 that the majority of schools are ill-equipped to facilitate a model whereby all Leaving Certificate students carrying out research investigations across Physics, Chemistry and Biology. The majority of teachers (82%) do not feel that they have sufficient resources to support the Research Investigations. The lack of access to resources / equipment, lack of lab availability and lack of laboratory technicians in non-fee-paying schools were all cited as major problems.	The proposed model of the Additional Assessment Component as outlined cannot be implemented without funding provided to ensure that all schools have access to the necessary laboratory resources / equipment, access to laboratories and access to technical support from laboratory technicians. If funding is not being provided, then alternative models as suggested in Chapter 7 should be considered, e.g. an oral examination and / or marks being allocated for evidence in students' laboratory notebooks of laboratory practical work being carried out by them.
8	Additional Assessment Component - Stress on Students and Teachers. Analysis of data in Chapter 7 highlighted the additional stress on students and teachers brought about by the implementation of this particular model involving a Research Investigation. Teachers predict that this will lead to adverse uptake of science subjects at Leaving Certificate and make the science teaching profession less attractive to science graduates. Some teachers mentioned that it would hasten their retirement from the science teaching profession.	Remove the stress on students and teachers by considering changing the model. Instead of students carrying out all the Research Investigations over a fixed period in sixth year, devise a model to give students credit for practical work carried out over two years.

9	Additional Assessment Component -Implications for cheating with aid of generative Artificial Intelligence. As highlighted in Chapter 7, the widespread availability of AI tools would make it impossible for teachers to detect cheating. Even if cheating is suspected, teachers expressed reluctance in the online questionnaire completed by them to make accusations against their students.	Modifications need to be made to the proposed model so that the use of Artificial Intelligence does not confer an advantage on students.
10	Additional Assessment Component - Increased Workload on Teachers. In Chapter 7 teachers highlighted the huge increase in their workload caused by the Additional Assessment Component. Teachers were deeply concerned about this.	Modify the model of assessment to give students credit for practical work by other means. Since many teachers teach more than one Leaving Certificate Science subject, consideration should be given to phasing in the three subjects over a number of years instead of introducing them all together in one year.
11	Additional Assessment Component – more clarity. In Chapter 7 teachers expressed frustration at the lack of clarity of the AAC in the draft specifications. Teachers referred to the problems encountered with the Agricultural Science Individual Investigative Study and feared that similar problems would be encountered in Physics, Chemistry and Biology.	Provide teachers with exemplar material including marking schemes to bring clarity to how the Additional Assessment Component will be assessed by the SEC.
12	As noted in Chapter 7, teachers are concerned about the quality of future CPD provision. Experience from Junior Cycle CPD where a lot of time was wasted on group discussions and teachers were told to "unpack" learning outcomes themselves caused great stress and dissatisfaction among teachers.	A new and more effective model of CPD provision needs to be drawn up and implemented by Oide. The model used by the Physical Sciences Initiative and the Biology Support Service which was used to provide CPD for the current Leaving Certificate Physics, Chemistry and Biology syllabi was very effective. Teachers had great confidence in this service, learned a lot about the subject and how to teach it at CPD events and had the ability to have questions about topics on the syllabus answered effectively

The NCCA Physics, Chemistry and Biology subject development groups should be closely involved in implementing the above recommendations. Members of these subject development groups contribute invaluable expertise and experience, on a pro bono basis, to Irish education. They help to bridge the gap between theory and practice, between the ideal and the possible. Teachers, in particular, have an important role to play as they are at the chalk-face on a daily basis and bring knowledge of the on-the-ground constraints to the discussion. Third level and employer representatives help to ensure that the revised syllabi prepare students appropriately for further learning and for work. The partnership model has served Irish education well in the past and will hopefully continue to do so in the future.

It is the earnest wish of ISTA that the above recommendations be implemented in a collaborative and diligent way that is respectful of the views of teachers and of other stakeholders in the world of education. The ISTA looks forward to working in a spirit of cordial cooperation and partnership with the NCCA and all stakeholders represented on the NCCA Subject Development Groups. We hope that all science teachers will be treated with respect and that their opinions valued in this spirit of partnership.

Chapter 1

Introduction

1.1 Introduction – The Irish Science Teachers' Association

The Irish Science Teachers' Association was founded in 1961. It is the professional body representing science teachers in Ireland. Its current membership is 1250 science teachers who teach mainly at secondary school level and university level. The ISTA maintains links with other bodies involved in science education in Ireland and with associations for science education in other countries.

The ISTA is an active member of the International Council of Associations for Science Education (ICASE). The ISTA currently holds the Presidency of ICASE and will be hosting the ICASE World Conference on Science Education in 2026. The fact that the ISTA is an active member of ICASE ensures that our members are kept informed of curriculum development not only in Ireland but also at international level.

The ISTA functions as a body dedicated to the professional development of its members and the advancement of science teaching. It is a voluntary organisation and, as Professor Luke O'Neill mentions in the Foreword of this report, all work done by the ISTA is carried out in somebody's spare time. The ISTA does not have any paid officials or paid administrative support but relies on the commitment and dedication of its members to function effectively for the benefit of science education in Ireland.

The Association works on a voluntary basis to develop co-operation between teachers of science at all levels. It aims to keep members up to date with changes in their subjects and with new ideas in teaching and assessment. The ISTA helps members to promote amongst their students a positive attitude to science and technology in society.

The ISTA has close links with our partners in industry who kindly sponsor events such as the ISTA National Science Quiz and the ISTA Science Educator of the Year award. Throughout the years since its foundation, the ISTA has worked in close collaboration with the Department of Education, State Examinations Commission and the National Council for Curriculum and Assessment. Several former members of the ISTA Executive have taken up roles as members of the Science Inspectorate and as Chief Examiners in the State Examinations Commission. In addition, the ISTA is represented on all NCCA subject development groups.

The ISTA is actively involved in the provision of continuing professional development (CPD) programmes to its members. These CPD events take place at local level and also at national level. At national level, approximately ten CPD events are held each year and are open to ISTA members throughout Ireland. All CPD events are held in the evenings or on Saturdays.

Among the aims of the ISTA are:

- To provide leadership in promoting science education.
- To promote the teaching of science at both primary and secondary level.
- To promote co-operation between science teachers.
- To continue to promote, and be involved in, curriculum development.
- To continually review the structure and organisation of the Association in order to keep in touch with the changing demands of its members.

To fulfil these aims, the ISTA has the following objectives:

- To make representations on behalf of its members to the National Council for Curriculum and Assessment (NCCA), the Department of Education, the State Examinations Commission and any other statutory body involved in science education.
- To develop and publish policy documents for the advancement of science education.
- To publish the journal SCIENCE, newsletters and resource material for the benefit of its members.
- To organise continuing professional development (CPD) programmes , lectures and workshops for its members.
- To organise the ISTA Annual Conference.
- To promote links between ISTA and third level institutions and industry, for the purpose of highlighting the importance of quality science education for the future of Irish industry.
- To promote amongst school pupils a long-lasting interest in science by organising lectures, tours, science projects competitions, quizzes and links with local science-based industries.
- To extend membership, and support science teaching at primary school level.
- To provide support to student science teachers and inexperienced science teachers.
- To maintain links with the International Council of Associations for Science Education (ICASE) and with our nearest neighbour association in the UK, the Association for Science Education (ASE).
- To formalise existing liaisons with (a) third level institutions, (b) other subject associations with overlapping interests, (c) the Department of Education (d) Irish Business Employers Confederation (IBEC).

1.2 Data collection

Work began on the writing of this report during the Christmas 2023 holiday break. The publication of the Leaving Certificate Physics, Chemistry and Biology Draft Specifications in December 2023 was a busy time in schools as teachers prepared for the Christmas examination period. However, it was clear that if the ISTA were to meet the NCCA's deadline of 23rd February 2024, work would have to begin during the Christmas holiday period. The ISTA Physics, Chemistry and Biology committees undertook a detailed analysis of the three draft specifications with a particular focus on areas such as clarity of learning outcomes, mandatory practical investigations, analysis of time to teach each specification and the "Additional Assessment Component" coursework involving the carrying out of a research investigation.

The experience of collaboration between the three committees was an interesting one. Whilst the convenors of each committee are represented on the respective NCCA subject development groups, no meetings had ever been held in which convenors could share documentation about the draft specifications of their subject development committee with members of the other two subject development groups.

The analysis of learning outcomes (using the format shown in Appendices 1, 2 and 3) resulted in considerable amounts of data being generated. This exercise highlighted areas of concern across the three specifications. To ensure that the final report would be as constructive as possible, where problems were highlighted by vague learning outcomes, suggestions were made on ways to clarify the vague learning outcome with the aid of alternative wording of the learning outcome.

Three online webinars were held in January and February 2024 in order to consult with ISTA members about the draft specifications. All webinars were held at evening time and a total of 648 science teachers attended these CPD events. The webinars were chaired by the respective ISTA convenors and a lot of data was generated by feedback received from teachers during and after the webinars.

Within a few days of the conclusion of the final webinar, an online questionnaire designed by the ISTA convenors was placed online. The questionnaire consisted of 41 questions (Appendix 7) and was completed by 320 teachers.

Analysis of the data and the writing of this report were undertaken by ISTA members from the Leaving Certificate Physics, Chemistry and Biology committees with assistance of ISTA members with expertise in typesetting and proofreading. Due to the short timescale allowed for feedback to be received by NCCA, the work was carried out under intense pressure of time. However, we hope that this report will assist in charting a way forward that ensures that the subjects of Physics, Chemistry and Biology will continue to thrive in our secondary schools and will not be undermined by specifications of a lower standard than those that are currently being taught in our secondary schools.

Chapter 2

Syllabus design in Ireland in recent years

2.1 Introduction

In recent years, concerns have been expressed by practising teachers, university academics, professional bodies, Oireachtas committees, and experts in curriculum design about the quality of Junior Cycle and Leaving Certificate syllabi[1] ("curriculum specifications") published by the National Council for Curriculum and Assessment (NCCA). These concerns have been based on the experience of teachers in the classroom as they struggle to implement vague syllabi and struggle to answer the question What must my students be able to do in order to show that they have achieved this learning outcome? In addition, concerns have been based on international best practice on syllabus design where it is clear that syllabi must contain all the detail required for successful implementation in the classroom and must display constructive alignment (Biggs 2005), i.e. there must be a clear alignment between learning outcomes, teaching and learning activities and assessment, Figure 2.1.

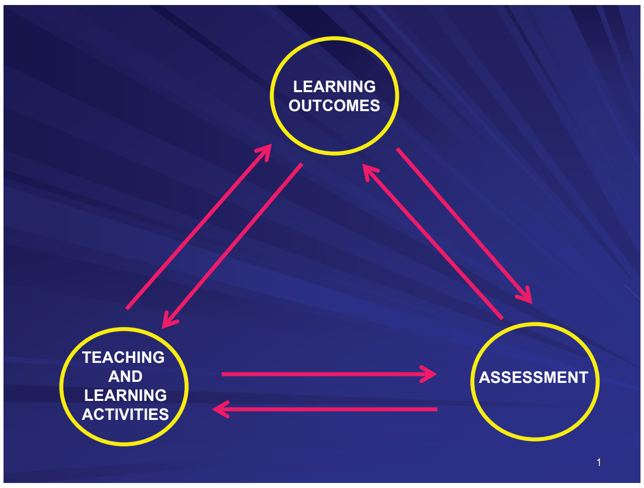

Figure 2.1 Constructive alignment in curriculum design involves the linking of learning outcomes to teaching and learning activities and also to assessment. Unless all three domains are linked as shown, constructive alignment cannot exist.

The draft specifications published by the NCCA (December 2023) do not display this constructive alignment as there is insufficient depth of treatment regarding teaching and learning activities in many learning outcomes and also insufficient detail on assessment of learning outcomes.

In short, for constructive alignment to exist, it must be clear to the teacher what teaching and learning activities must be put into operation in the classroom in order to ensure that the student achieves each individual learning outcome. In addition, it must be crystal clear how each learning outcome can be assessed in order to check if the student has achieved that learning outcome. If there is any vagueness about a learning outcome (i.e. insufficient depth of treatment), it follows that constructive alignment cannot exist.

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1 * In this chapter the term "syllabus" will be used instead of "specification" as the term "syllabus" has greater clarity and is the more commonly used term at international level.

2.2 Overview of concerns on syllabus design in Ireland

The following is a summary of concerns expressed over the past ten years:

- **The Design of Leaving Certificate science syllabi in Ireland: an International Comparison (Hyland, 2014).** This report pointed out that the practice of the NCCA in designing syllabi that consist solely of a list of topics and learning outcomes is not good international practice in syllabus design. The report stated that the author had not come across any centralised or public examination syllabus at the end of senior cycle second level education which provides only a list of topics and learning outcomes. It concluded that "while learning outcomes are a very valuable tool for identifying what learners should know and be able to do at the end of a course or programme, it is not appropriate to use learning outcomes alone to define a syllabus and its assessment." (p. 5). Considerable details accompanying the learning outcomes need to be provided. This detail is commonly referred to as "depth of treatment" since that is the term used in the Leaving Certificate Physics, Chemistry and Biology syllabi currently being taught in our secondary schools. Due to this clarity of depth of treatment in these current syllabi, science teachers are very happy with the quality of these syllabi, Figure 2.2

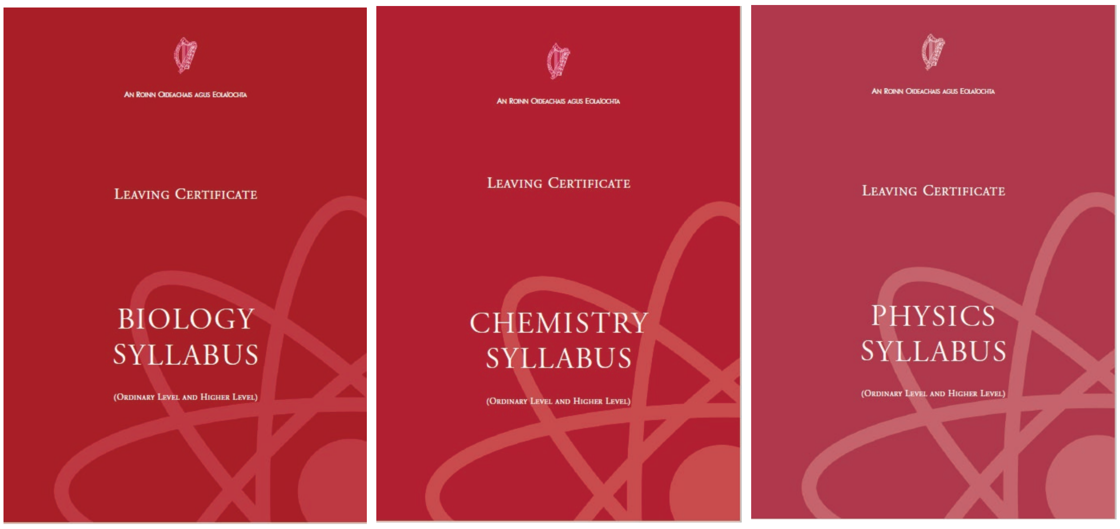


Figure 2.2 The Leaving Certificate Physics, Chemistry and Biology syllabi that are currently being taught in our schools are held in high esteem by teachers due the clarity of depth of treatment of topics being taught.

- **The Irish Science Teachers' Association (2019).** In 2019 the ISTA published a report *Listening to the Voice of Science Teachers*. This report summarised the findings of a survey completed by its members (ISTA 2019). A total of 762 science teachers completed the survey Among its findings were the following:
    - Lack of depth of treatment in the Junior Cycle science specification was a major problem for teachers in identifying what topics they should be teaching in the classroom.
    - 85% of teachers believed that the template of syllabus design used at Junior Cycle was unsuitable for use at Senior Cycle level.
    - There was concern for student and teacher wellbeing due to the stress caused by trying to successfully implement a vague syllabus in the classroom.

- **The Irish Agricultural Science Teachers' Association (2019, 2021)** made several submissions to the NCCA, to the Minister and to the Oireachtas Committee on Education about the problems encountered with the new Leaving Certificate Agricultural Science syllabus which was introduced into schools in 2019. Some of these documents are as follows:
    - IASTA (2019**)** ***IASTA Members' Survey Reveals Significant Issues with New Specification & the Individual Investigative Study.***
    - ***Flawed Leaving Certificate Agricultural Science syllabus examined for the first time*** (IASTA 2021). In this document the IASTA stated that "It is time to call a halt to the practice of the Department of Education publishing these vague and dumbed down syllabi. Teachers of Agricultural Science are the key to excellence in curriculum implementation in the classroom and deserve better than being provided with a sub-standard syllabus that does not measure up to international best practice". This document also quoted a teacher who stated at their annual conference: "I am teaching a topic on the Ag. Science specification at the moment and I don't know if I should be spending two months on the topic, two weeks, two days or two hours on it."
    - In the ***IASTA submission to the Oireachtas Committee on Education*** (IASTA 2021) it pointed out that "of 278 teachers that completed a survey circulated by the IASTA in January 2021, only one of the 278 teachers rated their level of confidence in delivering the new specification as 'very confident'".

- **Third level academics (2020)**. In a letter to the Irish Times (Childs 2020) Dr. Peter Childs, Emeritus Senior Lecturer in Science Education, University of Limerick, described the situation regarding the use of template of syllabus design based only on learning outcomes as follows:

    > *It is like trying to build a house based only on its desired features, but without an architectural drawing and detailed plans. Teachers need a detailed syllabus, like the ones currently used, in order to teach effectively.* He went on to say *It is a recipe for disaster when teachers do not know what they are supposed to teach and to what depth, where each teacher becomes the arbiter of the curriculum.*

The full text of the letter may be viewed at the URL in the list of references.

- **An Gréasán – the Association of Teachers of Irish (2021).** In April 2021 An Gréasán carried out a survey of their members on the draft specifications for Leaving Certificate Irish. The survey was completed by 420 teachers. The report stated that "teachers have expressed great dissatisfaction regarding the Junior Cycle Gaeilge course".

    The following recommendation was made in the report: "It is essential that the implementation of the Junior Cycle Gaeilge course is fully analysed, that the problems with this course are resolved, and that it is examined how the results of this review may affect the proposed Leaving Certificate specifications".

    The report also stated that "97% of teachers believe that more details should be provided in the draft specifications on the potential themes and topics that would evolve from the learning outcomes to give clear direction to teachers and students." (p. 6)

It also stated "Only very basic detail is given, and there is a danger therefore that different interpretations of the learning outcomes may be taken and developed by different groups (e.g. the SEC, the textbook publishers etc.) and that these may not be aligned with each other. This approach is not satisfactory for an exam as important as the Leaving Certificate." (p. 6)

- **Irish language organisations (2021).** Under the auspices of Conradh na Gaeilge, fourteen organisations interested in the promotion of Irish in the education system commissioned a report *Discussion Document responding to the Senior Cycle Draft Irish Specifications L1 an L2 published for consultation by the NCCA on 23 February 2021* (Hyland and Ui Uiginn 2021). This report provides a detailed analysis of international good practices in syllabus reform and highlighted some concerns about the template used by the NCCA. As these points are applicable to syllabi in every subject, they are reproduced in some detail here:

    - "In terms of content, the draft specifications, based on themes and learning outcomes, are sparse and lacking in depth. Detailed information is not given about what the teacher is to teach or what the student is to learn. No explanation is given of the depth of learning that should be covered within the themes or topics and teachers are not provided with guidelines or details on assessment." (p. 19)

    - "The learning outcomes should be clear **and** the depth and breadth of knowledge required should also be provided. Teacher guidelines should be provided as well as comprehensive information on the assessment of the subject. It is not sufficient to state that these will be made available at a later date. The consultation is currently underway and feedback is being sought from stakeholders. Worthwhile feedback cannot be given in the absence of this information." (p. 19)

    - "While learning outcomes, if clearly set out, are a useful tool in curriculum design, learning outcomes **alone** are not enough to design a specification for a high-stakes examination such as the Leaving Certificate. Learning outcomes are statements of essential learning, and as such they are written at minimum / threshold (i.e. pass/fail) standard. They do not provide the **range of skills and information** to be provided in any subject." (p.19)

    - "No senior cycle specification should be as bare and lacking in depth as these draft specifications. They merely provide a skeleton with no flesh on the bones and no detailed content." (p. 19)

    - "The NCCA has indicated that the SEC will follow its normal practice and that sample examination papers and marking schemes will not be made available until November 2024, a few months before the first exams based on these specifications in June 2025.This is a flawed approach. Accurate and comprehensive information on the assessment system, oral and written, **should be aligned** from the outset with the content of the specification and provided with the draft specification in advance of the consultation. There must be alignment between learning outcomes, specification content, teacher guidelines and assessment. Information in the draft specifications on assessment comprises two pages and is mainly an account of the weighting of marks. This is a huge shortcoming, and we believe that these draft specifications should not have been published without comprehensive information on the assessment components." (p. 23)

One of the main recommendations made in the report is that the draft syllabi should be set aside:

- "Our advice at this stage would be that any decision on a new specification for Irish in the senior cycle should be set aside until the review of the Junior Cycle has been completed and the results of the review have been made available. We then ask that the Department of Education, the NCCA and the State Examinations Commission give consideration to the recommendations we have made in this discussion document for the design of a new structure for Irish at senior cycle level, a structure that, for the first time, would cater adequately for the learning needs of all students in the country". (p. 47)

- **Association of Secondary Teachers in Ireland (2022).** The ASTI issued a questionnaire to its members asking them to document their experience of the implementation of the Framework for Junior Cycle. A total of 2981 teachers responded to the survey and the following extracts from the report indicate the type of comments received:

    - "… it would be an understatement to say that there is profound and universal concern among teachers about the capacity of the Junior Cycle subject specifications to prepare students for the senior cycle curriculum. Lack of depth of content knowledge was not the only source of this conviction." (p. 13)

    - "…. it must be emphasised that even those teachers who expressed positive views, most invariably qualified their comment by expressing concern about students' progression to senior cycle." (p. 13)

    - "Lack of depth of knowledge content over the three-year cycle was repeatedly identified by teaches as problematic. Many teachers stated that, several years into the new Framework curriculum, they were unsure if they were teaching the course properly. This is creating confusion and frustration for teachers and is also impacting on their workload." (p. 14)

    - "Learning outcomes remain problematic. They are too broad, too vague and are lacking in guidance to the teacher on what students are expected to be able to do in order to show that they have achieved each learning outcome. This causes confusion and frustration for both teachers and students adding to workload of teachers." (p. 14)

Among the recommendations of the ASTI report are:

- A comprehensive independent evaluation of the implementation of the Framework for Junior Cycle needs to be conducted.
- The NCCA and the Department of Education must address teachers' concerns in relation to the lack of depth of content in the subject specifications.

- **Oireachtas Committee on Education (2022)**. The Joint Committee on Education, Further and Higher Education, Research, Innovation and Science invited written submissions on Senior Cycle Reform from a wide range of stakeholders in education. In addition, it met with many of these stakeholders. The report of the committee *Learning for Life* was published in May 2022 and contained ten key report recommendations. The following was the second recommendation listed in the report:

> "As part of Senior Cycle reform, a key priority for the Department of Education must be that the revised syllabus for each subject is far more detailed with comprehensive instructions for teachers. The Committee recommends that the National Council for Curriculum and Assessment (NCCA) reviews the proposed design of the new specifications to ensure teachers are properly supported and students are taught to the highest professional standards."
>
> (Oireachtas Committee 2022 p. 11)

- **Oireachtas Committee on Education (2023)**. The Joint Committee on Education, Further and Higher Education, Research, Innovation and Science invited written submissions on the future of Science, Technology, Engineering and Maths (STEM) in Irish Education from a wide range of stakeholders in education. The report of the committee *The Future of Science, Technology, Engineering and Maths (STEM) in Irish Education* was published in July 2023 and contained the following recommendation:

> "The Department of Education should publish revised specifications for Physics, Chemistry and Biology at Senior Cycle by the end of 2023. A key priority should be that the revised syllabus for each subject is far more detailed with comprehensive instructions for teachers. The Committee recommends that the National Council for Curriculum and Assessment (NCCA) reviews the proposed design of the new specifications to ensure teachers are properly supported and students are taught to the highest professional standards."
>
> *(Oireachtas Committee, 2023 p.19)*

The Oireachtas Committee also highlighted the submission of the ISTA (represented by Humphrey Jones) and the submission of Professor Aine Hyland, expert on curriculum design.

> The Irish Science Teachers' Association (ISTA) in its submission was emphatic that the current template of syllabus design should be replaced by a template which reflects international best practice. It recommended that 'A new syllabus template needs to be developed for all syllabi at Junior Cycle and Leaving Certificate level. This template must contain more detailed information about the depth of treatment of subjects including the linking of learning outcomes to teaching and learning activities and to assessment.'
>
> Dr Áine Hyland, stated that 'there is a mismatch in a way between current developments, such as the changes in the Junior Cycle and Leaving Certificate, and the examination and assessment, the State Examinations Commission and the NCCA, which has been pointed out before. There are also the very skeletal programmes, syllabi or specifications, as they are called, that are coming out now for the proposed new Leaving Certificate subjects. I do not think they give enough information to teachers and they do not go into sufficient depth. There is a real risk that standards will begin to fall.'
>
> In oral evidence, on 21 March 2023, Mr. Humphrey Jones, Irish Science Teachers' Association (ISTA), once again expressed concerns about the syllabi 'The ISTA reiterates our commitment to supporting Ireland's STEM education plan, but we feel the current syllabus design model is a significant barrier to achieving its ambitions goals. We would like the committee to reiterate that several provisions must be made for the successful implementation of STEM subjects. A new syllabus template needs to be developed for all syllabi at Junior Cycle and Leaving Certificate levels. A full range of documentation must be available before implementation of the syllabi. This must include teacher guidelines, practical coursework guidelines, sample examination papers and sample marking schemes. We recommend an external, independent evaluation be carried out on the Junior Cycle framework and the Leaving Certificate subjects that have already been implemented using the same template. This external evaluation should be carried out by personnel from outside Ireland and by experts in curriculum design.'
>
> (Oireachtas Committee, 2023 p. 33)

In addition to the above, individual teachers voiced their concerns about the quality of syllabi at conference presentations. A video recording of an address by Stephen Murphy on the new Leaving Certificate Computer Science syllabus may be viewed at the URL in the list of references below and a subsequent article (Murphy, 2023) summarises the key problems associated with this syllabus.

At the 2022 ISTA conference in Cork, Mr Humphrey Jones, a teacher of Agricultural Science detailed the problems encountered by him in trying to implement the new Agricultural Science syllabus in the classroom. His experience is reflected in the reports of the Irish Agricultural Science Teachers' Association (IASTA 2019, 2021).

The above comments from various stakeholders are only some of the concerns which have been and continue to be expressed about the current approach being taken by the NCCA to syllabus design.

It has been pointed out that while the NCCA has indicated that their approach is influenced by 'international best practice,' authors of a recent paper (Hyland and Kennedy, 2023) point out that they have failed to find even one example of a jurisdiction or an examining board anywhere in the world which provides such sparse information on the syllabus to be examined.

2.3 Summary and conclusions

The ISTA is fully supportive of the concept of learning outcomes and of designing syllabi within a learning outcomes framework. But in Ireland, problems have arisen as a result of a "learning outcomes only" approach being adopted by NCCA in syllabus design. As already outlined, the "learning outcomes only" approach has caused problems in the classroom due to the lack of clarity for teachers on what subject content should be taught to the students and the depth to which the content should be taught. As a result, different teachers interpret the learning outcomes differently (and may have been encouraged to do so in some CPD programmes) – and the interpretation of learning outcomes by the State Examinations Commission may differ from that of some teachers. This has led to a situation where for some students and teachers there is a lack of alignment between the syllabus as they interpret it, and the questions on the Junior Cycle or Leaving Certificate examination papers.

Learning outcomes are a valuable tool for identifying what learners should know, understand and be able to do at the end of a lesson or programme. However, it is not appropriate to use learning outcomes alone to define a syllabus and its assessment, especially for a nationally assessed curriculum. Learning outcomes are statements of essential learning, and as such they are written at minimum acceptable or threshold (pass / fail) standard (Moon undated). If teachers focus only on learning outcomes, there is a real risk that the teaching and learning targets will be at a minimum rather than a maximum level, that the bar will not be set high enough for student learning, and that as a result, standards will fall. This "dumbing down" of standards has been referred to by teachers across many subjects at Junior Cycle level.

It is not the role of the teacher to interpret or "unpack" learning outcomes as was recommended to teachers in the provision of CPD programmes at Junior Cycle level. The experience of teachers should be listened to and their views treated with respect. As pointed out in the reports referred to earlier in this paper (ISTA 2019, IASTA 2019 2021, ASTI 2022), the new Junior Cycle syllabi and those Leaving Cert syllabi which have been revised to date are vague and unclear. They can be and have been interpreted in different ways by different teachers and the preliminary findings of the reviews of the Junior Cycle examinations in 2022 suggest that there was a lack of alignment between the syllabi in some subjects and the examination papers in summer 2022.

Chapter 3

Analysis of Leaving Certificate Physics Draft Specification

3.1 Introduction

The Leaving Certificate Draft Specification consists of the following main sections:

- **Introductory** material on Senior Cycle. This section consists of ten pages of broad introductory material that is not specific to physics as a subject but deals with Senior Cycle in general and covers broad key competencies in Senior Cycle. As these competencies are generic and very general, they are difficult to interpret, e.g. *being creative*, *communicatin*g, and *participating in society*.
- **Strands of study and learning outcomes.** This section introduces a unifying strand called *The Nature of Science* and also the four contextual strands in the Leaving Certificate Physics specification; *Forces and Motion, Waves and Energy transfer, Electricity and Magnetism, and Modern Physics*. The unifying strand is discussed in Chapter 6 and the other four strands are discussed in this Chapter. Reference is also made to some general cross-cutting themes. It is pointed out that while the strands are set out separately, this is not meant to imply that they should be studied in isolation or in the order in which they are presented. This section contains the list of learning outcomes and accompanying notes in the *Students learn about* column.
- **Assessment.** This section discusses the breakdown of marks between the written paper and what is called an "additional assessment component". The latter component involves coursework in which students carry out a Physics in Practice Investigation. This will be discussed in more detail in Chapter 7 of this report.
- **Appendix 1.** This section is headed "Glossary of Action verbs". This section has already been discussed in Chapter 2 of this report.

3.2 Analysis of learning outcomes

One of the key roles of the ISTA Physics Committee was to coordinate feedback about the draft Physics specification from ISTA members who teach Leaving Certificate Physics. As described in Chapter 1, this feedback was obtained via an online CPD event to discuss the draft specification as well as an online questionnaire.

Each learning outcome in the four contextual strands was analysed for clarity under the headings indicated in the Learning Outcomes Analysis Table reproduced in Appendix 1 of this report. Those learning outcome which were unclear to teachers were indicated by a red icon and those which were clear to teachers were marked by a green icon. There are 101 learning outcomes in the four contextual strands and 69 of these (60.3%) were judged by the teachers to be unclear. In other words, teachers were unable to answer the question "What must students be able to do in order to achieve this learning outcome?"

As may be observed from a study of the Learning Outcomes Analysis Table in Appendix 1, where a learning outcome is categorised as unclear, a clearer wording is proposed.

It was found that learning outcomes judged to be unclear fell into a number of categories.

1. Learning outcomes that use verbs that make no sense in the context in which they are being used.

- The most common problematic area in this category was the use of the word “model” whose meaning is clearly defined in English dictionaries but which is given a range of different meanings by NCCA. This is discussed in more detail in Appendix 4 of this report. The definition of “model” presented by the NCCA is ‘Use words, diagrams, numbers, graphs and equations to describe phenomena make justified predictions and solve problems’. Each of the 34 learning outcomes with the word model caused stress to teachers and obliges teachers to use numbers, graphs and equations in places that graphs and equations would not have been necessary and beyond the scope of the course in the past. For example, what graphs would be needed for x-ray production, resonance, two source interference, static electrical phenomenon, the relationship between electric current, conventional current, power and resistance and series and parallel circuits? This will create a lot of confusion for teachers and students.

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome	Comment on material in corresponding “Students Learn About (SLA) column.
25	7b. model • the generator effect • ac and dc generators • transformers		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome.	Examine the principles behind and describe: • the generator effect • ac and dc generators • transformers	

2. Learning outcomes that are so vague and so broad that it is impossible to know what students must be able to do in order to achieve the learning outcome.

An example of this type of learning outcome is given in the table below. Without information to indicate the depth of treatment of the learning outcome, it is impossible for the teacher to know where to begin and where to end the teaching and learning process.

Page	Learning Outcome	Clarity	Comment	Change	Proposed rewording of learning outcome
20	3d. explore the use of optics in a variety of applications using secondary sources		This is a very broad and vague learning outcome which gives no indication of applications to be considered in helping students to achieve this learning outcome.	The information in the SLA column is very wide ranging. Move SLA material on interference, diffraction and polarisation to the earlier learning outcome on wave motion as indicated above	Discuss the use of optics in the following areas (i) The microscope (ii) The astronomical telescope. .

3. Learning outcomes that use the term "primary data" when it is not necessary to use it.

In a significant number of learning outcomes that involve students performing practical investigations, the term "primary data" is unnecessary and only confuses students and teachers who have asked "why is the term primary data used when it is obvious that the data being collected by the students is their own data?".

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
21	**6g. analyse two source interference using primary and secondary data**		The use of the term primary data is unnecessary and confusing. Since this learning outcome clearly involves an investigation to be carried out by the students themselves, of course the data collected will be their own data. Note the overlap between this learning outcome and the next one.	Carry out an investigation to measure the wavelength of monochromatic light. (Mandatory student Investigation).

4. Learning outcomes that use the term “secondary data” when it is not necessary to use it.

In a significant number of learning outcomes reference is made to “secondary data”. This is unnecessary and only confuses students as obviously secondary data are used in homework assignments and studying past examination questions.

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
24	3b. use primary and secondary data to verify the relationship between current flowing through and the voltage across an ohmic conductor		The use of the term primary data is unnecessary and confusing. Since this learning outcome clearly involves an investigation to be carried out by the students themselves, of course the data collected will be their own data. There is no need to include reference to secondary data as this is covered in the next learning outcome.	Carry out an investigation to verify the relationship between current flowing through and the voltage across an ohmic conductor. (Mandatory Student Investigation).

5. Learning outcomes that are vague and ill defined.

In some cases the learning outcomes need to be clearly defined in order to help teachers understand what students must DO in order to achieve the learning outcome.

Page	Learning Outcome	Clarity	Comment	Proposed information to be given in the Students Learn About column
27	4a. analyse evidence to support the existence of natural background radiation		It is not clear from this learning outcome what analysis should be carried out by students.	Outline the evidence to support the existence of natural background radiation.

6. Learning outcomes that do not clarify what laboratory practical work should be carried out in order to achieve the learning outcome.

In many cases depth of treatment needs to be supplied in order to indicate to students and teachers what laboratory practical work should be carried out. For example, in the table below, this experiment may have been done as a teacher demonstration in the past. Students observed the relationship without collecting primary data. Based on this draft specification student will themselves have to measure loudness, pitch and wavelength and frequency. Is loudness to be measured in dB(A) or dB? Will a class set of this equipment be provided for each school?

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
20	5b. relate the pitch and loudness of sounds to their wave characteristics using primary and secondary data	❌	This learning outcome is very unclear and our members are puzzled as to what students are expected to do to achieve this learning outcome.	Demonstrate the relationship between amplitude of a wave and its loudness and also the relationship between frequency and pitch. (Mandatory Student Investigation).

In addition to the above we have suggested that the following experiments need clarification as to what data is to be collected or is an observation satisfactory. In the past these experiments were done as teacher demonstration without the collection of data. According to this draft specification student will be obliged to collect data themselves. Will a class set of equipment be provided for students to carry out these investigations, e.g. 12 ripple tanks, 12 frequency generators etc.?

- Analyse standing wave patterns
- Analyse diffraction.
- Analyse two source interference.

7. Learning outcomes that seem to overlap.

In some instances, it is difficult to differentiate one learning outcome from another.

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
17	3b. verify Hooke's law for elastic objects using primary and secondary data	❌	The use of the term primary data is unnecessary and confusing. Since this learning outcome clearly involves an investigation to be carried out by the students themselves, of course the data collected will be their own data.	Carry out an investigation to verify Hooke's Law for elastic objects. (Mandatory Student Investigation).

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
16	3a. investigate the force needed to compress or stretch an object using primary and secondary data	❌	The use of the term primary data is unnecessary and confusing. Since this learning outcome clearly involves an investigation to be carried out by the students themselves, of course the data collected will be their own data.	Investigate the force needed to compress or stretch an object. (Mandatory Student Investigation).

3.3 Analysis of time to teach the draft specifications

The members of the ISTA Physics Committee, in consultation with various colleagues, have studied each learning outcome in the four contextual strands and discussed the teaching time required to ensure that students achieve the relevant learning outcome. The time estimated is summarised in Table 3.1

Page	Learning Outcome	Clarity	Time (mins)
15	**Strand 1: Forces and Motion: Kinematics and Dynamics (FM)**		
15	1a. model motion of a particle in a straight line with justified assumptions	✗	200
15	1b. measure constant and varying linear motion using primary data	✓	120
16	1c. derive the kinematic equations of motion	✓	60
16	1d. verify the law of addition of vectors using primary and secondary data in one and two dimensions	✓	120
16	2a. model real-world situations using Newton's laws of motion	✗	120
16	2b. verify Newton's 2nd law of Motion by analysing primary and secondary data	✓	120
16	2c. model problems involving the motion of a particle under a constant resultant force	✗	80
16	2d. model pressure	✗	80
16	2e. relate pressure, force and density of a fluid	✗	40
16	2f. investigate the principle of conservation of momentum using primary and secondary data	✓	120
16	2g. verify using secondary data that collisions are governed by Newton's laws of motion	✓	40
16	2h. model direct collisions in one and two dimensions	✗	60
16	3a. investigate the force needed to compress or stretch an object using primary and secondary data	✗	40

17	3b. verify Hooke's law for elastic objects using primary and secondary data	✗	40
17	3c. model compressed and stretched objects	✗	60
17	4a. define work done by a constant force	✓	40
17	4b. model authentic situations describing gravitational potential energy, elastic potential energy, work done and the rate of doing work	✗	200
17	4c. investigate the principle of conservation of energy using primary and secondary data	✗	120
17	4d. apply the principle of conservation of energy to authentic situations	✓	60
17	5a. verify models to determine g using primary and secondary data	✗	120
17	5b. model the gravitational field strength at any point in a gravitational field, including at the surface of a planet	✗	80
17	6a. explain centripetal force	✓	40
17	6b. model the dynamics of an object moving in a circle with constant angular velocity.	✗	60
17	6c. verify Kepler's 3rd law using secondary data	✓	60
18	6d. model situations involving the orbits of planets and satellites in near Earth and geostationary orbits	✗	80
18	**Strand 2: Wave Motion and Energy Transfer (WMET)**		
18	1a. model thermometric properties	✗	120
18	1b. analyse the suitability of materials for use as thermometers using primary and secondary data	✗	120
18	1c. determine specific heat capacity and specific latent heat using primary data	✗	160
19	1d. verify models describing the relationships between heat energy, latent heat and temperature change using secondary data	✗	160

19	1e. model authentic problems involving heat transfer, change of state and efficiency	✗	160
19	1f. explore the impact of insulation on energy consumption and sustainability using secondary sources	✗	60
19	2a. model the transfer of energy by waves.	✗	200
19	3a. model wave behaviour in a variety of situations	✗	120
19	3b. verify models for refraction using primary and secondary data	✗	120
19 to 20	3c. verify models describing the relationship between image and object distances and the focal length of converging lenses using primary and secondary data and diverging lenses using secondary data	✗	120
20	3d. explore the use of optics in a variety of applications using secondary sources	✗	120
20	4a. categorise electromagnetic waves by their wavelength, frequency, ionising ability and everyday use	✓	40
20	4b. examine primary and secondary evidence to support the wave nature of electromagnetic energy	✗	80
20	4c. demonstrate dispersion and explain the phenomenon	✓	40
20	4d. investigate solar irradiance and its impact on life on Earth using secondary sources	✗	60
20	5a. examine primary and secondary evidence to support the mechanical wave nature of sound	✗	40
20	5b. relate the pitch and loudness of sounds to their wave characteristics using primary and secondary data	✗	80
20	5c. explore the use of ultrasound in technological and medical contexts using secondary sources	✗	60
20	6a. analyse standing wave patterns using primary and secondary data	✗	60
20	6b. model the relationship between harmonics and the standing wave pattern	✗	60
20	6c. verify the relationship between the length of a string and the frequency of a standing wave using primary and secondary data	✗	120

20 to 21	6d. model standing waves on a stretched string	✗	80
21	6e. analyse diffraction using primary and secondary data	✗	80
21	6f. model two source interference	✗	40
21	6g. analyse two source interference using primary and secondary data	✓	60
21	6h. determine the wavelength of light from primary data	✓	80
21	7a. investigate the Doppler effect using secondary data.	✓	60
21	7b. model authentic situations involving the relative motion between the source of a wave and the observer	✗	40
21	7c. Explore the Doppler effect in a variety of applications using secondary sources	✓	20
21	7d. model real-life situations involving resonance	✗	40
21	7e. relate a driving frequency to the natural frequency of an oscillating system, the amplitude of motion and the transfer of energy within the system	✓	40
22	**Strand 3: Electric and Magnetic Fields and their Interactions (EMF)**		
23	1a. demonstrate forces i. between charged objects ii. between charged and neutral objects	✓	60
23	1b. classify materials as conductors or insulators	✓	60
23	1c. model the behaviour of insulators and conductors.	✗	60
23	1d. model static electrical phenomena	✗	120
23	2a. model the electric force between point charges	✗	80
23	2b. discuss the electric field as a model for the non-contact interaction between charged objects	✓	40

23	2c. define electric field strength at a point	✓	40
23	2d. use field lines to represent the relative strength and direction of electric fields around charged objects	✓	20
23	3a. model - the relationship between work, charge and potential difference the relationship between current and charge - the relationship between electric current, conventional current, power and resistance - series and parallel circuits - the rate of conversion of electrical energy in components of electric circuits - fuses and circuit breakers	✗	80 120 80 40 30
24	3b. use primary and secondary data to verify the relationship between current flowing through and the voltage across an ohmic conductor	✗	80
24	3c. determine the resistance of ohmic and non-ohmic conductors	✗	200
24	3d. investigate the effect of temperature on the resistance of a conductor using primary and secondary data	✗	80
24	3e. model resistances in electrical circuits	✗	40
24	4a. explore the use of p-n junctions in real-world applications	✓	120
24	4b. model an n-p-n transistor	✗	120
24	5a. model the relative strength and direction of magnetic fields around - a single permanent magnet and permanent magnets in close proximity - crrent carrying wire - current carrying solenoid with and without ferrous core	✗	60 30 20
25	5b. explore the use of permanent and temporary magnets in authentic situations	✗	30
25	6a. investigate the relationship between the magnetic field and the electromagnetic force on a current- carrying wire	✓	60
25	6b. model the motor effect	✗	60

25	6c. model a DC motor	✗	60
25	7a. investigate the relationship between a change in magnetic flux on any induced EMF and subsequent current flow in a conducting coil	✓	160
25	7b. model - the generator effect - ac and dc generators - transformers	✗	20 60 40
25	7c. evaluate the use of induced potential difference in a variety of applications using secondary sources	✗	40
25	7d. solve problems involving the efficiency of transformers	✓	20
25	7e. evaluate transmission losses in the National Grid using secondary sources	✓	40
25	7f. evaluate evidence about local issues related to electrical generation and distribution using secondary sources	✗	80
22	**Strand 4: Modern Physics Atomic and Nuclear (MP)**		
26	1a. analyse evidence supporting the existence and properties of the electron	✓	80
26	1b. verify the basic principles of thermionic emission using secondary evidence	✗	40
27	1c. model the production and deflection of a beam of electrons in a vacuum	✗	80
27	2a. use secondary data to verify the photoelectric effect and the effect of varying - the intensity of incident radiation - the frequency of incident radiation	✗	120
27	2b. appreciate how photoelectric emission supports the particle model of light	✗	20
27	2c. model x-ray production and the photoelectric effect	✗	60
27	2d. compare x-ray production and the photoelectric effect	✓	20
27	2e. relate the photoelectric effect to the operation of a photocell	✓	10

27	2f. evaluate the use of photocells using secondary sources	✗	10
27	3a. model the atom and emission spectra of atoms.	✗	120
27	3b. appreciate how the analysis of emission spectra data has contributed to our understanding of objects in the universe	✗	30
27	4a. analyse evidence to support the existence of natural background radiation	✗	40
27	4b. classify radioactive emissions in terms of their - relative ionising effects - relative penetrating powers - charge and mass - deflection in electric and magnetic fields	✓	160
28	4c. model spontaneous radioactive decay	✗	120
28	4d. examine the model of half -life in radioactive decay and use it to solve problems involving the activity or the amount of a radioactive sample	✓	80
28	5a. analyse Cockcroft and Walton's experiment and appreciate its significance as the first nuclear transformation by artificially accelerated particles	✗	60
28	5b. describe matter in terms of fundamental particles and their antiparticles	✗	140
28	6a. model nuclear fission, nuclear fusion and particle– antiparticle interactions	✗	100
28	6b. evaluate evidence about issues related to nuclear fission and fusion in electrical generation using secondary sources	✗	40

Minimum Teaching time in minutes	**8380**
Assessment time (10%)	**838**
Review and crosscutting themes	**600**
Integration of Nature of Science	**600**
Total minutes	**10418**
Total Hours	**174**

Table 3.1. Analysis of teaching time required to ensure that students achieve each learning outcome.

It is important to stress that the estimate is based on the assumption that clarification is obtained as per the proposals for all vague learning outcomes as specified in Appendix 1.

Since the Leaving Certificate Physics specification is designed for a minimum of 180 hours of class contact time of which 20 hours is spent on the Physics In Practice Research Investigation, this leaves a minimum of 160 hours of class contact time for teachers to ensure that their students achieve the learning outcomes. As shown in Table 3.1, this minimum is now exceeded when the unifying strand on the Nature of Science is included. This topic has already been covered at Junior Cycle Science level. Note that the minimum time to teach each learning outcome in isolation is indicated and an estimate of the time needed to implement the crosscutting themes and integration on the Nature of Science is added on to this time.

This unifying strand is discussed in more detail in Chapter 6.

3.4 Breakdown of Higher Level / Ordinary Level components

As mentioned above, there are 101 learning outcomes in the four contextual strands. Of the 101 learning outcomes, 10 contain reference to Higher Level material. No detailed discussion on the balance between Higher Level and Ordinary Level has been held by the NCCA Physics Subject Development Group. We recommend that this discussion be held as part of the review process as we are concerned about the imbalance between Ordinary Level and Higher Level in some areas of the specification. We note that the active verbs in the vast majority of the learning outcomes are set at higher level and that some are to be removed at ordinary level.

Some examples of areas of particular concern are:

FM6. Uniform circular motion

a. explain centripetal force

b. model the dynamics of an object moving in a circle with constant angular velocity

c. verify Kepler's 3rd Law using secondary data

d. model situations involving the orbits of planets and satellites in near Earth and geostationary orbits

In summary, we feel that this matter is best discussed at an NCCA Subject Development Group meeting in order to ensure that the best balance between Ordinary Level and Higher Level is obtained.

3.5 Mandatory Student Investigations

The Leaving Certificate Biology, Physics and Physics syllabi that are currently being taught in our schools contain clear lists of Mandatory Student Laboratory investigations. There are 27 Mandatory Students Laboratory Investigations on the current Leaving Certificate Physics syllabus. The specification of Mandatory Student Laboratory Investigations is international best practice in syllabus design. For example, in the GCSE and A level system in the UK, the Examination Boards specify a list of laboratory investigations which are term "Required Practicals". Considerable background information on each practical investigation is given for both teachers and students. For a list of Biology, Physics and Physics GCSE laboratory practicals see:

https://filestore.aqa.org.uk/resources/science/AQA-8363-8365-PRACTICALS.PDF

Unfortunately, the draft specification in Physics does not contain a clear list of Mandatory Laboratory Student Investigations. However, it is vital that teachers and students are made aware what Mandatory Laboratory Student Investigations must be carried out in order to:

(i) Achieve the relevant learning outcomes

and

(ii) Build up a wide range of laboratory skills in order to carry out the Physics In Practice Investigation.

In the draft specification, mandatory practical work is indicated by the term 'using primary data. '

There is some confusion in the draft specification regarding how some of these experiments can be carried out by students in order to achieve the appropriate learning outcome. For example, Learning Outcome WMET 5 b 'relate the pitch and loudness of sounds to their wave characteristics using primary and secondary data'. This experiment may have been done as a teacher demonstration in the past. Students observed the relationship without collecting primary data. Based on this draft specification student will be obliged to measure loudness, pitch and wavelength and frequency. Is loudness to be measured in dB(A) or dB? Will a class set of this equipment be provided for each school?

Similarly, we have suggested that the methodology of the following experiments be clarified as to what data is to be collected or is an observation satisfactory. Will a class set of equipment be provided for students to carry out these investigations, e.g. 12 ripple tanks, 12 frequency generators etc.?

WMET 6 –a Analyse standing wave patterns

WMET 6 –e diffraction.

WMET 6 –g Analyse two source interference.

If numerical data is to be collected, clarity is required detailing the intended data to be collected and the associated method. For instance, to analyse diffraction on a ripple tank using numerical data collection is challenging. Young's Slits were not designed to have data collected in a numerical way by novice students. Further, a resource concern is also raised: Will a class set of equipment be provided for students to carry out these investigations, e.g. 12 ripple tanks, 12 frequency generators etc.?

We believe that clarity needs to be provided to teachers and students and, to this end, we have extracted from the draft specification what we consider are the laboratory investigations that should be carried out by Physics students. This list is shown in Table 3.2

Practical Investigations that are considered to be mandatory in order to achieve the appropriate learning outcomes

Expt. No.	Page	Learning outcome	Note
1	15	1b. Measure velocity by experiment. (Mandatory Student Investigation)	Learning outcome unpacked.
2	15	1b. Measure acceleration by experiment. (Mandatory Student Investigation)	Learning outcome unpacked.
3	16	1d. Verify the law of addition of vectors	Clarity needed as noted in LO Analysis Table
4	16	2b Investigate Newton's Second Law. (Mandatory Student Experiment)	Clarity needed as noted in LO Analysis Table
5	16	2 e Investigate Archimedes' Principle by experiment. (Mandatory Student Experiment)	Clarity needed as noted in LO Analysis Table
6	16	2f Investigate the principle of conservation of momentum. (Mandatory Student Experiment)	Clarity needed as noted in LO Analysis Table
7	16	3a Investigate the force needed to compress or stretch an object. (Mandatory Student Investigation)	Clarity needed as noted in LO Analysis Table
8	17	3b Carry out an investigation to verify Hooke's Law for elastic objects. (Mandatory Student Investigation).	Clarity needed as noted in LO Analysis Table
9	17	4c Investigate the principle of conservation of energy for an object moving from a height. (Mandatory Student Investigation).	Clarity needed as noted in LO Analysis Table
10	17	5a Carry out investigations to measure 'g' using a simple pendulum and free fall apparatus. (Mandatory Student Investigations).	Clarity needed as noted in LO Analysis Table
11	18	1b Investigate the suitability of given materials for use as thermometers. (Mandatory Student Investigation)	Clarity needed as noted in LO Analysis Table
12	18	1c Carry out an investigation to measure the specific heat capacity of a solid and a liquid. (Mandatory Student Investigations).	Clarity needed as noted in LO Analysis Table
13	18	1c Carry out an investigation to measure the specific latent heat of fusion of ice and the specific latent heat of vaporisation of steam. (Mandatory Student Investigations)	Clarity needed as noted in LO Analysis Table
14	19	3b Carry out an investigation to measure the refractive index of a glass block. (Mandatory Student Experiment)	Clarity needed as noted in LO Analysis Table
15	19	3c Investigate the relationship between image and object distances and the focal length of converging lenses. (Mandatory Student Investigation).	Clarity needed as noted in LO Analysis Table

16	20	4b Examine the diffraction pattern formed when monochromatic light is passed through Young's slits or a diffraction grating. (Mandatory Student Investigation).	Clarity needed as noted in LO Analysis Table
17	20	5a Demonstrate the effect of removal of air on the ability of sound to travel through a vacuum. (Mandatory Student Investigation)	Clarity needed as noted in LO Analysis Table
18	20	5b Demonstrate the relationship between amplitude of a wave and its loudness and also the relationship between frequency and pitch. (Mandatory Student Investigation).	Clarity needed as noted in LO Analysis Table
N/A	20	5c. Note demonstrate standing waves has been deleted from Mandatory student practical and included as a teacher demonstration.	Clarity needed as noted in LO Analysis Table
19	20	6c Investigate the variation of the fundamental frequency of a stretched string with length. (Mandatory Student Investigation).	Clarity needed as noted in LO Analysis Table
20	21	6e Examine the diffraction pattern formed when monochromatic light is passed through Young's slits or a diffraction grating. (Mandatory Student Investigation).	Clarity needed as noted in LO Analysis Table
21	21	6g Carry out an investigation to measure the wavelength of monochromatic light. (Mandatory student Investigation).	Clarity needed as noted in LO Analysis Table
22	24	3b Carry out an investigation to verify the relationship between current flowing through and the voltage across an Ohmic conductor. (Mandatory Student Investigation).	Clarity needed as noted in LO Analysis Table
23	24	3d Investigate the variation of the resistance of a metallic conductor with temperature. (Mandatory Students Investigation)	Clarity needed as noted in LO Analysis Table

Table 3.2. Practical Investigations that are considered to be mandatory in order to achieve the appropriate learning outcomes

3.6 Conclusions and Recommendations

It is clear that one of the main problems with the Leaving Certificate Physics Draft Specification is the lack of clarity in a significant number of learning outcomes. Of the 101 learning outcomes in the contextual strands, a total of 69 learning outcomes (68.3%) are unclear. Due to this lack of clarity, it is impossible for teachers to ensure that their students achieve these learning outcomes – and impossible for students to know if they have achieved them. Recommendations to bring clarity to each vague learning outcome have been made.

An analysis of time to teach each individual specification has been carried out and, in general, it is felt that the learning outcomes in the contextual strands cannot be achieved within 160 hours of teaching the specification. Since the Unifying Strand deals with the Nature of Science, it is felt that this has been adequately covered at Junior Cycle level.

Of the 101 learning outcomes in the specification, 10 contain reference to Higher Level material. It is recommended that this balance needs to be discussed at an NCCA Subject Development Group meeting as no detailed discussion has been held to date on this topic. A document has already been submitted from the ISTA representative on this issue.

An analysis of the unclear learning outcomes shows that they fell into various categories:

- (i) Learning outcomes that make no sense in the context in which they are being used.
- (ii) Learning outcomes that are so vague and so broad that it is impossible to know what students must be able to do in order to achieve the learning outcomes.
- (iii) Learning outcomes that use the term “primary data” when it is not necessary to use it.
- (iv) Learning outcomes that use the term “secondary data” when it is not necessary to use it.
- (v) Learning outcomes that are vague and ill defined.
- (vi) Learning outcomes that do not clarify what laboratory practical work should be carried out in order to achieve the learning outcome.
- (vii) Learning outcomes that overlap

In addition to lack of clarity in 69 learning outcomes, there is also a lack of clarity in the laboratory practical investigations that are mandatory in order to achieve the appropriate learning outcomes. The ISTA Physics Committee has analysed the draft specification and provided a list of 23 Laboratory Practical Investigations that are considered to be mandatory in order to successfully implement the specification in the classroom.

Chapter 4

Analysis of Leaving Certificate Chemistry Draft Specification

4.1 Introduction

The Leaving Certificate Chemistry Draft Specification consists of the following main sections**:**

- **Introductory** material on Senior Cycle. This section consists of twelve pages of broad introductory material that is not specific to chemistry as a subject but deals with Senior Cycle in general and covers broad key competencies in Senior Cycle. As these competencies are generic and very general, they are difficult to interpret, e.g. *being creative*, *communicatin*g, and *participating in society*.
- **Strands of study and learning outcomes**. This section introduces a unifying strand called The Nature of Science and also the four contextual strands in the Leaving Certificate chemistry specification *The Nature of Matter, Behaviour of Matter, Interactions of Matter* and *Matter in our World*. The unifying strand is discussed in Chapter 6 and the other four strands are discussed in this Chapter. Reference is also made to some general cross-cutting themes. It is pointed out that while the strands are set out separately, this is not meant to imply that they should be studied in isolation or in the order in which they are presented. This section contains the list of learning outcomes and accompanying notes in the *Students learn about* column.
- **Assessment**. This section discusses the breakdown of marks between the written paper and what is called an "additional assessment component". The latter component involves coursework in which students carry out a Chemistry in Practice Investigation. This will be discussed in more detail in Chapter 7 of this report.
- **Appendix 1.** This section is headed "Glossary of Action verbs". This section has already been discussed in Chapter 2 of this report.

4.2 Analysis of learning outcomes

One of the key roles of the ISTA Chemistry Committee was to coordinate feedback about the draft Chemistry specification from ISTA members who teach Leaving Certificate chemistry. As described in Chapter 1, this feedback was obtained via an online CPD event to discuss the draft specification as well as an online questionnaire.

Each learning outcome in the four contextual strands was analysed for clarity under the headings indicated in the Learning Outcomes Analysis Table reproduced in Appendix 2 of this report. Those learning outcome which were unclear to teachers were indicated by a red icon and those which were clear to teachers were marked by a green icon. There are 127 learning outcomes in the four contextual strands and 40 of these (31.5%) were judged by the teachers to be unclear. In other words, teachers were unable to answer the question "What must students be able to do in order to achieve this learning outcome?"

As may be observed from a study of the Learning Outcomes Analysis Table in Appendix 2, where a learning outcome is categorised as unclear, a clearer wording is proposed .

It was found that learning outcomes judged to be unclear fell into a number of categories.

1. Learning outcomes that do not contain active verbs

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
31	a. Appreciate that some reactions tend to be reversible and explain the concept of dynamic chemical equilibrium		Since the verb “appreciate” is not an active verb, we suggest that this learning outcome be rewritten to make it clear what students must be able to do in order to show that they appreciate this concept.	We suggest the following wording: Explain that some reactions tend to be reversible and discuss the concept of dynamic chemical equilibrium

2. Learning outcomes that use verbs that make no sense in the context in which they are being used.

The most common problematic area in this category was the use of the word “model” whose meaning is clearly defined in English dictionaries but which is given a range of different meanings by NCCA. This is discussed in more detail in Appendix 4 of this report.

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
22.	e. Model a range of solution concentrations and use knowledge to prepare solutions, including primary standard solutions		The problem with using “model” as a verb is covered in the introductory notes to this submission. The statement “model a range of solution concentration” is unclear as it gives no indication what students must be able to do to show that they have achieved this learning outcome.	We suggest this learning outcome be rewritten as follows: Explain the concept of concentration of a solution and outline how to prepare a range of solutions of different concentrations including primary standard solutions.

3. Learning outcomes that are so vague and so broad that it is impossible to know what students must be able to do in order to achieve the learning outcome.

An example of this type of learning outcome is given in the table below. Without information to indicate the depth of treatment of the learning outcome, it is impossible for the teacher to know where to begin and where to end the teaching and learning process.

Page	Learning Outcome	Clarity	Comment	Proposed information to be given in the Students Learn About column
37	c. **Solve and analyse volumetric problems**		This is a vague learning outcome and it is impossible to deduce from it what type of volumetric problems students must be able to solve in order to achieve this learning outcome.	We suggest the following information be provided in the SLA column: Solving volumetric problems, using the formula method. (Higher Level and Ordinary Level) **Solving volumetric problems from first principles, where the formula method is not applicable. Either method may be used when both methods are applicable. (Higher Level only)** Balanced equations will be given in all volumetric problems.

4. Learning outcomes that use the term "primary data" when it is not necessary to use it.

In a significant number of learning outcomes that involve students performing practical investigations, the term "primary data" is unnecessary and only confuses students and teachers who have asked "why is the term primary data used when it is obvious that the data being collected by the students is their own data?".

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
19	e. Verify, using primary data, the law of conservation of mass and explain through the use of models [EI]		The use of the term "primary data" is unnecessary and confusing. Since this is marked as an investigation to be carried out by the students themselves, of course the data collected will be their own data.	Carry out an investigation to verify the law of conservation of mass. (Mandatory Student Investigation) Explain your results by drawing and interpreting models of the reactions involved.

5. Learning outcomes that use the term “secondary data” when it is not necessary to use it.

In a significant number of learning outcomes reference is made to “secondary data”. This is unnecessary and only confuses students as obviously secondary data are used in homework assignments and studying past examination questions.

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
35	m. Investigate pH titration curves, using primary and secondary data from acid-base reactions, justifying appropriate indicators for each titration [EI]		This is a vague learning outcome and it is difficult to deduce from it what students must be able to do in order to achieve this learning outcome. As already pointed out, the use of the term “primary data” is unnecessary since students are collecting their own data (i.e. primary data) in the investigation.	The study of secondary data is not part of a laboratory investigation as this activity can be done as homework or studying past examination papers. Reference to secondary data analysis could be included in the SLA column or as a separate learning outcome. We suggest that this learning outcome be reworded as follows: Carry out a laboratory investigation to investigate pH titration curves.

6. Learning outcomes that are vague and ill defined.

In some cases the learning outcomes need to be clearly defined in order to help teachers understand what students must DO in order to achieve the learning outcome.

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
23	a. Describe and compare different types of chemical bonding		It is not clear from the learning outcome or the information SLA column what types of bonding on the continuum should be studied.	We suggest that this learning outcome be rewritten as follows: Describe and compare ionic, polar covalent and pure covalent bonding.

7. Use of broad terms such as “range of”

In some cases the learning outcomes contain phrases that are meaningless without more details being specified.

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
35	m. Investigate pH titration curves, using primary and secondary data from acid-base reactions, justifying appropriate indicators for each titration EI		This is a vague learning outcome and it is difficult to deduce from it what students must be able to do in order to achieve this learning outcome. As already pointed out, the use of the term “primary data” is unnecessary since students are collecting their own data (i.e. primary data) in the investigation.	The study of secondary data is not part of a laboratory investigation as this activity can be done as homework or studying past examination papers. Reference to secondary data analysis could be included in the SLA column or as a separate learning outcome. We suggest that this learning outcome be reworded as follows: Carry out a laboratory investigation to investigate pH titration curves. I

8. Learning outcomes that use the term “secondary data” when it is not necessary to use it.

In some cases the learning outcomes need to be clearly defined in order to help teachers understand what students must DO in order to achieve the learning outcome.

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
23	a. Describe and compare different types of chemical bonding		It is not clear from the learning outcome or the information SLA column what types of bonding on the continuum should be studied.	We propose that this learning outcome be rewritten as follows: Describe and compare ionic, polar covalent and pure covalent bonding.

9. Learning outcomes that use broad terms such as "range of" without any further clarification.

In some cases the learning outcomes contain phrases that are meaningless without more details being specified.

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
25	b. Relate observed physical properties for a range of compounds to the type of intermolecular forces, **accounting for trends**		It is not clear what students must be able to do in order to achieve this very broad learning outcome.	We propose that the learning outcome be reworded as follows: Investigate the effect of hydrogen bonding on the rate of evaporation of some organic compounds and analyse the resulting trends.

10. Learning outcomes that do not clarify what laboratory practical work should be carried out in order to achieve the learning outcome.

In many cases depth of treatment needs to be supplied in order to indicate to students and teachers what laboratory practical work should be carried out.

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
30	a. Investigate, using primary data, the factors that affect rates of a reaction and interpret rate of reaction graphs, using primary and secondary data EI		This is a very vague learning outcome and it is impossible to deduce from it what students must be able to do in order to achieve this learning outcome. As already pointed out, the use of the term "primary data" is unnecessary since students are collecting their own data (i.e. primary data) in the investigations.	The notes in the STA column suggest three examples of investigations that students could carry out. Each of the experiments is quite different and cause different learning outcomes to be achieved by students. Hence, we recommend that these three investigations be listed as three separate investigations as follows 1. To investigate the effect of particle size on the rate of reaction when hydrochloric acid reacts with marble chips and interpret rate of reaction graphs. 2. To investigate the effect of concentration on reaction rate when sodium thiosulfate solution reacts with hydrochloric acid and interpret rate of reaction graphs. 3. To investigate the effect of a catalyst (e.g. manganese dioxide) on the decomposition of hydrogen peroxide and interpret rate of reaction graphs.

11. Learning outcomes that include unsuitable active verbs.

In some cases, clarification can be brought to the learning outcome by using a more suitable active verb. Whilst there are many points of comparison between primary and secondary cells, the key point that needs to be stressed is what distinguishes the two types of cells.

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
34	d. Compare a primary and secondary cell	✗	This needs clarification as to what is required.	We propose that this be reworded as: Distinguish between a primary and secondary cell.

4.3 Analysis of time to teach the draft specifications

The members of the ISTA Chemistry Committee, in consultation with various colleagues, have studied each learning outcome in the four contextual strands and discussed the teaching time required to ensure that students achieve the relevant learning outcome.

The estimated time is summarised in Table 4.1 on the next pages.

Page	Learning Outcome	Clarity	Time (mins)	Comment
19	a. Investigate experimental evidence for the Kinetic Theory of Matter EI	✗	60	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
19	b. Analyse the Kinetic Theory of Matter to: (i) explain the nature and behaviour of matter at the particulate level , (ii) model how matter changes state	✗	40	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
19	c. Justify the use of different separation techniques for isolating one or more components of a mixture and conduct experiments using appropriate techniques EI	✗	180	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
19	d. Distinguish between physical change and chemical change of matter	✓	15	
19	e. Verify, using primary data, the law of conservation of mass and explain through the use of models EI	✗	80	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
20	a. Outline the development of current atomic theory, including main contributions and refinements by key scientists	✓	180	

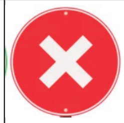
20	b. Evaluate previous models of the atom against the current model, stating the assumptions and limitations in each case	✔	80	
20	c. describe the atom using the current model of atomic theory, including subatomic particles	✔	80	
20	d. Describe and explain the origin of lines on the atomic emission spectrum of hydrogen	✔	40	
20	e. Identify an element using appropriate primary and secondary data	✘	80	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
20	f. Describe the electronic structure of elements and associated ions, identifying stable electronic configurations	✔	80	This estimate is based on the assumption that the learning outcome is clarified as shown
20	g. Compare chemical and nuclear reactions	✔	15	
20	h. Distinguish different forms of radiation	✔	80	
21	a. Describe the development of the modern periodic table	✔	60	
21	b. Identify specific groups of elements and describe physical and chemical properties of elements within each of these groups	✘	60	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
21	c. Examine and explain the arrangement of elements in groups, periods and blocks in the periodic table of elements	✔	80	
21	d. Distinguish between d-block elements and transition elements	✔	20	
21	e. Examine trends and relationships in the periodic table	✘	80	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
21	f. Explain trends in first ionisation energies, including exceptions, and in successive ionisation energies and atomic radii	✘	80	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2

21	a. Define and explain the mole in terms of the Avogadro constant, and relate the mole to how the amount of a substance can be quantified	✓	80	
22	b. Solve problems involving relative atomic mass and percentage abundance	✗	120	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
22	c. State Avogadro's law and deduce the molar volume of a gas	✓	60	
22	d. Conduct an experiment to determine the relative molecular mass of a gas volatile liquid.	✓	120	
22	e. Model a range of solution concentrations and use knowledge to prepare solutions, including primary standard solutions	✗	80	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
22	f. Convert between units of concentration	✓	80	
22	g. Use the concept of a mole to: (i) determine empirical and molecular formulae : (ii) balance equations for reactions where reactants and products are specified : (iii) analyse and solve quantitative problems based on balanced Equations	✓	160	
23	a. Describe and compare different types of chemical bonding	✗	80	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
23	b. Predict the nature of chemical bonds between atoms, using trends in electronegativity values	✓	60	
24	c. Model different types of bonding to predict chemical formulae and outline the limitations in predicting bonding between atoms	✗	80	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
24	d. Relate the properties of simple compounds to the nature of bonding present	✓	40	
24	e. Compare the nature of metallic bonding with the nature of bonding along the continuum, accounting for differences and similarities in properties	✓	60	

24	f. Investigate, using primary data, the presence of ions in salts and in solutions, and identify an anion and cation in an unknown salt EI	✘	120	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
24	g. Compare the properties and structures of allotropes of carbon	✔	40	
24	h. Discuss the use of carbon allotropes in society	✔	40	
25	a. Distinguish between intramolecular bonding and a range of intermolecular forces	✔	80	
25	b. Relate observed physical properties for a range of compounds to the type of intermolecular forces, accounting for trends	✘	80	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
25	c. Explain qualitatively the influence of polarity, and symmetry, on intermolecular forces	✔	20	
25	d. Use the shapes of molecules of simple compounds to predict physical properties	✘	30	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
25	e. Use VSEPR theory to predict and model the shapes of molecules	✔	80	
25	f. Distinguish between the structures of amorphous and crystalline solids	✔	30	
26	g. Model ionic, molecular, metallic and covalent crystalline structures and relate the structure to the physical properties	✔	80	
26	a. Outline the development of the gas laws and the ideal gas equation	✔	80	
26	b. Explain what is meant by the ideal gas, accounting for deviations of real gases from ideal gas behaviour	✔	30	
26	c. Solve and interpret quantitative problems using the gas laws	✔	80	

26	a. Outline the main sources of hydrocarbons and their uses in industry and society	✓	30	
26	b. Identify and research one major impact on society of the extensive use of hydrocarbons. RI	✓	40	
27	c. Prepare ethene, observe its physical properties, and investigate some of its chemical properties EI	✓	80	
27	d. Describe and compare different groups of hydrocarbons, including composition, bonding and structure, and relate these to their characteristic properties	✓	150	
27	e. Explain and predict differences in properties of: : (i) straight chain alkanes of different carbon number : (ii) alkanes of the same carbon number (iii) monounsaturated straight chain alkenes	✗	60	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
27	f. Explain the relative chemical stability of alkanes	✓	20	
27	g. Construct and examine 3 dimensional models of hydrocarbon molecules and explain how bonding and isomers influence the spatial arrangement of atoms for these molecules	✓	60	
27	h. Explain and compare the shapes of ethane, ethene, ethyne and benzene molecules in terms of sigma and pi bonds, including delocalised pi bonding	✓	80	
27	i. Distinguish between structural and geometrical isomerism, including how isomerism gives rise to different properties	✓	60	
29	a. define bond enthalpy and explain enthalpy changes in a reaction in terms of making and breaking bonds	✓	50	
29	b. Explain, and model diagrammatically, processes of energy transfer using exothermic and endothermic reactions	✗	60	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2

29	c. Investigate, using primary data, how to determine ΔH for a suitable neutralisation reaction. EI	✗	100	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
29	d. Calculate ΔH for a chemical reaction and describe the energy transfer through a simple energy profile diagram	✗	160	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
29	e. Analyse a given reaction, involving covalent molecules, to explain and predict the value of ΔH using average bond enthalpy values	✓	60	
29	f. Calculate and predict enthalpy changes using Hess's Law	✓	40	
30	g. Construct balanced equations for the complete combustion of hydrocarbons and primary alcohols, and explain trends in the associated standard ΔH values	✓	60	
30	h. Investigate, using primary data, the energy change of combustion and compare experimental values to standard values, accounting for differences [EI]	✗	100	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
30	a. Investigate, using primary data, the factors that affect rates of a reaction and interpret rate of reaction graphs, using primary and secondary data [EI]	✗	200	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
30	b. Describe collision theory, and give examples of slow and fast reactions	✓	40	
30	c. Define rate of reaction	✓	10	
31	d. Compare the energy profile diagrams of catalysed and uncatalysed reactions, for both exothermic and endothermic reactions	✓	20	
31	e. Outline two general catalytic mechanisms	✗	80	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2

31	a. Appreciate that some reactions tend to be reversible and explain the concept of dynamic chemical equilibrium		30	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
31	b. Explain the factors that affect the value of the equilibrium constant *Kc*, and use the mathematical model of Kc to describe and predict how given reactions would proceed		60	
31	c. Solve problems involving the mathematical model for the equilibrium constant Kc		180	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
31	d. Apply Le Chatelier's principle to a variety of processes to predict responses to disturbances to the equilibrium and to predict conditions for optimising yields of product		60	
32	e. Investigate, using primary and secondary data, how changes in temperature and concentration can affect the state of equilibrium EI		100	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
32	f. Explain the Haber process as an industrial application of chemical equilibrium, and how chemical equilibrium principles can be applied to the production of ammonia		30	
32	g. Outline the impact of the Haber process on society and consider its ongoing role		15	
32	h. Outline the importance of a compromise between yield and rate of reaction for the industrial use of the Haber process		20	
32	a. Justify categorisation of commonly used substances as acid or base, based on the display of certain properties and discuss common everyday examples of neutralisation		30	

32	b. Predict the products of, and write balanced equations for, acid base reactions	✓	80	
33	c. Compare two theories of acid-base systems and justify why Brønsted-Lowry theory is a more extensive model for explaining behaviour	✓	40	
33	d. Apply Brønsted-Lowry theory to identify, in chemical equations: (i) conjugate acid-base pairs : (ii) species acting as acids and bases	✓	60	
33	e. Explain the self-ionisation of water and deduce a mathematical representation for the ionic product of water (Kw), accounting for its temperature dependence	✓	60	
33	f. Measure pH, and explain the pH scale and its limitations	✓	60	
33	g. Investigate, using primary data, factors that affect the pH of a solution EI	✗	100	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
33	h. Distinguish between:: (i) weak and strong acids (and bases) : (ii) concentrated and dilute acids (and bases)	✓	40	
33	i. Solve mathematical problems involving pH for dilute aqueous solutions	✓	120	
33	j. Deduce mathematical representations for weak acid dissociation constant (*Ka*) and weak base dissociation constant (*Kb*)	✓	80	
33	k. Compare degrees of dissociation of strong and weak acids, and strong and weak bases, using *Ka* and *Kb* values	✓	40	
34	l. Explain how weak acid and weak base acid-base indicators function	✓	30	
34	m. Investigate pH titration curves, using primary and secondary data from acid-base reactions, justifying appropriate indicators for each titration EI	✗	300	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2

34	a. Describe oxidation and reduction, using suitable examples and applications, identifying oxidising and reducing agents in given chemical reactions	✓	60	
34	b. Apply oxidation numbers to balance redox reaction equations	✓	80	
34	c. Investigate, using primary data EI: (i) redox reactions, using simple experiments involving halogens : (ii displacement reactions of metals, relating them to the electrochemical series	✗	200	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
34	d. Compare a primary and secondary cell	✗	60	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
34	e. Conduct an experiment to create a simple galvanic cell and explain its operation	✓	100	
35	f. Conduct experiments in electrolysis, and explain the operation of the electrolytic cells	✗	150	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
35	g. Research the role of electrochemistry in an area related to sustainability and technology in everyday life RI	✗	40	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
36	a. Recognise the importance of primary standards and standard solutions	✓	20	
36	b. Determine the concentration of analytes by titration, using primary standard solutions and/or solutions standardised using primary standards EI	✗	400	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
37	c. Solve and analyse volumetric problems	✗	180	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
37	a. Outline sources of organic compounds and the use and impact of products based on organic compounds	✓	40	

37	a. Apply rules for nomenclature and classify each functional group in terms of general formula and structure	✓	120	
37	c. Construct and compare representations of organic molecules	✓	40	
38	d. Conduct qualitative analysis tests: : (i) to distinguish between aldehydes and ketones : (ii) for the presence of carboxylic acid and alcohol functional groups	✓	80	
38	e. Relate the physical properties of organic molecules to molecular size, type of bonding present and intermolecular forces	✓	40	
38	f. Describe and discuss five types of reactions and analyse a given reaction in terms of the type(s) of reaction taking place	✓	100	
38	g. Analyse an organic reaction scheme and predict possible reactions and reaction products	✗	80	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
38	h. conduct experiments to: : (i) prepare an ester : (ii) synthesise benzoic acid, determining purity, melting point and yield	✓	300	
39	i. Describe reaction mechanisms involving movement of electrons, including supporting evidence	✓	120	
39	j. Discuss redox reactions and acid-base reactions of organic compounds	✓	60	
39	k. explain the acidity of carboxylic acid and alcohol functional groups	✓	40	
39	l. Outline how a soap works, as an example of a surfactant, and the applications of surfactants in everyday life	✓	30	
39	m. Conduct an activity to prepare soap, with NaOH either limiting or in excess	✓	120	

39	n. Compare the manufacture and basicity of a simply-made soap product with a commercial product	✓	40	
40	o. Illustrate the use of organic compounds in pharmaceutical products	✓	20	
40	p. Investigate, using primary data, how to find percentage aspirin in an aspirin tablet EI	✗	120	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
40	q. describe the structure and applications of addition polymers	✓	40	
40	r. Relate the physical properties of addition polymers to their structures, and how non-biodegradability is related to chemical stability	✓	30	
40	a. Discuss our chemical environment for each of the three domains and consider the interconnections across domains	✗	30	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
40	b. Research, individually or collaboratively, one area of each of the three domains regarding the impact of humans on our chemical environment RI	✗	40	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
41	c. Relate aspects of the Nitrogen, Oxygen and Carbon cycles to climate change and sustainability	✓	80	
41	d. Describe the natural greenhouse effect and explain its significance	✓	40	
41	e. Discuss the evidence for the enhanced greenhouse effect and possible solutions to anthropogenic influences on the atmosphere	✓	30	
41	f. Outline the water cycle, including its significance	✓	40	
41	g. Describe the steps necessary in the treatment of drinking water and appreciate the impact of providing clean water for human use	✗	40	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2

41	h. Analyse water samples, both qualitatively and quantitatively EI	✗	300	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
41	i. Discuss causes of water contamination, biochemical consequences and possible solutions to one of the causes	✓	80	
42	j. Outline methods for the extraction of metals from their natural states based on their positions in the electrochemical series	✗	120	This estimate is based on the assumption that the learning outcome is clarified as proposed in Appendix 2
42	k. Discuss the recycling of aluminium and plastics	✓	40	
42	l. Discuss the impact on sustainability of reduced dependence on energy sourced from fossil fuels, and sustainable alternatives	✓	40	
		Total	9885	minutes
		Total	164.75	hours

Table 4.1. Analysis of teaching time required to ensure that students achieve each learning outcome.

4.4 Breakdown of Higher Level / Ordinary Level components

As mentioned above, there are 127 learning outcomes in the four contextual strands. Of there 127 learning outcomes, 35 contain reference to Higher Level material. No detailed discussion on the balance between Higher Level and Ordinary Level has been held by the NCCA Chemistry Subject Development Group. We recommend that this discussion be held as part of the review process as we are concerned about the imbalance between Ordinary Level and Higher Level in some areas of the specification.

Some examples of areas of concern are:

- The learning outcome *Solve and analyse volumetric problems* (p. 37 c) is marked as Higher Level only. We feel that this needs to be clarified for both Higher Level and Ordinary Level as discussed in Appendix 2 of this report.

- Some learning outcomes are classified as Ordinary Level and Higher Level but we feel that some aspects of the learning outcome should be Higher Level only, e.g. *Outline methods for the extraction of metals from their natural states based on their positions in the electrochemical series* (p. 42 j)

In summary, we feel that this matter is best discussed at an NCCA Subject Development Group meeting in order to ensure that the best balance between Ordinary Level and Higher Level is obtained.

4.5 Mandatory Student Investigations

The Leaving Certificate Biology, Chemistry and Physics syllabi that are currently being taught in our schools contain clear lists of Mandatory Student Laboratory investigations. There are 28 Mandatory Students Laboratory Investigations on the current Leaving Certificate chemistry syllabus. The specification of Mandatory Student Laboratory Investigations is international best practice in syllabus design. For example, in the GCSE and A level system in the UK, the Examination Boards specify a list of laboratory investigations which are term “Required Practicals”. Considerable background information on each practical investigatin is given for both teachers and students. For a list of Biology, Chemistry and Physics GCSE laboratory practicals see:

https://filestore.aqa.org.uk/resources/science/AQA-8464-8465-PRACTICALS.PDF

Unfortunately, the draft specification in Chemistry does not contain a clear list of Mandatory Laboratory Student Investigations. However, it is vital that teachers and students are made aware what Mandatory Laboratory Student Investigations must be carried out in order to:

(i) Achieve the relevant learning outcomes

and

(ii) Build up a wide range of laboratory skills in order to carry out the Chemistry In Practice Investigation.

There is some confusion in the draft specification regarding the exact list of laboratory investigations that should be carried out by students in order to achieve the appropriate learning outcome. In some cases, these practical investigations are marked “EI” and in other cases there is no marking. The ISTA believes that clarity needs to be provided to teachers and students and, to this end, we have extracted from the draft specification what we consider are the laboratory investigations that should be carried out by chemistry students. This list is shown in Table 4.2

Practical Investigations that are considered to be mandatory in order to achieve the appropriate learning outcomes

Expt. No.	Page	Learning outcome	Note
1	19	a. Investigate experimental evidence for the Kinetic Theory of Matter [EI]	Clarity needed as noted in LO Analysis Table
2	19	c. Justify the use of different separation techniques for isolating one or more components of a mixture and conduct experiments using appropriate techniques [EI]	Clarity needed on these 10 techniques as noted in LO Analysis Table 10 Expts?
3	19	e. Verify, using primary data, the law of conservation of mass and explain through the use of models [EI]	
4	20	e. Identify an element using appropriate primary and secondary data	Clarity needed as noted in LO Analysis Table

5	22	d. **Conduct an experiment to determine the relative molecular mass of a gas**	Clarity needed as noted in LO Analysis Table
6	22.	e. Model a range of solution concentrations and use knowledge to prepare solutions, including primary standard solutions	Clarity needed as noted in LO Analysis Table
7	24	f. Investigate, using primary data, the presence of ions in salts and in solutions, and identify an anion and cation in an unknown salt EI	Clarity needed as noted in LO Analysis Table
8	25	b. Relate observed physical properties for a range of compounds to the type of intermolecular forces, **accounting for trends**	Clarity needed as noted in LO Analysis Table
9	27	c. Prepare ethene, observe its physical properties, and investigate some of its chemical properties [EI]	Clarity needed as noted in LO Analysis Table
10	29	c. Investigate, using primary data, how to determine ΔH for a suitable neutralisation reaction. [EI]	
11	30.	h. Investigate, using primary data, the energy change of combustion and compare experimental values to standard values, accounting for differences [EI]	
12	30	a. Investigate, using primary data, the factors that affect rates of a reaction and interpret rate of reaction graphs, using primary and secondary data [EI]	Clarity needed as noted in LO Analysis Table 3 Expts?
13	32	e. Investigate, using primary and secondary data, how changes in temperature and concentration can affect the state of equilibrium [EI]	Clarity needed as noted in LO Analysis Table
14	33	f. Measure pH, and explain the pH scale **and its limitations**	
15	33	g. **Investigate, using primary data, factors that affect the pH of a solution** [EI]	Clarity needed as noted in LO Analysis Table
16	35	m. Investigate pH titration curves, using primary and secondary data from acid-base reactions, justifying appropriate indicators for each titration [EI]	Clarity needed as noted in LO Analysis Table
17	34	c. **Investigate, using primary data [EI]:** **• redox reactions, using simple experiments involving halogens** **• displacement reactions of metals, relating them to the electrochemical series**	
18	34	e. Conduct an experiment to create a simple galvanic cell and explain its operation	
19	35	f. Conduct experiments in electrolysis, and explain the operation of the electrolytic cells	
20	36	b. Determine the concentration of analytes by titration, using primary standard solutions and/or solutions standardised using primary standards [EI]	Clarity needed as noted in LO Analysis Table 5 Expts?

21	38	d. Conduct qualitative analysis tests: • to distinguish between aldehydes and ketones • for the presence of carboxylic acid and alcohol functional groups	
22	38	h**. conduct experiments to:** **• prepare an ester**	2 expts
23	38	h**. conduct experiments to:** **• synthesise benzoic acid, determining purity, melting point and yield**	
24	39	m. Conduct an activity to prepare soap, with NaOH either limiting or in excess	
25	40	p. **Investigate, using primary data, how to find percentage aspirin in an aspirin tablet** [EI]	
26	41	h. Analyse water samples, both qualitatively and quantitatively [EI]	Clarity needed as noted in LO Analysis Table 5 Expts

Table 4.2. Practical Investigations that are considered to be mandatory in order to achieve the appropriate learning outcomes

4.6 Conclusions and Recommendations

It is clear that one of the main problems with the Leaving Certificate Chemistry Draft Specification is the lack of clarity in a significant number of learning outcomes. Of the 127 learning outcomes in the contextual strands, a total of 40 learning outcomes (31.5%) are unclear. Due to this lack of clarity, it is impossible for teachers to ensure that their students achieve these learning outcomes – and impossible for students to know if they have achieved them. Recommendations to bring clarity to each vague learning outcome have been made.

An analysis of time to teach each individual specification has been carried out and, in general, it is felt that the learning outcomes in the contextual strands can be achieved within 160 hours of teaching provided that the Unifying Strand is deleted from the specification. Since this strand deals with the Nature of Science, it is felt that this has been adequately covered at Junior Cycle level.

Of the 127 learning outcomes in the specification, 35 contain reference to Higher Level material. It is recommended that this balance needs to be discussed at an NCCA Subject Development Group meeting as no detailed discussion has been held to date on this topic.

An analysis of the unclear learning outcomes shows that they fell into various categories:

(i) Learning outcomes that do not contain active verbs.

(ii) Learning outcomes that make no sense in the context in which they are being used.

(iii) Learning outcomes that are so vague and so broad that it is impossible to know what students must be able to do in order to achieve the learning outcomes.

(iv) Learning outcomes that use the term "primary data" when it is not necessary to use it.

(v) Learning outcomes that use the term "secondary data" when it is not necessary to use it.

(vi) Learning outcomes that are vague and ill defined.

(vii) Learning outcomes that use broad terms such as "range of" without any further clarification.

(viii) Learning outcomes that do not clarify what laboratory practical work should be carried out in order to achieve the learning outcome.

(ix) Learning outcomes that include unsuitable active verbs.

In addition to lack of clarity in 40 learning outcomes, there is also a lack of clarity in the laboratory practical investigations that are mandatory in order to achieve the appropriate learning outcomes. The ISTA Chemistry Committee has analysed the draft specification and provided a list of 26 Laboratory Practical Investigations that are considered to be mandatory in order to successfully implement the specification in the classroom.

Chapter 5

Analysis of Leaving Certificate Biology Draft Specification

5.1 Introduction

The following sections will outline the initial findings of the ISTA Biology Committee's assessment of the Leaving Certificate Biology Draft Specification 2023. In addition, the views of the wider membership, after an online consultation webinar and follow up survey will be presented. The committee would like to stress that we are not criticising the work of the Subject Development Group or the NCCA; this chapter seeks to present an objective analysis of the specification document, with the needs of teachers and their students at the heart of any observations and recommendations.

The introduction of the new specification is generally welcome. Biology is a vibrant subject, which has evolved significantly over the past twenty years. New discoveries, greater understanding and evolving technologies mean Biology, as a subject, has progressed significantly since the introduction of the current syllabus. There is a clear need for an evolution of the subject and a level of modernisation. In saying that, there are strengths to the current syllabus, particularly in layout, clarity and assessment. In addition, a comprehensive Teacher Guideline's handbook complements the syllabus and provides guidance and clarity on depth of treatment on the course.

It is disappointing that so much of the opening material in the specification is not subject specific. Much of the opening twelve pages provide an overview of the Senior Cycle in general and the new Senior Cycle key competencies in Senior Cycle, which themselves have a draft document.

The rationale for the study of Biology, laid out in the draft specification, is clear and concise. It describes the complexity and variety within the subject accurately, linking it with real life problems and challenges. There could be a greater emphasis on the importance of Biology in understanding our health within this section though, as it only gets a brief mention.

The aims of the specification, as outlined in the draft document, are rather thin. There are simply four aims, which don't address the strands or cross cutting themes; this is perhaps a missed opportunity?

The section on 'Continuity & Progression' accurately reflects the transition from Junior Cycle in terms of key skills and scientific literacy, although the significant knowledge gap between Junior Cycle and Senior Cycle is not addressed.

There was an opportunity to really focus the *Teaching & Learning* section on providing detail on methodologies to develop the key competencies within the document, with an eye also on the learning outcomes detailed later. Sadly, much of what is provided in this section is rather vague and generic, leaning too heavily on teaching philosophy rather than practice. There is no mention here of the application of cognitive science - with deep roots in Biology and neuroscience - on how it can be applied to teaching and learning. Assessment and feedback are provided as mere soundbites at the end of this section. Again, there is a missed opportunity here to address the needs of the teacher in the classroom by providing more specific examples. In the digital technology section, there is no mention of artificial intelligence and how it can be utilised by the teacher and student, and also how it can be potentially abused.

5.2 Subject Strands & Cross Cutting Themes

This section introduces a unifying strand called *The Nature of Science* and also the three contextual strands in the Leaving Certificate biology specification: *The Organisation of Life, The Structures and Processes of Life and The Interactions of Life.* The unifying strand is, which has some merit, will be discussed in Chapter 6. Reference is also made to some general cross-cutting themes. This section contains the list of learning outcomes and accompanying notes in the *Students learn about* column.

The Unifying Strand, which is common across the senior sciences, will be discussed in more detail in the next chapter; it has its merits although there are elements of the strand which need consideration. The other three present a rather oversimplified breakdown of the complexity of the study of the biological world.

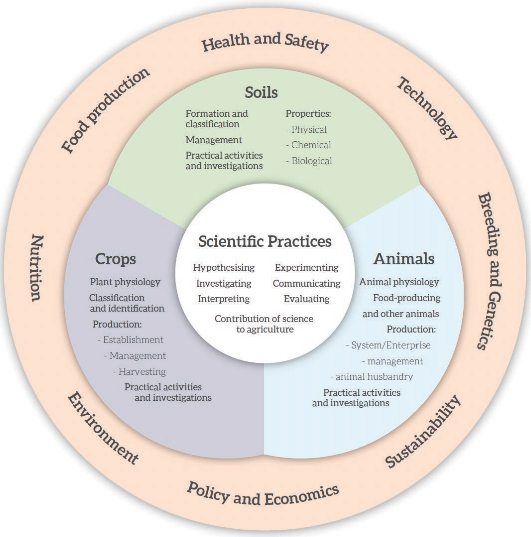
Strand 1 (The Organisation of Life) has a good overall general theme but the fourth section, Orgl4, *The Information of Life, Genetic Inheritance*, seems out of place and out of sequence. Strand 2, the Structures and Processes of Life, is far too broad and would have benefitted from further division. The section on enzymes (Spl1) should be moved into the first strand, where enzymes are mentioned as metabolic proteins. The section within Strand 2 called *The Information of Life (Cell Division & Protein Synthesis)* again seems out of place. Strand 3, the *Interactions of Life*, also contains a section on *Information of Life*, this time with a focus on biotechnology. The other elements within this strand are all well connected and flow well.

While it is clear the *Interactions of Life* learning outcomes are meant to accommodate the intersections between the three strands in the Venn Diagram, it paints an inaccurate picture. Such a model would suggest that items outside of the intersection don't link with the other strands and this is inaccurate e.g. biomolecules, cells, enzymes etc., link with all existing strands. **It would make structural sense to remove the three separate *Information of Life* sections from the three existing strands and create a fourth strand using these elements, called <u>Information of Life</u>**. A Venn Diagram is not required and the integrity of the specification's content is not diminished and it could potentially provide greater clarity to both the student and the teacher. It would certainly aid in planning the implementation of the new specification in the classroom.

The model used to arrange the strands and cross cutting themes in the Agricultural Science specification (shown below) is better suited to structuring the curriculum. The Unified Strand should be placed in the centre, the suggested four strands outside that and the cross cutting themes on the periphery.

The four proposed biological strands:

1. The Organisation of Life
2. The Information of Life (incorporating existing sections, reordered slightly)
   a. Cell Division & Protein Synthesis
   b. Genetic Inheritance
   c. Biotechnology
3. The Structures & Processes of Life
4. The Interactions of Life



The Cross-Cutting Themes provide a good opportunity for students to explore how Biology affects the modern world. The three themes are all well aligned to the learning outcomes, providing a wider view of the individual strands. It would be useful to gain a greater understanding of how much emphasis is to be placed on the themes when planning a curriculum and how they will be incorporated into the assessment of the course.

The use of two columns, ('Students Learn About' (SLA) and 'Learning Outcomes') is maintained from the Senior Cycle Agricultural Science specification. The SLA section is expanded compared to that in the Agricultural Science specification. . While this is welcome, and improves the clarity of some learning outcomes, there are a number of instances where the SLA section contradicts the learning outcomes or doesn't provide the clarity required. At times, it isn't clear how the SLA section links with the learning outcomes in the other column and a clearer presentation of links elements would be welcome.

It is the view of the ISTA Biology Subject Committee that, while an improvement, the use of just two columns is insufficient to model the complexity of a subject like Biology. A third column, perhaps labelled '**Knowledge Depth**' might provide more concise detail on how comprehensively a learning outcome should be explored. A fourth column could also be used, labelled '**Skills**', which would provide detail on the practical activities suggested or required, with a focus on building skills and competencies.

5.3 Analysis of learning outcomes

The ISTA Biology Subject Committee carried out a comprehensive analysis of the ninety nine Biology specific learning outcomes within the specification and the corresponding 'Students Learn About' sections. The analysis took place in a number of stages.

1. **Analysis of Learning Outcome Clarity** i.e. ease at which the learning outcome can be interpreted in the classroom by the teacher to ensure that students achieve the learning outcome.
2. **Analysis of Student Learn About Section** - evaluate how the SLA section links with and supports the learning outcome to allow teachers to judge the depth of treatment required in curriculum planning.
3. **Comments on Clarity** - evaluate the extent to which the LOs and SLA material help to bring clarity for the teacher to help ensure teachers ensure that students achieve the learning outcomes.

One of the key roles of the ISTA Biology Subject Committee was to coordinate feedback about the draft Biology specification from ISTA members who teach Leaving Certificate biology. As described in Chapter 1, this feedback was obtained via an online CPD event to discuss the draft specification as well as an online questionnaire.

Each learning outcome in the three contextual strands was analysed for clarity under the headings indicated in the Learning Outcomes Analysis Table reproduced in Appendix 3 of this report. Those learning outcomes which were unclear to teachers were indicated by a red icon and those which were clear to teachers were marked by a green icon.

There are 99 learning outcomes in the three contextual strands and 66 of these (66.7%) were judged by the teachers to be unclear. In other words, teachers were unable to answer the question "What must students be able to do in order to achieve this learning outcome?"

The complete analysis of the learning outcomes is presented in Appendix 3. The purpose of this analysis is to ensure teachers of Biology can prepare and plan for the implementation of the new specification and clear, concise and easily interpreted learning outcomes are central to that. This analysis seeks to present potential issues with the clarity in some learning outcomes, proposing clearer alternatives where possible.

It was found that learning outcomes judged to be unclear fell into a number of categories.

1. Learning outcomes that do not contain active verbs

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
25	SPL5 e. Appreciate the impact of advancements in modern technology on prenatal and postnatal care.		Since the verb "appreciate" is not an active verb, we propose that this learning outcome be rewritten to make it clear what students must be able to do in order to show that they appreciate this concept. The term 'appreciate' is impossible to assess summatively.	We propose the following wording: *Outline the benefits that modern technology has had on prenatal and postnatal care.*

2. Learning outcomes that are so vague and so broad that it is impossible to know what students must be able to do in order to achieve the learning outcome.

Some examples of this type of learning outcome are given in the table below. Without information to indicate the depth of treatment of the learning outcome, it is impossible for the teacher to know where to begin and where to end the teaching and learning process. The learning outcome below is both common to Higher and Ordinary levels.

Page	Learning Outcome	Clarity	Comment	Proposed information to be given in the Students Learn About column
	d. develop and use models to explore the interaction of the hormonal and nervous systems to maintain homeostasis		An incredibly vague learning outcome; impossible to ascertain the depth required. Must give specific examples in the SLA to make this LO workable.	A missed opportunity to relate to learning outcomes on enzymes. Almost no concrete information provided here. Specific examples should be provided here e.g. water levels, body, temperature, pulse etc.

22	SPL2 a Outline the processes of anaerobic respiration, aerobic respiration and photosynthesis.		This is a vague learning outcome and it is impossible to deduce from it what students need to do to achieve this learning outcome. The word 'outline' means restrict to essentials. However no clarity is provided in the 'Students learn about' column as to what the essentials are.	We propose the following information be provided in the SLA column: Definition and role of "aerobic respiration". Cellular locations of the first and second stages of aerobic respiration. Breakdown of glucose to pyruvate and production of ATP. Breakdown of pyruvate to carbon dioxide and water. Definition and role of "anaerobic respiration". Definition and role of "photosynthesis". Representation by a balanced equation of photosynthesis. Cellular location of photosynthesis. Role of chlorophyll. Location of chlorophyll within cells.

3. Learning outcomes that use the term "primary data" when it is not necessary to use it.

In a significant number of learning outcomes that involve students performing practical investigations, the term "primary data" is unnecessary and only confuses students and teachers who have asked "why is the term primary data used when it is obvious that the data being collected by the students is their own data?".

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
22	SPL2 b. investigate factors that affect the rate of photosynthesis, use primary and secondary data to support conclusions.		The use of the term "primary data" is unnecessary and confusing. Since this is marked as an investigation to be carried out by the students themselves, of course the data collected will be their own data.	Carry out an experiment to investigate the effect of one factor on the rate of photosynthesis. (Mandatory Student Investigation) Explain your results by drawing and interpreting models of the reactions involved.

4. Learning outcomes that use the term "secondary data" when it is not necessary to use it.

In a significant number of learning outcomes reference is made to "secondary data". This is unnecessary and only confuses students as obviously secondary data are used in homework assignments and studying past examination questions.

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
22	SPL1 c. investigate factors that affect the rate of enzyme-catalysed reactions, use primary and secondary data to support conclusions		This is a vague learning outcome and it is difficult to deduce from it what students must be able to do in order to achieve this learning outcome. As already pointed out, the use of the term “primary data” is unnecessary since students are collecting their own data (i.e. primary data) in the investigation.	We propose that this learning outcome be reworded as follows: *Carry out a laboratory experiment to investigate the effect of two factors on the rate of enzyme-catalysed reactions.* The study of secondary data is not part of a laboratory investigation as this activity can be done as homework or studying past examination papers. Reference to secondary data analysis could be included in the SLA column or as a separate learning outcome.

5. Learning outcomes that are vague and ill defined.

In many cases the learning outcomes need to be clearly defined in order to help teachers understand what students must do in order to achieve the learning outcome.

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
24	SPL4 I Explore how new diseases emerge.		It is not clear from the learning outcome or the information SLA column what students must do in order to achieve this learning outcome. In addition, the verb ‘explore’ is not listed in the Glossary of Action Verbs.	We propose that this learning outcome be rewritten as follows: Outline how mutations and environmental change result in the emergence of new diseases.
28	**b. analyse evidence of species diversity in ecosystems using a mathematical model**		Learning outcome provides no detail on the mathematical model. Significant clarification needed on SLA content.	Analyse methods of determining diversity in ecosystems. Use the Simpson’s Species Diversity Index to calculate species diversity, using secondary data.

6. Use of broad terms, such as "range of", or lack of detail in learning outcome

In some cases the learning outcomes contain phrases that are meaningless without more details being specified.

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
29	IL1 e2. investigate the influence of a range in general of abiotic factors on the distribution of a species	✖	It is not clear what students must be able to do in order to achieve this very broad learning outcome.	We propose that the learning outcome be reworded as follows: Investigate the effect of three abiotic factors on the distribution of a species.
29	SPL6b. Investigate factors affecting rates of osmosis across semi-permeable membranes, use primary data to support conclusions	✖	It would be useful to have a list of acceptable factors to be investigated. How many factors need to be investigated, especially considering primary data is required?	Investigate how temperature, concentration gradient or surface area affects the rate of osmosis across semi-permeable membranes, use primary data to support conclusions.

7. Learning outcomes that do not clarify what laboratory practical work should be carried out in order to achieve the learning outcome.

In many cases depth of treatment needs to be supplied in order to indicate to students and teachers what laboratory practical work should be carried out.

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
19	OrgL3 d investigate qualitatively the level of any one constituent in a range of food samples, use primary data to support conclusions	✖	The "level" of a food constituent cannot be measured qualitatively – level implies quantitative data. This is a very vague learning outcome and it is impossible to deduce from it what students must be able to do in order to achieve this learning outcome. As already pointed out, the use of the term "primary data" is unnecessary since students are collecting their own data (i.e. primary data) in the investigations.	Proposed rewording is Investigate qualitatively the presence of protein, lipid, starch and reducing sugar in food.

8. Learning outcomes that include unsuitable active verbs.

In some cases, clarification can be brought to the learning outcome by using a more suitable active verb. Whilst there are many points of comparison between genetic and epigenetic mechanisms, the key point that needs to be stressed is what distinguishes the two types of cells.

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome
19	OrgL4 b. Compare genetic and epigenetic mechanisms.	✖	This needs clarification as to what is required. Difficult to unpack the depth required here - which genetic and epigenetic mechanisms? Typically, epigenetics works in one of three ways: DNA methylation, histone modification and non-coding RNA action. It's not clear in the previous LO if methyl groups and histones are even required in chromosome structure.	We propose that this be reworded as: Distinguish between genetic and epigenetic mechanisms.

5.4 Analysis of time to teach the draft specifications

The members of the ISTA Biology Committee, in consultation with various colleagues, have studied each learning outcome in the three contextual strands and discussed the teaching time required to ensure that students achieve the relevant learning outcome. The time estimated is summarised in Table 5.1

The estimates below are based on the assumption that the learning outcomes are clarified as proposed in Appendix 3.

Page	LO No.	Learning Outcome	Estimated Time (mins)
18	OrgL1	a. evaluate the characteristics of living things	60
18	OrgL1	b. explain how viruses replicate within cells	**40**
18	OrgL1	c. discuss the difficulty of defining viruses, their economic and medical importance	**40**
18	OrgL1	d. use classification principles to identify and classify living things in known and unknown contexts; examine the importance of classification systems in biology	**60**
18	OrgL2	a. describe the complexity of multicellular organisms	**40**
18	OrgL2	b. compare the ultrastructure of prokaryotic and eukaryotic cells	**60**

18	OrgL2	c. investigate, using primary and secondary data, the structures and organelles of animal and plant cells and relate them to their functions	**160**
18	OrgL3	a. outline a nutritional source, and the structural and metabolic roles, of carbohydrate, lipid and protein	**80**
18	OrgL3	b. recognise the roles of vitamins and minerals in biological processes	**30**
18	OrgL3	c. outline the main roles of water in living organisms	**10**
19	OrgL3	d. investigate qualitatively the level of any one constituent in a range of food samples, ue primary data to support conclusions	**180**
20	OrgL3	e. describe the role of ATP and NAD+/NADP+ in metabolic pathways	**40**
20	OrgL3	g. describe the basic structure and function of DNA and RNA	**120**
20	OrgL3	h. relate genes, proteins and traits in organisms; outline the concept of the genetic code	**120**
20	OrgL4	a. describe the structure of a chromosome and the role of a gene; compare nuclear and non-nuclear inheritance	**60**
20	OrgL4	b. compare genetic and epigenetic mechanisms	**60**
20	OrgL4	c. predict inheritance to the first generation of a single unlinked trait in crosses involving homozygous and heterozygous parents	**60**
20	OrgL4	d. predict a cross involving incomplete dominance	**60**
20	OrgL4	e. illustrate Mendel's Laws of Segregation and Independent Assortment	**40**
20	OrgL4	f. predict inheritance to the second generation of two unlinked traits in crosses involving homozygous and heterozygous parents	**80**
20	OrgL4	g. explain how linkage affects Mendel's Law of Independent Assortment (knowledge of crossing over not required)	**30**
20	OrgL4	h. describe sex determination by X and Y chromosomes in humans	**40**
20	OrgL4	i. develop and use models to explain and predict the inheritance of sex- linked traits from known examples	**40**
20	OrgL5	a. explain the variations that come from sexual reproduction and mutations	**40**
20	OrgL5	b. discuss the rationale for, and basis of, the theory of evolution by natural selection	**40**
20	OrgL5	c. consider evidence that supports the theory of evolution by natural selection; recognise the value of the theory of evolution in understanding the modern world	**30**
20	OrgL5	d. evaluate the practical applications of artificial selection; discuss ethical and societal issues	**40**

22	SPL1	a. explain how enzymes function to facilitate the catalysis of biochemical reactions	**30**
22	SPL1	b. illustrate enzyme specificity using the Induced Fit model.	**40**
22	SPL1	c. investigate factors that affect the rate of enzyme-catalysed reactions, use primary and secondary data to support conclusions	**180**
22	SPL1	d. evaluate the use of enzymes in a known enterprise; appreciate the central role of enzymes in industrial applications	**40**
22	SPL2	a. outline the processes of anaerobic respiration, aerobic respiration and photosynthesis	**180**
22	SPL2	b. investigate factors that affect the rate of photosynthesis, use primary and secondary data to support conclusions	**180**
22	SPL2	c. investigate the conditions necessary for fermentation, use primary and secondary data to support conclusions	**120**
22	SPL2	d. examine how leaf structure is adapted for photosynthetic efficiency; discuss the role that manipulation of photosynthesis can play in horticulture	**80**
22	SPL2	e. develop and use models to explain the two-stage processes of photosynthesis and respiration; make particular reference to the role of transfer molecules	**200**
23	SPL2	f. recognise the significance of the internal structures of mitochondria and chloroplasts in facilitating the processes of photosynthesis and respiration	**60**
23	SPL3	a. describe simply the process of mitosis and meiosis; compare the roles of mitosis and meiosis	**120**
23	SPL3	b. explain the role of DNA replication and mitosis in the cell cycle	**40**
23	SPL3	c. describe how DNA is replicated and the flow of information through mRNA to protein	**120**
23	SPL3	d. describe how gene and chromosomal mutations occur, making reference to known examples of both	**60**
23	SPL3	e. describe the processes of transcription and translation	**180**
23	SPL3	f. outline how uncontrolled cell growth and proliferation can lead to development of cancers	**80**
23	SPL3	g. examine the role of infectious agents, environmental factors and/or genetic susceptibility in the development of different cancers in an organism; evaluate solutions to address the development of cancers	**120**
23	SPL4	a. relate the structure of the parts of the central nervous system and the peripheral nervous system to their functions; compare nervous and hormonal coordination	**80**
24	SPL4	b. describe the roles of the main parts of the brain	**120**

24	SPL4	c .describe the structure of a neuron and the mechanisms of impulse transfer	**80**
24	SPL4	d. develop and use models to explore the interaction of the hormonal and nervous systems to maintain homeostasis	**180**
24	SPL4	e. illustrate the location and function of the major glands in the endocrine system and their associated hormones	**80**
24	SPL4	f. recognise the impact of hormonal manipulation on organisms	**40**
24	SPL4	g. distinguish between innate and acquired immunity; outline the strategies applied to prevent and treat microbial diseases	**80**
24	SPL4	h. distinguish between the roles of B and T lymphocytes in the body's immune response	**80**
24	SPL4	i. explore how new diseases emerge; discuss the importance of emerging diseases for society	**120**
24	SPL5	a. relate the general structure of the male and female mammalian reproductive systems to their functions	**120**
24	SPL5	b. outline the relationship between hormonal levels and stages of the menstrual cycle	**120**
24	SPL5	c. describe pregnancy from the development of fertilised embryo to birth; relate the structure of the placenta to its functions	**100**
25	SPL5	d. develop and use models to illustrate the role of hormones before, during and after pregnancy	**80**
25	SPL5	e. appreciate the impact of advancements in modern technology on prenatal and postnatal care	**60**
25	SPL5	f. discuss the use and medical implications of strategies to control fertility and treatments for infertility	**120**
25	SPL5	g. investigate the structures of insect and wind pollinated plants and relate them to their functions, use primary and secondary data to support conclusions	**120**
25	SPL5	h. investigate the digestive activity of seeds during germination, use primary data to support conclusions	**120**
25	SPL6	a. distinguish between diffusion, osmosis and active transport; examine the role of osmosis in food preservation and plant health	**80**
25	SPL6	b. investigate factors affecting rates of osmosis across semi-permeable membranes, use primary data to support conclusions	**180**
26	SPL6	c. relate the macrostructure of the urinary system to its function in filtering and removing waste; outline the filtration of blood in the nephron	**220**
26	SPL6	d. describe how the macrostructure of the human digestive system and associated organs and glands carry out the process of digesting fats, carbohydrates and proteins	**200**

26	SPL6	e. describe the absorption, transport and storage of the products of digestion	**80**
26	SPL6	f. consider the biological implications of dietary choices	**30**
26	SPL6	g. relate the anatomy and physiology of the breathing system to its role in gaseous exchange in the lungs	**80**
26	SPL6	h. outline the role of carbon dioxide concentration as a controlling factor in stomatal opening and in the human breathing system	**40**
26	SPL6	i. investigate the structures of the heart and relate them to their functions, use primary and secondary data to support conclusions	**80**
26	SPL6	j. develop and use models to describe the interaction between the circulatory and other human body systems in facilitating transport of materials around the body	**80**
26	SPL6	k. explain heartbeat and its control by the pacemaker, pulse, blood pressure and the cardiac blood supply	**80**
27	SPL6	l. relate the composition of the blood to its functions; appreciate the value of knowledge on blood grouping for human health	**80**
27	SPL6	m. distinguish between arteries, veins and capillaries based on their macrostructures and role in the circulatory system of humans	**40**
27	SPL6	n. relate the structure of the lymphatic system to its functions	**80**
27	SPL6	o. relate the structure of the root, stem and leaf and their associated tissues with their functions	**200**
27	SPL6	p. describe the transport of water, minerals, carbon dioxide and photosynthetic products in the plant	**80**
28	IL1	a. discuss the ways in which science interacts with social, economic, cultural and ethical factors to inform the making of decisions on local ecological issues	**100**
28	IL1	b. analyse evidence of species diversity in ecosystems using a mathematical model	**120**
28	IL1	c. interpret pyramids of biomass to explain and make predictions about the carrying capacity of ecosystems at different scales	**80**
29	IL1	d. interpret primary or secondary data relating to the effects of human activity on species diversity; evaluate associated benefits and risks	**180**
29	IL1	e. using primary data from a chosen ecosystem: construct a model of the ecosystem illustrating species, relevant biotic and abiotic factors	**300**
29	IL1	e2. investigate the influence of a range of abiotic factors on the distribution of a species	**180**

29	IL1	e3. investigate quantitatively the impact of variation in abiotic factors on the distribution of a species	**300**
29	IL1	e4. describe the transfer of matter and energy from producers to at least 3 trophic levels	**80**
29	IL1	e5. describe how an organism's adaptations enable it to exploit a niche in the ecosystem	**40**
29	IL1	e6. explain the feeding and symbiotic relationships that occur between organisms	**40**
29	IL2	a. distinguish between bacteria and fungi in terms of structure, nutrition, reproduction and cellular nature	**240**
29	IL2	b. investigate factors affecting the growth of microorganisms, use primary and secondary data to support conclusions	**180**
29	IL2	c. discuss the economic, medical and pharmaceutical importance of microorganisms	**40**
30	IL2	d. illustrate and explain the carbon and nitrogen cycles	**180**
30	IL2	e. evaluate ethical and sustainability issues associated with the cycling of nutrients	**40**
30	IL2	f. discuss the link between atmospheric carbon dioxide, methane and climate change; evaluate biological strategies to reduce atmospheric levels of these gases	**60**
30	IL3	a. describe the principles and processes involved in genetic engineering	**80**
30	IL3	b. describe the process of DNA profiling and its potential uses	**40**
30	IL3	c. outline the principle of DNA sequencing and its use in bioinformatics	**80**
30	IL3	d. use a genome database to search for alleles that are known to cause (or be responsible for) specific genetic diseases	**120**
30	IL3	e. investigate patterns using a DNA profile, use primary and/or secondary data to support conclusions	**180**
30	IL3	f. discuss the ethical and sustainability issues arising from advancements in genetic technologies	**60**
		Total (minutes)	**9540**
		Total (hours)	**159**

Table 5.1. Analysis of teaching time required to ensure that students achieve each learning outcome.

The total estimated time required to implement the Biology Learning Outcomes in the classroom is 159 hours.

It is important to stress that the estimate is based on the assumption that clarification is obtained as per the proposals for all vague learning outcomes as specified in Appendix 2.

Since the Leaving Certificate Biology specification is designed for a minimum of 180 hours of class contact time of which 20 hours is spent on the Biology In Practice Research Investigation, this leaves a minimum of 160 hours of class contact time for teachers to ensure that their students achieve the learning outcomes. As shown in Table 5.1, this minimum is effectively now reached, we suggest that the unifying strand on the Nature of Science be removed from the specification since this topic has already been covered at Junior Cycle Science level. This unifying strand is discussed in more detail in Chapter 6.

5.5 Breakdown of Higher Level / Ordinary Level components

There are **99** learning outcomes in the three contextual strands. 17 contain references to Higher Level material - two of these require clarification across the "Students learn about" and "Students should be able to" columns. There are no references to higher level material in the Unifying strand. No detailed discussion on the balance between Higher Level and Ordinary Level has been held by the NCCA Biology Subject Development Group. We recommend that this discussion be held as part of the review process as we are concerned about the imbalance between Ordinary Level and Higher Level in some areas of the specification.

Some examples of areas of concern are:

> P 13 of the specification describes how students studying at Higher and Ordinary Level will "engage" with the learning outcomes:
>
> Students studying at both Ordinary level and Higher level will critically engage with Biology, but the context, information and results associated with that analysis are presented at different levels. (p13)

A Table (Table 1 p13) then describes how the learning outcomes should be interpreted for each level. Is this appropriate that each learning outcome will require different interpretation depending on the level taken by the student?

> Some learning outcomes lack clarity between what is required for Higher and Ordinary Level. In the learning outcome *Transport and transfer of nutrients….* (p26) Nephron structure is indicated for higher level in the Students learn about column, students should be able to (c) "outline the filtration of blood in the nephron" is not in bold.

In summary, we feel that this matter is best discussed at an NCCA Subject Development Group meeting in order to ensure that the best balance between Ordinary Level and Higher Level is obtained.

Ordinary level	Higher level
Only the learning outcomes that are presented in normal type. Students engage with a broad range of knowledge, mainly concrete in nature, but with some elements of abstraction or theory. Students demonstrate and use a moderate range of cognitive skills and tools and select from a range of procedures and apply known solutions to a variety of problems in both familiar and unfamiliar contexts. Students develop scientific literacy skills and use evidence and data to communicate findings and draw conclusions to questions posed by themselves and others.	All learning outcomes including those **in bold type**. Students engage with a broad range of knowledge, including theoretical concepts and abstract thinking with significant depth in some areas. Students demonstrate and use a broad range of specialised skills to evaluate, and use information, to plan and develop investigative strategies, and to determine solutions to varied, unfamiliar problems. They identify and apply skills and knowledge in a wide variety of both familiar and unfamiliar contexts. Students develop scientific literacy skills and use appropriate evidence and data to effectively communicate findings and draw valid conclusions to questions posed by themselves and others.

Table 1: Design of learning outcomes for ordinary and higher level

5.6 Mandatory Student Investigations

The Leaving Certificate Biology, Chemistry and Physics syllabi that are currently being taught in our schools contain clear lists of Mandatory Student Laboratory investigations. There are 19 Mandatory Students Laboratory Investigations on the current Leaving Certificate biology syllabus. The specification of Mandatory Student Laboratory Investigations is international best practice in syllabus design. For example, in the GCSE and A level system in the UK, the Examination Boards specify a list of laboratory investigations which are termed “Required Practicals”. Considerable background information on each practical investigation is given for both teachers and students.

For a list of Biology, Chemistry and Physics GCSE laboratory practicals see:
https://filestore.aqa.org.uk/resources/science/AQA-8464-8465-PRACTICALS.PDF

Unfortunately, the draft specifications in Biology does not contain a clear list of Mandatory Laboratory Student Investigations. However, it is vital that teachers and students are made aware what Mandatory Laboratory Student Investigations must be carried out in order to:

1) Achieve the relevant learning outcomes
   and
2) Build up a wide range of laboratory skills in order to carry out the Biology In Practice Investigation.

There is some confusion in the draft biology specification regarding the exact list of laboratory investigations that should be carried out by students in order to achieve the appropriate learning outcome. The ISTA believes that clarity needs to be provided to teachers and students and, to this end, we have extracted from the draft specification what we consider are the laboratory investigations that should be carried out by biology students. This list is shown in Table 5.1

Practical Investigations that are considered to be mandatory in order to achieve the appropriate learning outcomes

Expt. No.	Page	Learning outcome	Note
1	18	Investigate, using primary and secondary data, the structures and organelles of animal and plant cells and related them to their functions.	Clarity needed as noted in LO Analysis Table
2	19	Investigate qualitatively the level of any one constituent in a range of food samples, use primary data to support conclusions.	Clarity needed as noted in LO Analysis Table.
3	22	Investigate factors that effect the rate of enzyme-catalysed reactions, use primary and secondary data to support conclusions	Clarity needed as noted in LO Analysis Table.
4	22	Investigate factors that affect the rate of photosynthesis use primary and secondary data to support conclusions.	Clarity needed as noted in LO Analysis Table
5	22	Investigate the conditions necessary for fermentation, use primary and secondary data to support conclusions	Clarity needed as noted in LO Analysis Table
6	25	Investigate the structures of insect and wind pollinated plants and relate them to their functions, use primary and secondary data to support conclusions	Clarity needed as noted in LO Analysis Table
7	25	Investigate the digestive activity of seeds during germination, use primary data to support conclusions	Clarity needed as noted in LO Analysis Table
8	25	Investigate factors affecting rates of osmosis across semi-permeable membranes, use primary data to support conclusions	Clarity needed as noted in LO Analysis Table
9	26	Investigate the structures of the heart and relate them to their functions, use primary and secondary data to support conclusions	Clarity needed as noted in LO Analysis Table
10	29	Investigate the influence of a range of abiotic factors on the distribution of a species	Clarity needed as noted in LO Analysis Table.
11	29	Investigate **quantitatively** the impact of variation in abiotic factors on the distribution of a species	Clarity needed as noted in LO Analysis Table.
12	29	Investigate factors affecting the growth of microorganisms, use primary and secondary data to support conclusions.	Clarity needed as noted in LO Analysis Table.
13	30	Investigate patterns using a DNA profile, use primary and/or secondary data to support conclusions.	Clarity needed as noted in LO Analysis Table

Table 5.2.

It should be noted that thirteen investigations, carried out over a two year period, is insufficient to develop the necessary practical laboratory skills, data analysis skills and communication skills and do not provide sufficient practice to develop the Senior Cycle Key Competencies. In addition, there are issues with the ‘investigate’ learning outcomes. It is suggested that some can be completed using secondary data only (e.g. number 13 above) while number 10 and number 11 appear to be the same investigation, with one minor difference.

5.7 Assessment

The section on assessment within the Draft Specification is lacking in specific detail. There is a general paragraph on the rationale for summative assessment, which is rather condescending in truth and provides no concrete examples that might support teachers to implement the aims and learning outcomes of the curriculum. The section on assessment for certification is equally vague. It is shameful that no sample assessment questions are provided by the SEC, even at the draft stage, or more detail on the layout of the paper is provided. **When discussing Senior Cycle reform, it is crucial that all stakeholders are aligned from the early stages of curriculum redevelopment.**

The Additional Assessment Component (AAC) - Biology in Practice Investigation - has the potential to enhance the learning process for students but significant questions exist. These include:

- The suggested time allocation of 20 hours to this component will put significant pressure on the teaching of the 99 learning outcomes.
- It is not clear if the AAC will be an individual or group investigation.
- There is no indication or advice on how to resource the implementation of the AAC in the classroom - will additional funds be provided to build and upgrade new science laboratories in schools or upgrade the equipment needed? The availability of laboratory space will be paramount to the successful implementation of the AAC in schools and, if the three AACs from Biology, Chemistry and Physics are taking place at the same time, this will put enormous pressure on school resources.
- The allocation of a blanket 40% for this assessment seems misplaced, especially with the recent developments in "chatbots" like Google Gemini and ChatGPT. These tools, while having the potential to support teachers in implementing the new specification, also serve to undermine the rationale and aims of the specification.

The AAC will be discussed in more detail in Chapter 7.

5.8 Conclusions and Recommendations

It is clear that one of the main problems with the Leaving Certificate Biology Draft Specification is the lack of clarity in a significant number of learning outcomes. Of the 99 learning outcomes in the contextual strands, a total of 66 learning outcomes (66.7%) are unclear. Due to this lack of clarity, it is impossible for teachers to ensure that their students achieve these learning outcomes – and impossible for students to know if they have achieved them. Recommendations to bring clarity to each vague learning outcome have been made.

An analysis of time to teach each individual specification has been carried out and, in general, it is felt that the learning outcomes in the contextual strands can be achieved within 160 hours of teaching provided that the Unifying Strand is deleted from the specification. Since this strand deals with the Nature of Science, it is felt that this has been adequately covered at Junior Cycle level.

Of the 99 learning outcomes in the specification, 17 contain reference to Higher Level material. It is recommended that this balance needs to be discussed at an NCCA Subject Development Group meeting as no detailed discussion has been held to date on this topic.

An analysis of the unclear learning outcomes shows that they fall into various categories:

(i) Learning outcomes that do not contain active verbs.

Chapter 6

Analysis of the Unifying Strand of Learning Outcomes

6.1 Introduction

The Unifying Strand is located in the introductory material to the Physics, Chemistry and Biology specifications. It is a strand that deals with the Nature of Science and consists of 11-12 learning outcomes according to the individual specification. Most of the learning outcomes are identical in all three specifications. These learning outcomes will now be analysed in the same way that the learning outcomes in the Physics, Chemistry and Biology contextual strands were analysed in Chapters 3, 4 and 5 respectively.

6.2 Analysis of learning outcomes

All learning outcomes in the Unifying Strand are listed in Table 6.1. In most cases the learning outcomes are identical across Physics (P), Chemistry (C) and Biology (B). Where slight differences are observed, these are indicated as shown in the table.

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome	Comment on material in corresponding "Students Learn About (SLA) column.
13 (P) 16 (C) 15 (B)	a. appreciate how scientists work and how scientific ideas are modified over time		Since the verb "appreciate" is not an active verb, we propose that this learning outcome be rewritten to make it clear what students must be able to do in order to show that they appreciate this concept.	We propose the following wording: Discuss case studies to explain how named scientists implemented the scientific method.	Scientists to include Michael Faraday, Edward Jenner and Marie Curie.
13 (P) 16 (C) 15 (B)	b. conduct research relevant to a scientific issue and evaluate different sources of information including secondary data, understanding that a source may lack detail or show bias		This is a very vague learning outcome and it is impossible to know what students must be able to do in order to achieve this learning outcome.	Describe how scientists gather evidence, analyse it and communicate their findings to their peers.	Only the basic principles of the scientific method need be covered.

13 (P) 16 (C) 15 (B)	a. recognise and pose questions that are appropriate for scientific investigation (Physics) a. recognise questions that are appropriate for scientific investigation in chemistry (Chemistry) a. recognise questions that are appropriate for scientific investigation (Biology)		A clear learning outcome		
13 (P) 16 (C) 15 (B)	b. pose testable hypotheses developed using scientific theories and explanations, and evaluate and compare strategies for investigating hypotheses		This learning outcome is far too broad and unclear. One could spend several weeks on this topic.	Explain the meaning of the term hypothesis and outline a method of testing an example of a hypothesis in the school laboratory.	Students will only be required to outline methods for investigations that could be carried out in the school laboratory.
14 (P) 17 (C) 15 (B)	c. design, plan and conduct investigations; explain how reliability, validity, accuracy, precision, error, fairness, safety, integrity, and the selection of suitable equipment have been considered		A very poorly constructed learning outcome. It is far too broad and too vague. It is impossible to know what students should be able to do to achieve this learning outcome.	Explain the meaning of the terms reliability, accuracy, precision and a fair test. Discuss the importance of the selection of suitable equipment to carry out a particular investigation.	Simple explanations of these terms and accompanying examples are all that is required.

14 (P) 17 (C) 15 (B)	d. produce and select data (qualitatively / quantitatively), critically analyse data to identify patterns and relationships, identify anomalous observations, draw and justify conclusions	✗	This is a very vague and broad learning outcome and it is impossible to know what students must be able to do in order to achieve this learning outcome.	Analyse quantitative data collected when carrying out investigations in the school science laboratory.	Graphical analysis is all that is required here.
14 (P) 17 (C) 15 (B)	e. review and reflect on the skills and thinking used in carrying out investigations, and apply their learning and skills to solving problems in unfamiliar contexts	✗	This is a very broad learning outcome and it is impossible to know what students must be able to do in order to achieve this learning outcome.	Solve problems that are related to the Mandatory Student Investigations and the Additional Assessment Component Investigation.	
14 (P) 17 (C) 15 (B)	a. organise and communicate their research and investigative findings, using relevant scientific terminology and representations	✓	A clear learning outcome.		
14 (P) 17 (C) 15 (B)	b. evaluate media-based arguments concerning science and technology	✗	This is a very broad learning outcome and it is impossible to know what students must be able to do in order to achieve this learning outcome.	Discuss Science and Society issues that are related to topics studied in the classroom.	Science and Society issues need to be highlighted throughout the specifications.
14 (P) 17 (C) 15 (B)	a. research and present information on the contribution that scientists make to scientific discovery and invention, and its impact on society	✗	This is a very broad learning outcome and it is impossible to know what students must be able to do in order to achieve this learning outcome. What scientists should students research?	Discuss the contributions that scientists named on the specification have made and continue to make to society.	Reference should be made to those scientists specifically mentioned on the relevant specifications.

14 (P)	a. evaluate and articulate whether an answer is reasonable by analysing the dimensions / units and the order of magnitude	✓	A clear learning outcome.		
18 (C)	b. appreciate the role of chemistry in society; and its personal, social and global importance; and how society influences scientific research	✗	Since the verb “appreciate” is not an active verb, we propose that this learning outcome be rewritten to make it clear what students must be able to do in order to show that they appreciate this	Discuss the role of chemistry / physics / biology in society and explain how society influences scientific research.	Examples related to curriculum topics should be covered e.g. the need for safe drinking water and research on chlorination; the need for vaccination to guard against illness from diseases; the need for the development of photovoltaic cells to contribute to sustainability.
19 (C)	a. Relate observable phenomena to the chemical processes at the atomic or molecular level.	✗	This is a vague statement as it is not clear what phenomena and what chemical processes should be covered.	Discuss how some topics covered in the curriculum can be explained at an atomic or molecular level.	
16 (B)	a. Explain biological phenomena using appropriate means.	✗	This is a very broad learning outcomes and it is impossible to know what students must be able to do in order to achieve this learning outcome.	It would take a huge number of learning outcomes to even start trying to interpret this learning outcome.	We propose that this learning outcome be deleted.

Table 6.1 Analysis of learning outcomes in the Unifying Strand.

6.3 Conclusions and Recommendations

It is clear that the Unifying Strand consists of a list of very broad learning outcomes that have been cut and pasted into the introductory section of the Physics, Chemistry and Biology specifications. The Unifying Strand adds little or nothing to the three specifications. On the contrary, the broad learning outcomes in the Unifying Strand have the potential to be a source of confusion and stress to teachers who fear that what has happened in the examining of Agricultural Science will also apply to the new Physics, Chemistry and Biology specifications.

In the case of the new Agricultural Science specification, research has highlighted a number of problems with the Leaving Certificate examination papers as follows:

1. Students are being asked questions on topics that are not mentioned in any of the learning outcomes.
2. Questions are appearing on the exam paper on details that teacher never realised were on the syllabus.
3. In some cases it is impossible to relate questions on the exam paper to any learning outcome.

(Gallagher, Cronin and O'Brien, 2023)

The inclusion of the broad learning outcomes in Physics, Chemistry and Biology as summarised in Table 4.1 will give full license to the SEC Examiners to set any sort of question on any topic and at any depth. How is a biology teacher expect to ensure that students have achieved the learning outcome *Explain biological phenomena using appropriate means*? Teachers will be under a lot of stress trying to cover the learning outcomes in the contextual strands of the Physics, Chemistry and Biology specifications without the added stress of having to make sense of the learning outcomes in the Unifying Strand.

In addition to the broad nature of the Unifying Strand, there is no attempt in the specification to link these broad learning outcomes to the learning outcomes in the contextual strands. This is one of the key aspects of constructive alignment in curriculum design. Without this constructive alignment, the Unifying Strand is meaningless as the strand simply consists of a list of broad learning outcomes that have been cut and pasted into the introductory section as a stand-alone strand with no effort made to link these learning outcomes to those in the contextual strands. Since constructive alignment is an essential component in all syllabi designed within a learning outcomes framework, we recommend that either the Unifying Strand be deleted from all three specifications or that a clear constructive alignment strategy be drawn up to link the broad learning outcomes in the Unifying Strand to the appropriate learning outcomes in the contextual strands.

Chapter 7

Analysis of feedback from science teachers

7.1 Introduction

This chapter analyses the data obtained from science teachers via the online questionnaire and the three national online CPD events to discuss the draft specifications. The online questionnaire was completed by 317 science teachers and the CPD events were attended by a total of 648 science teachers (Physics = 106 , Chemistry = 224 and Biology = 648) .

A copy of the online questionnaire completed by science teachers is reproduced in Appendix 7. The questionnaire design followed the format of 11 introductory questions of relevance to teachers of Physics, Chemistry and Biology followed by 10 questions specific to each draft specification. Teachers who teach more than one Leaving Certificate science subject had the option to answer the questions that were specific to each of the science subjects taught by them.

The discussion of the data analysis will be carried out under the areas covered in the questionnaire.

7.2 Additional Assessment Component – Research Investigation

Questions 3, 4 and 5 asked teachers for their views on the Additional Assessment Component involving a Research Investigation in each of the Physics, Chemistry and Biology draft syllabi.

As can be seen from Figure 7.1, the vast majority of teachers were not happy with the proposal of 40% of marks being allocated

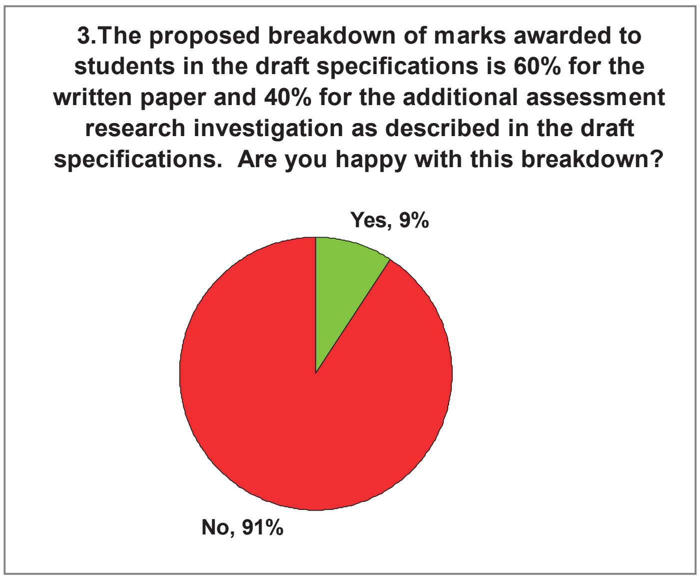


Figure 7.1

Question 4

Please explain your answer to the previous question.

Analysis of the explanations to answers given in question 4 highlighted a number of themes emerging such as the imbalance of marks compared to overall syllabus workload, the potential for cheating, the difficulties for teachers in managing large number of students undertaking their own individual projects at the same time, experience of teachers dealing with the Agricultural Science research investigation and the stress on students who will have several projects to undertake at the same time.

> *40% is to high an allocation to be given to a project that takes up less than 40% of the hours of the course (20 hours out of 180 hours is 11%). The influence of AI in assisting students with their work means there is no guarantee this work with be their own. Most schools are not equipped to cope with labs being used for CBA 1 at Junior Cycle level and now three additional assessment components that involve a practical element.*

24 students in a class working on different projects with different apparatus - the logistics of managing multiple different experiments simultaneously is an impossible task for the science teacher. This difficulty is already evident in the Junior Cycle CBAs.

40% of marks for roughly 11% of the time allocation is hugely unfair. It would also be far preferable to have a practical assessment rather than a research investigation especially in light of the capabilities of AI.

The Leaving Cert is a high stakes exam. As an experienced JC examiner, I am very familiar with the difficulty of ensuring that Coursework was indeed the candidate's own work. With developments in AI, this will become an even bigger issue. Also the proposed time allotment is 180 hours with 20 hours for the additional assessment component research Investigation. 40% being awarded for 11% of the time is completely skewed.

There are far too many marks for twenty hours, the description is incredibly vague and offers effectively no guidance at all. From having dealt with the Agricultural Science project the students do not understand academic papers and the work ends up coming back on the teachers

I feel student become consumed with project work especially with a 40% allocation. They find it very difficult to balance project work and classwork. Especially with the increase in the course content for the new specification.

40% is too much for science course work proposed... Only equates to 11% of teaching hours for each subject. Either revise percentage down OR award the percentage for course work along the lines of students records of experiments conducted over the course of the 2 year course... 8 to 10 experiments.

60% for 160 hours of work and 40% for 20 hours of work are very unbalanced

Labs are not properly equipped for that level of project work. Time constraints to complete projects. JC CBAs are already draining a lot of resources. Too high a percentage given. Will be very difficult to complete with students who have attendance issues.

I have students who are also studying Design and Communication Graphics, Computer Science, Home Economics, Agricultural Science, PE all of which include a project element. This will add yet another project to students who are already overloaded with coursework. There are students choosing subjects based on the time commitment required for projects with some attempting to avoid them entirely. Also there is no equality in access to suitable labs and equipment. This will negatively impact both intake of students for some schools and then the uptake of the senior sciences.

40% is much too high a percentage. This will only cause anxiety and stress among students preparing for a high stakes exam.

40% is too high a percentage for a piece of work that could easily be written by AI technology. It is also a lot of stress to be putting on students, especially students who might be taken two science subjects for the leaving cert.

Question 5

Teachers were given the choice of 10%, 20%, 30% and greater than 40%. As may be seen from the data analysis, the majority of teachers felt that 20% was an appropriate percentage with a significant number of teachers suggesting that 10% was an appropriate percentage. .

Questions 6, 7 and 8 asked teachers to report on the level of laboratory equipment / resources in their schools.

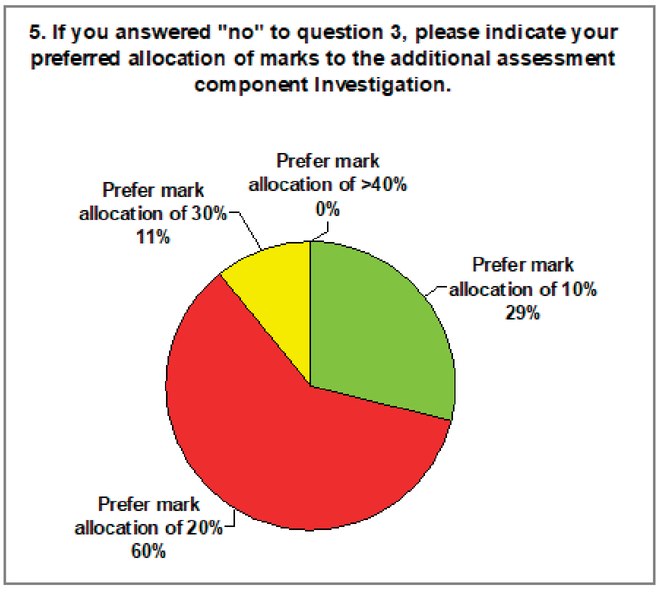


Figure 7.2

Question 6

Figure 7.3.

As can be seen from Figure 7.3, only a small percentage of teachers reported that their schools were very well equipped and about half of the teachers reporting that their laboratories were fairly well equipped.

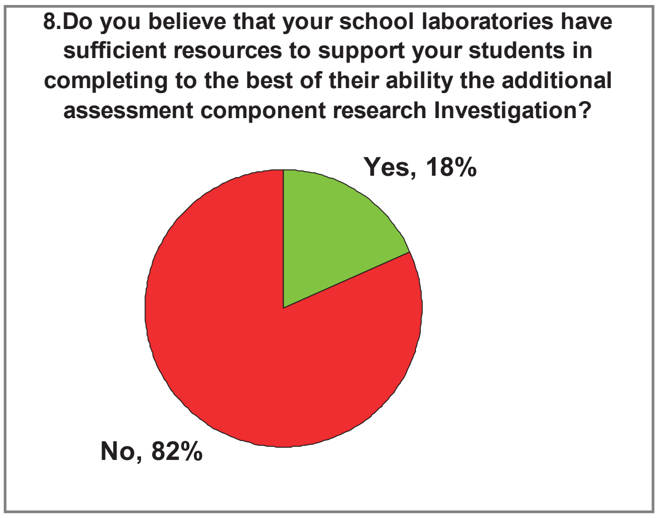


Figure 7.3

Question 7

> ***Please explain your answer to the previous question.***

Analysis of the explanations to answers given in question 7 highlighted a number of themes emerging, e.g. old and outdated equipment, inequalities between some schools that have laboratory technicians and others that do not, need for sharing equipment between laboratories, lack of modern datalogging equipment, variation in funding between schools and the pressure on laboratory equipment due to Junior Cycle CBA projects.

> *Equipment is old and hasn't been replaced in years. Too many students for the amount of consumables and one off equipment that we are allowed to purchase.*
>
> *Fighting for access with JC classes as there are not enough labs for the current numbers.*
>
> *Microscopes all need repairing and replacing. Sharing equipment between 2 labs, so difficult to have enough for everyone and everything. Need lab tech to maintain and keep stock of everything, it's an extra job to monitor everything.*
>
> *In a school that us currently in prefabs. Even with new equipment I feel there will be an unfair disadvantage for private/wealthy schools to buy more advanced equipment and technologies*
>
> *We have 30 students in most of our senior science classes. The labs are old and we have no data logging equipment.*
>
> *Has taken years to get funding for 12 microscopes, budgets always an issue, no hot water in lab. No lab technician.*

While we have enough equipment for current LC experiments we don't have a technician so I don't understand how 1 teacher can oversee 20-24 students doing individual research investigations as well as teach a course with more material that the existing course.

We have five labs, currently in 5th year we have 3 biology classes, 2 ag science classes, 1 chemistry and 1 physics. There is not enough equipment to cover everyone or to fully stock each lab.

Not only are the labs poorly equipped, there are not sufficient labs to accommodate all the double Science subject classes per week.

We will not have enough equipment for the large number of senior science students in our school, especially if they will be working on individual projects which will tie up equipment. Storage of their project work may also be difficult

We are not well equipped enough to have 24 Individual Leaving Certificate Chemistry experiments being carried out at the same time. Students generally share resources between pairs, i.e. burettes, conical flasks etc. We do not have a lab technician and it is disgraceful to expect teachers to give more free time to make up solutions.

We have a dedicated laboratory technician, 4 labs with equipment in each and 2 prep rooms. The equipment is linked to current practical requirements so any new practicals or practicals students devise for their assessment we will not be equipped for. Orders for science equipment and chemicals are currently taking a long time to arrive (especially post brexit) which impacts the range of practical activities we can offer to students on short notice.

Much of our equipment in our labs is very old and too expensive to upgrade with the funding we have.

There are 6 labs in my school. Each lab has a standard set of equipment but have to share everything else. It can take a very long time to locate everything you need for practical subjects

My school is a CEIST school and does not get the same funding as an ETB school, so it puts our students at a disadvantage to some schools whose labs are more modern and better equipped.

We have a new lab and are able to do all chemistry practicals

We are currently trying g to run all JC classes, Ag Sci, Physics, Chemistry and Biology classes out of a stock of equipment suitable for 1 lab.

The school is already above its maximum capacity and the department have requested we take an additional 30 first year students next year. At the moment, I teach chemistry in a kitchen, and biology in a classroom for one double each week. Even before tackling the issue with equipment, rooming is an issue. With the Junior Cycle CBA's and science as a compulsory subject, we are very stretched for equipment as it is. For experiments such as gas prep, we have one class set of kits available between the three labs. Although I would feel that an assessed practical investigation would be very beneficial for seniors, it is just not possible to do and will lead to significant stress amongst students and teachers.

I have a budget of €2500 including a 23% VAT to buy J.C Science, L.C Chemistry and L.C physics departments per year. I am in my school 14 years and my budget has not changed within this time.

Labs are well equipped but there are not enough labs to ensure all lessons are lab based- some are in classrooms. Big demand for lab time with junior CBAs.

Two labs between two chemistry classes and four biology classes and one physics class , therefore lab time, equipment and materials very limited

The management of the school that I work in refuse to allow the purchase of lab equipment.

Question 8

Teachers were asked to indicate Yes or No to this question

It is clear from Figure 7.4 that the majority of teachers do not feel that they had sufficient resources to support the additional assessment component Research Investigation.

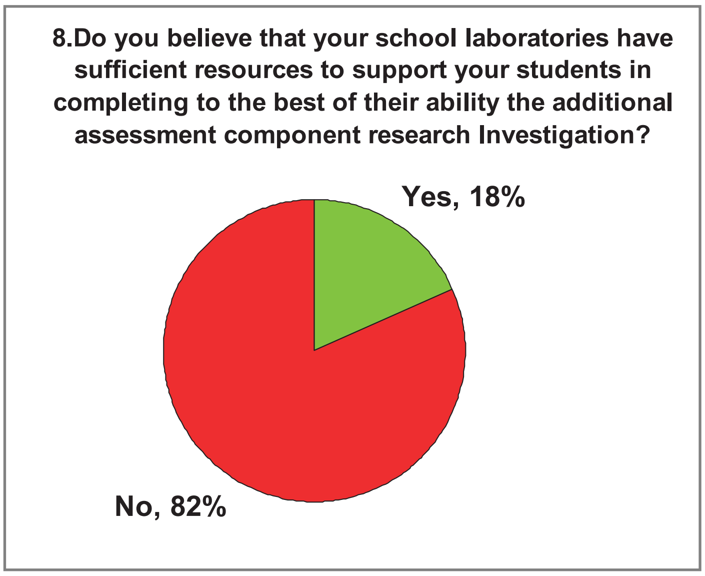


Figure 7.4

Question 9

Please explain your answer to the previous question

Analysis of the explanations to answers given in question 9 highlighted a number of themes emerging, e.g. lack of space to set up projects, lack of glassware and reagents, lack of lab technicians, difficulty of accessing labs, students missing lessons to work on projects and lab resource problems in extending the research investigation in Agricultural Science to Physics, Chemistry and Biology.

We don't have enough glassware sometimes not to mind anything more complex the students may need.

Absolutely not . Where will there be time to make up reagents, solutions for 24 individual projects in both Chemistry and biology

No lab technician in a school of 1200 students. We also don't have near adequate equipment for regular equipment never mind any fancy equipment. Really concerned about this.

Lack of space to set up projects - no printing facilities or IT facilities always in use with pressure on labs. not every senior cycle class is in a lab at all times

We probably do have sufficient resources but I don't see how 1 teacher can oversee a class of 20-24 students all doing individual projects - if Dept of Ed want this type of work to be done in schools they can fund lab technicians. Most chemistry teachers have never received training in organising and managing labs but are expected to do it.

The additional assessment component is too vague for me to really know but we would be limited to only the basic experiments (mostly titrations). If a student wanted to do anything beyond these we would be pushed.

There are over 1000 all boys attending our school. We have one science lab that is shared among all the science teachers. A booking form is completed to book a class into the lab .I teach Leaving Cert chemistry in a classroom and only have access to the lab around once every 3 weeks .

We are not well equipped enough to have 24 Individual Leaving Certificate Chemistry experiments being carried out at the same time. Students generally share resources between pairs, ie Burettes, conical flasks etc. We do not have a lab technician and it is disgraceful to expect teachers to give more free time to make up solutions.

I carry out the Ag Science IIS with my students . I have adequate resources for this subject but space may be an issue when all projects are in operation

Currently we share 5 labs between 1200 students (junior science and senior science). We only have 1 hr classes so investigations need to be cleared away at the end of each class. We cannot keep labs for example 1 week for a class to keep an investigation going as it would affect all the other senior classes and Junior Cycle CBAs.

I feel we will need additional funding from the Department to carry out these assessments

Typically students will pick a language, a science and 2 other subjects they enjoy. The amount of time they miss in class for existing projects is significant. If they have a 40% incentive students will miss other classes.

We are barely able to cover the needs of the current JC and LC syllabi. This will require a significant increase in funding and guarantees that the equipment and materials are available to schools in time for the start of the new courses

I am worried about the cost and availability of chemical consumables and also the number of glassware/specialist equipment that might be needed.

The physics and chemistry lab in my school is 20 years old and is in poor condition currently. We also have a huge lack of storage space so experiments would have to be tidied away at the end of every class and reassembled again the next day. There is no counter space available for things to be left out.

Based on my experience from the jc investigations most labs are ill equipped to manage a large group of students doing several different investigations at the same time.

I am in a DEIS school with 919 students and 2 laboratories.

I feel we will need a lot of new equipment for the variety of experiments the students will be carrying out and also a lot of new technology- Data loggers, etc.

We have no technician. Only one chemistry teacher and 2 labs shared between 5 science teachers.. Very poor on time and space to prepare.

We have one decent lab and one tiny ill-equipped lab. It will be extremely difficult to coordinate and timetable laboratory availability to allow for completion of additional assessment components in Chemistry and Biology.

As stated above, I believe that our lab is adequate to support the needs of the curriculum as it stands, but it would not suffice for a research project at senior cycle.

If all 4 LC science subjects have individual project components there is no feasible way to facilitate it. We have 2 prep rooms, one is entirely taken over with Ag Science projects. No prep/storage for another 100 projects.

We do not have enough - waterbaths, storage space to store experiments if they are ongoing over a number of weeks , computers in the labs for students to research or write up their project.

I don't feel that we will have the diversity of equipment that may be needed for inspirational work. I would worry that our equipment may limit our students imaginations when devising experiments

While this will depend on the choice of projects, I am teaching in a private school and management is proactive in facilitating the purchase of apparatus/supplies. I am very aware that for many schools the situation could be very different.

We have six labs but we have 8 x 6th year biology classes, 7 x 5th year biology classes, 1 x 5th and 1 x 6th year physics class and 3 each of 5th and 6th year chemistry classes. This is in addition to TY and 1st-3rd Year Sciences where we would have approx 8 -1 0 classes per year. We do not have enough labs for all groups to be in the lab for all periods, especially not at the same time. Currently we run CBA1 during the mock exams as it is the only time we can free up enough labs for 2nd year CBAs. I don't know how we will manage if all 6th year biology and chemistry and physics students are to do six weeks of a practical project at the same time.

In our school of 900 students we have 4 labs. With LC sciences expected to run projects at the same time this will lead to huge problems.

Question 10

Please outline any concerns that you may have regarding the impact that the additional assessment component might have on the availability of school laboratories and laboratory resources to other classes such as Junior Cycle and Transition Year.

Analysis of the explanations to answers given in question 10 highlighted a number of themes emerging, e.g. less practical work having to be carried out at Junior Cycle and Transition Year level, students having to be moved out of laboratories to facilitate Leaving Certificate project work, implications of teacher availability for students who wish to participate in BT Young Scientists' Exhibition and the perceived rush to introduce the new specifications in schools in 2025 without schools being adequately equipped.

To be honest practical work for TY will have be scraped particularly at some times of the year. Similarly there will be issues for second years undertaking CBAs. Overall students won't get much lab experience and Will be ill prepared when they actually need it.

We have one full sized lab in our school and another that can only seat 18 at benches. This is for a school of 350 pupils. My LC classes are in the lab once a week and coursework like this will require them to be in the lab for all lessons - this will be very difficult from a timetable point of view considering that all senior cycle Science subjects and JC Science will now have to complete coursework.

Senior cycle students will be given priority and my concerns would be that these year groups may have to move out of laboratories to accommodate LC students during completing of the additional assessment component

Huge impact - we don't have enough labs as it is - there will be a big clash between JC science regular labs / CBAs & the 4 senior cycle subjects if each senior cycle science subject has brings in the additional assessment component

We simply do not have the lab capacity. And I would hate to reduce the number of science classes we accept.

There are only two laboratories in the school. The completion of the laboratory practical work for these projects would mean that other year groups would lose valuable lab time

Other classes may have to lose out on laboratory times in order for the research part to be carried

The school I am in does not have the resources or the staff to assist students with completing the investigations to a high standard. This is also causing a knock-on effect for students who wish to compete in the BT Young Scientists competition as they have only completed experiments by demonstration or watching video links from online. Students completing a research investigation will also suffer by not having the equipment they need on a regular class basis and this will negatively impact their results.

Having an investigation with such a high weighting of marks across three Leaving Certificate Subjects will seriously impact the availability of labs to all other years

For schools without lab technicians - which is the majority - it may put a strain on teachers for prep time. Whilst it could be said that students are responsible for their own prep, time may not allow for that during class periods. This could inadvertently result in a lack of practical work with other year groups as the Leaving Cert. groups take priority, especially during the time of the CiPI in which a teacher may be required to aid the prep of up to 24 individual experiments, reducing the prep time towards other years

Question 11

Have you any other comments on the proposed model of assessment of Leaving Certificate biology chemistry and physics additional assessment component" by means of a laboratory-based Investigation in sixth year as outlined in the draft specifications?

The responses to this question provided data which ranged over a wide area of topics which are summarised according to the main themes identified in the data. The main themes that emerged were:

- Additional stress on teachers and students
- Adverse effect on uptake of Leaving Certificate Physics, Chemistry and Biology.
- Cheating associated with proposed model and alternative models to give credit to students for practical work should be considered.
- Widening of the social divide.
- Timing in sixth year and timescale of introduction
- Learning from experience of the Agricultural Science research projects.
- Importance of provision of laboratory technicians.
- Importance of making School Management aware of implications of research investigations in Physics, Chemistry and Biology.

Additional stress on teachers and students

As a chemistry teacher with 30 years experience, I am open to any change which is for the good of my students, but this is not it. It will only put more pressure on students who are already overwhelmed with the content of most senior level subjects. It is obvious to most teachers that the current JC programme is not working in terms of the impact of CBA's - talk to students and parents and it is clear it is very stressful and not having a positive impact on their learning. Yet we are about to do the same to our Leaving Cert students. As a teacher and as a mother, I am becoming very disillusioned and disappointed with the new system. Change is necessary but not like this. Someone needs to start listening to the teachers and students on the ground.

Hugely stressful for students who are doing more than one science subject and other subjects with assessment components all occurring within the same time frame

Personally I do not think that this model was thought through. At the same time that the projects from the 3 sciences are due, mock exams will be getting done along with Oral language exams. So the pressure on students will not be eased by doing projects instead it will be extended now from February until the end of June. I also personally think that it will reduce the number of students taking physics for Leaving Cert. as students will reduce the number of science subjects that they take because of the concurrent project load. I think the model of a project and exam reduces the fundamental teaching and therefore learnings of the student. Yes students do projects in college it doesn't mean that we necessarily follow suit and complete them to this extent at second level. I think in terms of updating the physics curriculum, adding in some Astronomy while reducing the section on electricity would instead up the numbers of students taking physics while increasing their fundamental knowledge before they start college.

Biology, Chemistry and Physics should not all being changed on the same year. They should be phased in one subject at a time so that students are not as anxious and so that schools are able to manage timetabling the lab more easily

I think the level of stress this will place on students would be immense, particularly since the investigation is overlapping with other practical/oral examinations. Any student who may take more than one science subject will be overloaded with work and therefore neither subject's assessment will be a true representation of capabilities had more time been afforded. This may lead on to a decrease in selection of more than one science subject due to workload.

The new Junior Cycle was a terrible mistake which the Dept just went ahead with while ignoring the genuine concerns of the teaching professionals. I would not like to see this situation arise again where they ignore the professionals in the classrooms to blindly implement this new system. This will put pressure on resources and will add lots of extra work on the class teacher to prep students for the assessment. The influence of AI and plagiarism needs to be taken into account also.

Many Senior Cycle students study more than one of Chemistry, Biology etc. These students will now have multiple projects all at the most stressful time for them. This is not fair and not feasible with shared labs.

The line given in the media is these changes are to reduce stress for students whereas introducing all these projects will do the exact opposite. The majority of students get on with the LC with little or no drama every year - small minority and same lazy journalism every year make the LC out to be a bigger deal than it actually is or needs to be. If students have 3, 4, 5 projects as well as orals and written exams to do, stress levels will sky rocket. Again, need clear guidelines on what is expected. Health and safety issues for teachers - are they expected to oversee a full class of students all doing different research projects? Surely, something like the old coursework B for Junior Cert would be better - Dept issues 3 project titles and students choose 1?

We need a more specific set of learning outcomes. We need a list of mandatory experiments. We need a reduced % for the project. We need to see samples of projects. We need to see the proposed booklet students would use. We need to see how it will be marked. IT IS UNREALISTIC TO HAVE THIS UNPREPARED SYLLABUS COMING INTO SCHOOLS IN UNDER 2 YEARS TIME!!!

It is ridiculous that we are again being fed information piecemeal about this whole process - it smacks again of making it up as they go along. Bringing together the 2 JC CBAs as a LC investigation will not reduce stress levels on either student or teacher.

I have serious concerns about the amount of time that would need to be allocated to the Lab-based Investigation because there is still a huge amount of theory to cover. It is very challenging as it is to complete the course on time, so I don't see how all theory will be covered along with completing the additional component. I would also have huge concerns over how vague a lot of the learning outcomes are.

I do not get the Chemistry course completed till May. I will be under enormous pressure to try and carry out the assessment task as well . Mocks are now taking three weeks to complete, so trying to fit in 20hours on the investigation seems daunting. Also, its irrelevant what % the investigation is as it has to be done and will impact the written exam unless the content that has to be covered is reduced,

I have huge concerns if I totally honest. Going back to box 4 - what happens when Teachers are absent due to sickness and no suitable sub can be worth. Extra curriculars will be curtailed more -you have students missing when doing some 40% and teacher themselves can't be absent with teams etc. What happens for Teachers who maybe covering a maternity leave, for example but they aren't a subject specialist - how this fair these students. Some schools have better facilities- how is this fair.

Change is necessary but not like this. Someone needs to start listening to the teachers and students on the ground.

It will have the unintentional consequence of increasing stress for diligent students

We will need clear guidelines to help us, not vague headings. Please bear in mind that the majority of students are just 16/17/18 years old. They do not have vast scientific knowledge and have limited laboratory experience.. They have difficulty coming up with project ideas , questioning and problem solving. The new course may improve these skills but all students are not scientifically brilliant. The new courses are long and so do not allow enough time for the large amount of lab work. The teachers should get time off the timetable to allow for prep if lab technicians are not put in place. Again I mention that if students are doing a number of science subjects , the project work will add to their stress rather than reduce stress .(stress being associated with the current LC, which is a fair system)When other subjects change, there will probably be project work incorporated into them as well, more stress for our students

Incredibly disappointing, unrealistic with the lack of resources and lab technicians etc. Dumbing down what were incredible curriculums. Adding to the mental health crisis with our young people and quite frankly the teacher shortages. No consultation with those actually on the ground carrying out the work daily. So many unanswered questions and we couldn't even be provided with what's entailed in the actual assessment task or written paper. Disgraceful and disheartening.

Adverse effect on uptake of Leaving Certificate Physics, Chemistry and Biology

I believe that if the 40% goes ahead, many students will not choose as many Science subjects as they do now. We have some students who take all 3 science subjects and if they had 3 additional assessments to complete, this would be extremely difficult on them. I am against the assessment component but if it must be included, 10 or 20% is the maximum that it should be worth.

I used to teach the IBDP program while I was teaching abroad. Their coursework is 20% and it worked very well

I think a 40% project will make students less likely to choose science for LC as it's too daunting to take on. If the project was worth 10 or 20%, I feel they would see it as a positive thing.

It may put off the student who would be pushing for a H1, If there's a wishy washy non-specific hand wavy project as part of the spec.

For schools without lab technicians which is the majority, it may put a strain on teachers for prep time. Whilst it could be said that students are responsible for their own prep, time may not allow for that during class periods. This could inadvertently result in a lack of practical work with other year groups as the Leaving Cert. groups take priority, especially during the time of the CiPI in which a teacher may be required to aid the prep of up to 24 individual experiments, reducing the prep time towards other years – loss of interest in science.

Be careful that we don't send students to other subjects. Finally, I notice that students coming into fifth year have less knowledge since the new Junior Cycle Science programme was introduced.

We should be encouraging uptake of STEM subjects and I worry that this additional assessment component will discourage students from taking up Biology, Chemistry or Physics

Cheating associated with proposed model and alternative models to give credit to students for practical work should be considered

How can we safeguard against cheating? How will it be fair for disadvantaged schools competing with schools who have unlimited resources

Is there any way an oral type interview could be conducted by the examiner to assess the students? This was done for nearly 40 years for the Agricultural Science projects.

I worked in Northern Ireland for 18 years and found the controlled assessment, a lab based practical and separate exam paper on laboratory work worked extremely well and thoroughly enjoyed by the pupils. This required a lot of planning and equipment which need to be provided as my school at present simply would not have the quantities needed. This is a real pity as practical work is such a vital component of LC chemistry and I feel pupils should be assessed on their laboratories skills and techniques.

As a member of the community in which I teach, I would find it very difficult to tackle the issue of plagiarism via AI. That is, it is difficult to prove its use (unlike other forms of plagiarism). I wouldn't worry of the potential implications of accusing a student of this sort of plagiarism on my relationships with students and parents.

These are not university students. They have not developed adequate research skills to complete this work independently. Little time allocated to help student develop such skills.

Students struggle an awful lot with research. Chemistry research in particular will prove to be very difficult for some of them and it will end up being the teachers work. The project will then discourage students from following chemistry into senior cycle.

If the end goal is to get students more focused on their practical skills, would it be possible to award a percentage of marks (e.g. 10%) to showing evidence of completing the mandatory practicals, similar to a previous Junior Cert.

Widening of the social divide

This is going to create a huge divide between children from different backgrounds. It hugely disadvantages students from lower social class backgrounds who will be relying solely on a teacher who is trying to get their heads around the chemistry of 48 projects at the same time. While students with parents who have a background in this will be able to go home and parents will complete the work for them happily. Parents will do anything to increase the amount of points a student gets, even if they don't know the information themselves, they will find (or worse pay for) people who do know the science. I myself am in my fifth year of teaching and feel I have just got a grasp on the current curricula. The change to the content I am not against, but the proposed AAC seriously concerns me. I speak with my colleagues in Ag. Science and Applied maths who have these AAC's already and their workload has increased hugely because of the AAC's. From seeing their experience I have to say I am considering other options outside of teaching because I don't think I can stand over the credibility of this model and certainty do not want the stress that has been mounted onto them.

We do not have lab technicians like the private schools

I am not fully against the idea. However I think steps should be taken to prevent those at a disadvantage from becoming more disadvantaged. A set title should be given by the department when students start in September of fifth year so that teachers have ample time to prepare and plan for the challenges their students may face e.g. lab time, computer room space, management suspending S&S etc

I would be very disappointed if schools with poor lab facilities are encouraged to steer students towards research based projects. This would be grossly unfair and would not serve students in this disadvantaged position well in developing their practical skills. It also creates an "us and them" situation.

I am so open to change and even though a lot of clarification is due, I do look forward to bringing a new syllabus to our senior students. As previously stated, I think a practical assessment would be wonderful, but it is not realistic nor feasible and creates an immediate disadvantage to students in schools that are not properly equipped for this component of the specifications. I think if the additional assessment has to be worth 40%, students should be given some reward (maybe 10-20%) for completing the mandatory practicals (similar to old coursework B) and the rest would have to be research based in my opinion. In the interest of fairness for all students, I feel that this is the only way - unless the department has a significant amount of funding for every secondary school in the country!

I feel that the lab based investigation will give an advantage to students from better socio economic backgrounds, depending on their parents occupation (eg pharmaceutical industry, research based etc), these students will have access to materials that other students will not. They may be able to base their projects on topics from industry. Also input from parents will give these students an unfair advantage. Lab facilities in some schools are far superior to others where labs are rotated week by week. A major factor is the time input required from already very busy teachers to organise equipment, check that it is working etc. Also I know from other subjects that submitting projects on line is also very time consuming and is normally carried out in the teachers own time. The portal opening time often puts teachers under pressure to carry it out at a specific time that might not suit them, and can affect family commitments. Teachers will be under pressure to think of or modify suggestions from students. Overall I feel that it make the LC Biology exam a very unlevel playing field.

I can't help but think that those that are financially well off will benefit most or have connections in the educational field

Fee paying school and we have a lab technician

It may also be unfair to have a lab/project complaint as some schools have different resources in their labs. Access to lab technicians and labs, etc will give some schools an unfair advantage.

I welcome the changes and the practical component but am strongly considering stepping away from the classroom if the changes go forward in the current format. The expected learning by students must be fair and transparent and accessible to all. JC students are already falling foul of the CBA assessments due to school resources. This is going to add to that disparity. DEIS students will need extra supports to complete project work due to poor attendance and resourcing.

Timing in sixth year and timescale of introduction

I think it will be stressful for the students in their Leaving Cert year. Maybe it would be better to do this assessment at the end of fifth year.

The laboratory based Research Investigation should be worth no more than 20% and those setting the themes for the Investigation should bear in mind the limitations of lab availability, lack of lab technicians in schools and difficulties with lab availability. Should be in fifth year to allow catch up time in sixth year

Do not roll out a syllabus that the teachers and students are not prepared for. There is too much up for stakes on this whim. Sixth year is not the right time!

I am teaching biology for 22 years and was really looking forward to a shake up of the course but these draft guidelines are extremely disappointing. 40% course work is absolute nonsense and needs to be adjusted downwards significantly. We also need significant in service BEFORE we start teaching the new course, so with this in mind it is my opinion that the new courses should not be rolled out in Sept 2025 and inservice should be given for next 2 years in lieu of oide (old JCT) inservice.

The new course is being rushed in. It should be trialled in pilot schools to see if is going to work. The old course needs to be updated but this is happening too fast and not all teachers will be able to avail of the necessary upskilling required. Not all schools have equal opportunities and facilities, this is going to disadvantage students

Learning from the experience of the Agricultural Science research projects

As seen in Ag Science, numbers have fallen due to the intensive nature of the IIS. Students are now choosing subjects carefully to manage their time and avoid overload on so called project work (DCG / economics / construction) and not necessarily choosing their favourite subjects. Will numbers studying the sciences fall? Also as teacher of both Biology, Chemistry and JC Science, the workload will be immense. 2nd year CBA, 3 year CBA, LC Biol and Chem AACRI. this will put both myself as a teacher and my students under too much time stress...so much for Wellbeing!!!

Having been involved with students in the completion of the Agricultural Science IIS I feel the workload on the teacher will increase and that covering this extra module will put a strain on already limited resources. Additional Assessment at all LC Science subjects plus demands to complete CBA's with JC groups when and where do we fit it all in?

From working with students on their Ag Science projects, it is clear that they struggle massively with the research aspect of the project. They do not yet have enough of a grounding to make sense of the papers at all. Chemistry papers are far harder to understand that ag science papers. To best counteract this we will have to reorganise the scheme of work every *year to try and best equip the students to try and make sense of the research that they must carry out. The students who do a chemistry based ag science project are the ones who tend to struggle the most as they do not yet understand the chemistry behind what they are trying to research (even if they are chemistry students already).*

Concerned about the time it will take to cover the course material additionally to giving enough time to the coursework element. I feel the LC ag science coursework is too difficult for many students and it has led to reduced numbers taking up the subject, and worry that the Bio/Chem/Physics new coursework element could lead to the same if it's a similar framework to the Ag Sci. Also huge amount of additional workload on teachers who teach at least 2 of the subjects- needs to be considered

Importance of provision of laboratory technicians

Teachers workload has increased massively, this will make that worse . We may have to be working outside class time to help students get this extra work covered. It is extra as the courses are not shorter ! Lab technicians are also essential.

Are we going to be shown sample pieces if work that have been graded? Will lab technicians be provided to do the extra lab work involved ?

Time is a major factor in the running of the laboratory efficiently. Lab technician is needed.

Without the support of Lab technicians, the extra workload imposed here will be very difficult.

We have no technician. Only one chemistry teacher and 2 labs shared between 5 science teachers.. Very poor on time and space to prepare.

The government will have to pump a lot of money into Science and provide technicians

3 labs, 4 science subjects at Senior cycle.. usually 2 biology classes, 1 Chemistry, 1 physics and 1 ag science all looking for 20 hrs in a lab. Absolutely crazy!! Where will the prep come from? Who will be doing this preparation? Will they give us a lab technician?

My lab and school are not equipped enough for practical work as it is. Can't get a decent budget for equipment/chemicals as it is. Need a lab technician also for this to be sustainable.

Has taken years to get funding for 12 microscopes, budgets always an issue, no hot water in lab. No lab technician.

No lab technician in a school of 1200 students. We also don't have near adequate equipment for regular equipment never mind any fancy equipment. Really concerned about this.

Will lab technicians be provided to do the extra lab work involved ?

Without the support of Lab technicians, the extra workload imposed here will be very difficult.

Impossible to carry out without funding for labs and provision of lab technicians.

The absence of technicians at Second level is going to create further stress for teachers.

I do a lot of practical work with TY to encourage uptake in LC , I am always under pressure cleaning and organising equipment without lab technicians.

Teachers workload has increased massively, this will make that worse . We may have to be working outside class time to help students get this extra work covered. It is extra as the courses are not shorter ! Lab technicians are also essential.

While we have enough equipment for current LC experiments we don't have a technician so I don't understand how 1 teacher can oversee 20-24 students doing individual research investigations as well as teach a course with more material that the existing course.

We may have equipment but with CBAs and additional practical requirements for Biology, Physics and Chemistry I think we may be over stretched and all this without lab technicians-just too much

The Irish system of teaching without the assistance of a lab technician in a secondary school is totally unacceptable. All these additional projects without technical support will push Science teachers from stretched to burnt out very quickly. We are expected to do two jobs in this role - we need to be allowed to focus on quality teaching, rather than being side-tracked with the work of a technician also.

Physical space will be a major problem. This is already apparent where Agricultural Science IIS investigations are underway while the Junior Science CBA1 also needs to be done. More projects for LC will be difficult to accommodate- but the assistance of a lab technician would make a huge difference.

Principal very supportive financially but time to organise and order is the issue. Lab technicians needed!

How does 1 teacher supervise 24 individual chemistry experiments at one time? Who will prepare the chemicals for the projects (many schools do not have lab technicians) and who will pay for the equipment? In terms of safety again, 4 students at one desk completing 4 different investigations using different chemicals, how can safety be guaranteed?

The laboratory based Research Investigation should be worth no more than 20% and those setting the themes for the Investigation should bear in mind the limitations of lab availability, lack of lab technicians in schools and difficulties with lab availability.

Not all Leaving Cert. and Junior Cycle classes are time-tabled in the lab. Many CBAs are carried out in groups, with individual analysis. These are often carried out outside the lab e.g. in the gym or basketball court e.g. effect of various factors on exercise etc. Obviously this could not be done for Leaving Cert. chemistry. Also we do not have a lab technician so are students supposed to make up solutions themselves? have access to chemical store? what about the safety risk here? or do I need to make up all solutions etc for students? Is this to be done in my own time?

Importance of making School Management aware of implications of research investigations in Physics, Chemistry and Biology

Principals and school leaders should be required to attend consultations or have formal briefings as to what is changing and the implications for timetabling, refurb work, budgeting and AEN student placement. I know I have highlighted this directly but the tokenistic, hands off approach of school managers when curricular change is implemented-is simply astounding. The buck rests with the teacher who has full accountability to students and parents-trying to teach lab work-with beakers and vitamin C tablets! There is also the elephant in the room where in individual schools some teachers have their own lab -teach no other subjects and can prepare lessons as they should be -some in the same school -have a very different experience. Management need to get involved in the workings of departments and the best time to actualise this practise is when curricular change is implemented. This needs to come from the inspectorate.

Lab work is already diminished due to lack of labs. Curriculum changes need to implemented with directions to school management and ETB directorate that the business of teaching and learning is the business of schools and appropriate funding and equitable timetabling practises need to rigorously employed -this ensures some attempt to address rampant inequity of science experience for all students and teachers.

We need a Mandatory List to 1. Convince the school principal that money needs to be spent on lab supplies and equipment to fulfil the requirements of the specification. 2. To make it clear to teachers and students what practical work should be carried out.

7.3 Clarity of learning outcomes

In questions 12, 22 and 32 teachers were asked the following question in relation to the specific subjects of Biology, Chemistry and Physics respectively.

> ***From reading the learning outcomes in the draft biology /chemistry / physics specification, please estimate the percentage of learning outcomes that you feel are unclear.***

In general, the estimates received from teachers were similar to those presented by the ISTA Biology, Chemistry and Physics online CPD sessions. The documents highlighting those learning outcomes which are clear and which are vague were finalised in the light of feedback from the online CPD sessions and analysis from the questionnaires. The results of the analysis are discussed in Chapters 2, 3, 4 and in Appendices 1, 2 and 3 of this document.

In questions 13, 23 and 33 teachers were asked to explain their answer to the previous question and typical comments were:

Would agree with the ISTA highlighted LOs from meeting. Too many to write here.

Too many to list, even if you look at the very first one on food it doesn't explain how many vitamins students need to know, it is very difficult in a lot of them to know the depth of treatment, it might require inserting a line or two into what we already teach and take an extra five minutes or it may take five classes.

I attended the ISTA Biology consultation webinar for two hours and agreed with every learning outcome they felt needed more clarity.

ISTA did excellent work on this, I agree with them

The use of the word model, and many learning outcomes being too vague

I welcome and am excited about a changing syllabus but it is unfair if teachers are not crystal clear on learning outcomes as students have to sit an exam at the end of the day

I have no problem with the course changing but at Leaving Cert level there should be no questions over what needs to be covered or what depth of treatment topics need

Clear teacher instructions needed. Need plans ahead of time, not like ag. Science where teachers were teaching blind for the first group of students. Not fair on teachers or students.

Please make your best case to the relevant parties .some science teachers will be facing this for 2 or 3 subjects in two years time and it will definitely cause stress anxiety among staff and students

7.4 Suggested topics that should be included in draft specifications

In questions 14, 24 and 34 teachers were asked the following question in relation to the specific subjects of Biology, Chemistry and Physics respectively:

> ***What topics, if any, have not been included in the draft biology/chemistry/physics specification which you feel should be included to cover the knowledge, skills and values required of Leaving Certificate biology/chemistry/physics students? Please state your reasons why these topics should be included.***

Some topics which teachers felt should be included in the draft biology specification were:

> *Skeleton and muscles, eyes and ears, all important for students wanting to do medicine, nursing, beauty therapies etc. They should have some knowledge of these before moving to 3rd level*

> *SENSES - EYE, EAR etc, SKIN and BONES - nursing, beauty therapy, doctor, physio, vet, etc all need basics of these.*

> *The senses, skeletal and muscular systems, these were taken out of the junior course and are now removed from the senior cycle, when and how will our student be educated on these topics it is vital to have an understanding and basic knowledge of these areas, the skin links into excretion and homeostasis that is fine but the eye and ear are no longer present.*

> *Musculoskeletal system is accessible content for all.*

> *Human anatomy should not be reduced*

> *I think the sense organs and musculoskeletal system should have been left in, I think an opportunity was missed to include more about vaccines, given the misinformation that is out there any time vaccines are mentioned.*

> *They should not have removed the eye, ear, skin or musculoskeletal systems. The human biology is usually the parts the students like the most. They are also important for nursing, beauticians etc..*

> *No musculoskeletal system, skin, eye and ear is concerning. Students need to know these for life. We have lots of students who go on to work in health and beautician settings*

> *Nervous system and senses should not be removed. Needed for healthcare professions and for general interest in the knowledge of students' own bodies.*

> *Musculoskeletal system - appalled that this AND the eye/ear/skin have been removed. Any students wanting to study any medical field will lack a large section of human biology now going forward. Any hairdressers and beauticians will have no knowledge of the skin leaving secondary school before beginning their courses either.*

> *The senses is a huge loss. Again I suspect the NCCA didn't do their job here again. I feel there will be many third level courses very upset with the loss of these topics. Clear the NCCA has not listened to all stake holders and do not care the disadvantage the students that go into beauty courses or human biological course. Another real failing.*

Sense organs - eye, ear and skin - students love these topics. Important for students interested in cosmetic or beauty salons. Skeleton/muscular- students love these topics- important for students who have an interest in sport and want to pursue physio/sports science.

I feel the removal of the eye and ear, and the musculoskeletal topics are counterproductive. These were very accessible to OL students in particular and were some of the few areas that crossed over with physics.

Skin, eye and ear for sure. Students will go onto college or plc courses in which understanding on their anatomy will be keep. Students are going to student science for potentially 6 years in secondary school and not understand their basic anatomy but understand in depth about plants. That is so disappointing.

The Skeleton, The Senses, Enzyme Immobilisation. The Skeleton links to other parts of the course e.g. Food, Blood as does the Senses e.g. the Nervous System. The immobilisation experiment and the concept are key to bioprocessing which is really important to putting enzymes in an everyday, industrial context.

An understanding of Crisper as it is so relevant and recent.

I don't think the eye or ear should be removed. CRISPR could be introduced

The eye, CRISPR - the eye is a link to physics, the students mainly find human biology one of the most engaging topics and they can visualise what they are learning. CRISPR as this is what is going on with gene editing at the moment - the genetic engineering that we teach is incorrect.

Some topics which teachers felt should be included in the draft chemistry specification were:

Reading of proton and carbon NMR, functional group identification. If you're leaning towards the Australian system then why leave these out.

I would like to see more current Chemistry topics - more applications of organic (glad to see Aspirin added as lots of resources on RSC for this)

Acid and Base titrations and associated skills seem to be limited now

I thought more on pharmaceutical chemistry (drug delivery etc) would have made the course more interesting and considering how big the pharmaceutical industry is in Ireland I thought it would be an easy win! They have a section on that in GCSE chemistry in England and students loved that topic when I taught in England.

Pharmaceutical chemistry - fast growing industry that students should learn about in school

HPLC, GC Mass Spec. These are such widely used techniques in industry. It would be useful to have an introduction to these covered in LC Chemistry.

One area that might have been overlooked was a deeper look at electrochemistry in particular around the area of battery technology. As Electric vehicle market is growing a lot this chemistry becomes a lot more important. I am aware that electrochemistry is a poorly answered and not much liked area of the course but it is quite relevant currently. Attended chemistry conference in UCC last summer and a great and interesting intro to lithium ion technology was delivered by a professor from the engineering dept(cant remember his name John?)

I feel that students do not have a good understanding of bonding as it has been taken out of the JC course. I would like us to be able to give more time to it in Senior Cycle.

Lithium ion batteries. The Electrochemistry section is very outdated.

More pharmaceutical-based chemistry - linking with the many industries we have in Ireland.

The content that is included in the chemistry specification is overall good in terms of content. It would be perfect if the learning outcomes were made clear. My worry is the time needed to complete the content. I cannot see how it is possible to complete the necessary content AND have the 40% investigation. It is just overloaded.

I would not include more topics.

Expanding the depth of nuclear chemistry

With the removal of the scientists responsible for the development of our understanding of the structure of the atom, I feel as if there is a lack of Science Technology and Society (STS) issues.

Some topics which teachers felt should be included in the draft physics specification were:

Topics following on from Earth and Space at Junior Cycle such as astrophysics (telescopes, luminosity, PARSWC and light year, Hertzsprung-Russell (HR) diagram, lifecycle of stars, Hubbles Law) or more Medical Physics (optics linked to eye, sound linked to the ear e.g sound intensity level)

Capacitance, spherical mirrors, telescopes, more on medical physics, the eye which is also removed off biology

Course content is very similar to current course. Time is the concern

Astrophysics. Earth and Space was a major section of junior science which a lot of students loved, no continuity from Junior to Senior Cycle.

Astrophysics. I am often asked by students in 3rd and 4th whether this is on the physics course and also by 5th and 6th years who are taking physics. I think we are missing a huge opportunity in not covering it as most students in the Junior Cycle enjoy the space chapters.

Space. It is the major reason students choose to study physics.

Astrophysics. They have just come through JC Science where ever made a big effort with earth and space . Then for the students interested in this area there is no follow through at LC !! We have created no clear career path into Astro/ particle physics. And I'm not happy that capacitance is gone.

I think there should be some Astrophysics on the course, to continue on from the Earth and Space section of JC Science. I also think students would learn a bit about the Standard Model and the new developments in Fusion research. It would be a mistake not to include new developments in physics when we have the opportunity.

I think this is the perfect time to add in some relativity and astronomy. I think the addition of astronomy would increase the number of students taking physics, I think this would encourage more girls into physics.

Boyle's Law, such a fundamental part of science and an Irish scientist

Is reflection and mirrors gone ? fundamental forces- surely it would be good to tie together all the forces that they have learnt, capacitors - good for real world - defibrillators, smoothing of dc, E-field lines, The eye - it' not done in Junior Cycle, a lot wear glasses, good example of refraction at work

Capacitance is a fundamental area of electricity thats missing.

Capacitance, levers

Please don't get rid of moments, levers, and the laws of equilibrium. They are already gone from JC Science and LC Applied Maths. The fact that someone could get to a college level Physics or Engineering course and not know how a door works is absolutely staggering to me. It's also disappointing to see some really important Applied Electricity topics going away, such as logic gates and truth tables.

I would like to see something on Medical Physics on the syllabus.

The options! Gave student a chance for self directed learning. They had a keen interest. This will be a disaster.

Boyle's law, Moment of a force, Capacitors, Spherical mirrors, Potential Divider, Callan's induction coil, Particle detectors.

I did not see much in the way of reference to thermodynamics and heat engines.

Light, magnetism, static electricity. These subjects have everyday applications and are very important to physics in current-day research and technology development

7.5 Suggested Topics that should be excluded from draft specifications

In questions 15, 25 and 35 teachers were asked the following question in relation to the specific subjects of Biology, Chemistry and Physics respectively:

What topics, if any, have not been included in the draft biology/chemistry/physics specification which you feel should be included to cover the knowledge, skills and values required of Leaving Certificate biology/chemistry/physics students? Please state your reasons why these topics should be included.

Some topics which teachers felt should <u>not</u> be included in the draft biology specification were:

PLANTS. Students find them boring and Plant reproduction is both long and difficult to understand.

Reduction of plant material. Too much botany.

Some of the biotechnology/genetics is relevant but not too the level it is in some instances and it is a shame to remove the skeleton & senses which is a very relatable topic and interesting for students.

Using gel electrophoresis as primary source as not all schools have the equipment

Too many topics given only 60% . I would urge caution with too much detail on Biotechnology IL3, Students of this age are often drawn' to he sexy terminology of this material but due to young age and lack of and experience often struggle to understand the details involved, so clear simple details should be provided here. (none of this marked as Higher level)

Phylogenetics as above seems to move away from making the subject relatable for students.

Phylogenetics is a topic that should be left to university. I taught a level biology in the UK for 6 years and our system seems to be moving towards the same content as their course. It was very student or teacher friendly.

Too much detail in Ecology, new mathematical models. We all do Ecology but it is not universally loved, studying it deeper doesn't suit everyone.

I would be concerned about epigenetic and genetics can be very challenging for some students, this addition may be very difficult. The abundance of new elements not manageable

Detail of genetics- too challenging for students and I feel the genetics LO's from the current syllabus are sufficient as they are.

Some topics which teachers felt should <u>not</u> be included in the draft chemistry specification were:

Everything has been included!!! How are we meant to get it all done!!!?

If 20 hours is to be given over to a separate investigation project the content for the written exam needs to be reduced from what it currently is not increased..

None in particular, but there does seem to be a lot of material seeming as it is now only worth 60%.

Extraction of metals - most teachers chose not to teach it for a good reason

Extraction of metals needs to be cut down a lot.

I am concerned that the syllabus is including two sections from the previous Options while at the same time requiring time to do the research/investigation assessment module. I would be glad to leave out Metal extraction section.

The course is too long. They haven't got rid of anything and have added in extras plus the project.

It is not that I think any of the topics should not be in the curriculum but there is much too much topics in it to be covered in the 180 hours allocated times. I think topics such as radioactivity would make sense to get rid of as I am sure Physics will teach them that. Topics such as Bohr's Theory could be reduced down. Atmospheric chemistry could be removed.

Hard question to answer in a sense as there are arguments for the validity of each topic in the draft specification. However I feel there are too many topics in the specifications and completing them all in the 180 hours that are being recommended will not be possible. The following are ones that should not be included to create a specification that could be completed within the given timeframe. P 27 LO i, P29 LO e, P34 LO's d and e, P 38 LO h (prep. of an ester), P 39 LO n, P 41 LO f.

I think that if there is no further clarity on the research projects (RIs), and a realistic timeline for these is not factored into the specification, they need to be removed. This specification is already overloaded, and requiring students to carry out several research projects on top of the 40% Research Investigation will be a much too heavy workload

This too is very difficult to answer. The course as it stands is very difficult to finish in good time whereas the new one seems to have a lot more added on top of a 7 week investigation.

The present options choices should be removed from new syllabus. There is already plenty of material without their inclusion. I am very concerned over the time required to teach all this.

I love the current syllabus and I find it very difficult to establish topics that should be removed. Reducing the number of titrations and possibly considering some organic practicals that take longer than one hour (which most schools are timetabled for at this stage) - e.g. Benzoic acid prep., soap prep. The Benzoic acid experiment alone can take a week between preparation, recrystallisation and determining melting point - and this is not including the theory and exam questions on this practical. I am finding it difficult to identify the content that has been removed, but I can clearly see the additional content in the new syllabus - and this is before mentioning the additional assessment component.

Some topics which teachers felt should not be included in the draft physics specification were:

Transistors and DC motors… require a lot of time to teach properly. Were removed to an option where people scored poorly

transistor as a switch, emf7 LO f, levers and moments of force (gone in Junior Cycle too) - what about our future engineers?

While I don't quite think it should be excluded, magnetism is often a difficult topic to teach due to its inherent (mathematical) complexity that can't really be explained at second-level. It requires a high degree of intuition and understanding that is often not particularly well-understood in comparison to most of the rest of the course. Consider reworking how this is taught.

In order to include astronomy I would remove EMF7. I think students tend to avoid this section of the course, I think its better placed within Engineering or Technology where there is a greater hands on use of the underlying principles.

None, but I think the depth of treatment of topics should be clarified

I found it hard to tell what had been removed as some of the outcomes were unclear.

Kirchhoff's Laws

In general, I have concerns about the length of the course. If 40% is based on the research project

7.6 Mandatory Practical Investigations

Questions 16, 26 and 36

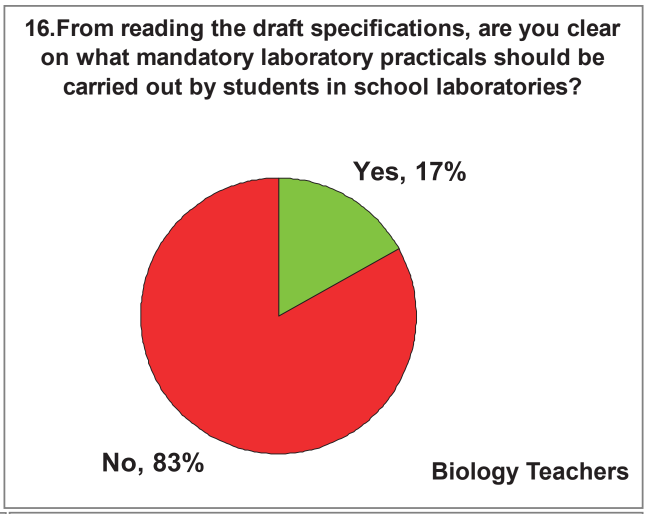
In questions 16 (biology), 26 (chemistry) and 36 (physics) teachers were asked the following question in relation to the specific subjects of Biology, Chemistry and Physics respectively:

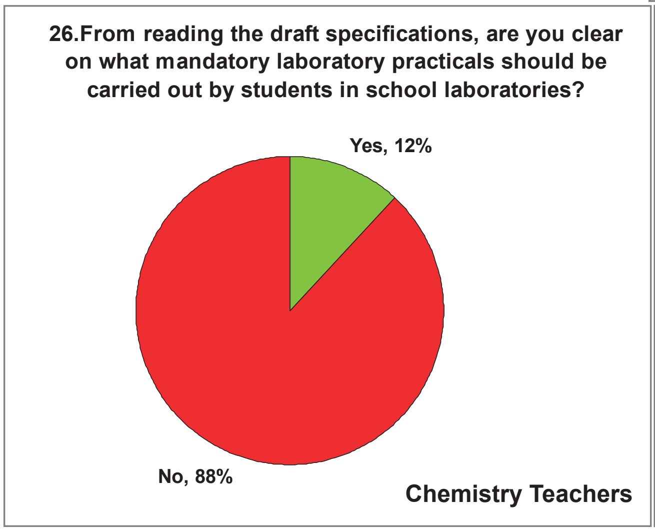
From reading the draft specifications, are you clear on what mandatory laboratory practicals should be carried out by students in school laboratories?

Teachers were asked to indicate Yes or No to this question.

The data obtained from this question are summarised in Figure 7.5

It is clear that the mandatory practical activities to be carried out by students is unclear to the majority of teachers in all three draft specifications.





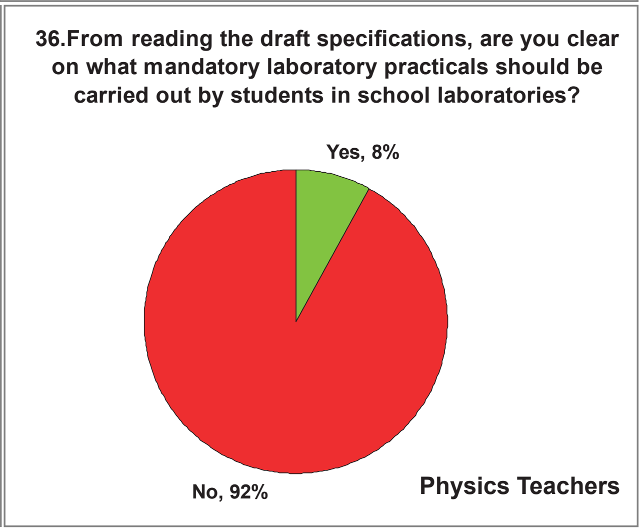


Figure 7.5

Questions 17, 27 and 37

In questions 17 (biology), 27 (chemistry) and 37 (physics) teachers were asked to explain their answer to the previous question.

Typical responses were:

Biology

The use of the term primary and secondary data is confusing in some of them, a list needs to be provided.

While many are titled with EI it can be unclear and would be easy to miss. A specific list of mandatory experiments as exists currently would be much more useful.

Plenty of learning outcomes with investigate but no specific list of mandatory experiments

What is the difficulty for the NCCA to list the mandatory experiments and the chemicals and equipment needed? Again why are they not doing their job?

There is reference to investigations in the specification (SLO column) but much of these are unclear in terms of specific factors to be investigated.

There are 13 Learning Outcomes which include the word Investigate however unless there is *a list of mandatory practicals it is ambiguous as to whether these concepts warrant a practical investigation during class time.*

Give a separate list of the mandatory experiments, as it's vague, it needs to be clearer,

There are no clearly stated mandatory experiments as there is in the current curriculum.

Some are indicated, in other places 'investigate ' is mentioned, which may or may not be an experiment. Also ' not limited too' does not put a limit on what experiment if any should be covered and will lead to many interpretations across the country.

Some experiments are marked as student investigations but others aren't.

Chemistry

Too easy to miss the small EI and titles of some are vague.

When I read the introduction, I thought the EI notation was a great idea as it would make it very clear what experiments needed to be done. But there were a lot of learning outcomes that clearly need an experiment done to achieve the learning outcome but they are not marked with EI.

Unclear how to prepare an ester . Rates of reaction experiments are unclear, which factors do we investigate?

EI notation is only used for some practicals while the phrase ' primary data' is used in many other learning outcomes when an experimental investigation is clearly meant.

Some learning outcomes are marked with EI to indicate that they involve experimental investigations, but there are many other experimental methods and techniques mentioned and it is unclear if they are also mandatory practical investigations

The verb "investigate" is used in a lot of learning outcomes but it is not marked as an EI. Also there is an overuse of the term "investigate using primary and secondary data". What does that even mean? I also don't like the phrase "not limited to" To me, that is purposely opaque. That is not helpful to teachers or students.

Letter EI beside them

It is not clear what is mandatory or demonstration.

Perhaps the mandatory practicals are encapsulated by the phrase 'investigate', but it is very unclear.

Physics

'The reference to use primary and secondary data hints at a practical element but is this a mandatory practical that could be assessed in an exam or watching a demo by teacher and taking data from that source?'

Primary data? Could the students just watch the teacher do the experiment?

I am being asked sometimes to use primary data and on other occasions told to analyse using primary or secondary data. I can't see why a list of mandatory experiments is not explicitly written down, that would remove all the ambiguity.

There are vague statements like deal with or interpret Primary data. We need a list of experiments and equipment list with technician sheets for prep. (I don't work in a school with a lab tech, I want the sheets for me).

There is no clear mention of mandatory experiments on the draft specification

We have no list of the mandatory experiments, surely this is not a hard list to provide.

The wording is not clear to me.

Are there mandatory practicals? is it anything that mentions primary data?

While the specifications mention primary data and the terms 'verify' or 'investigate' or 'evaluate', these might imply an investigation but also a demonstration or just a learning experience. But it does not clearly indicate, as in the previous syllabus, what may be examined as a 'mandatory experiment'.

Draft specification is not specific enough- shouldn't have to guess what is meant.

No specific experiments are named, just model using primary data.

There should be a numbered list of mandatory experiments with clear titles / descriptors

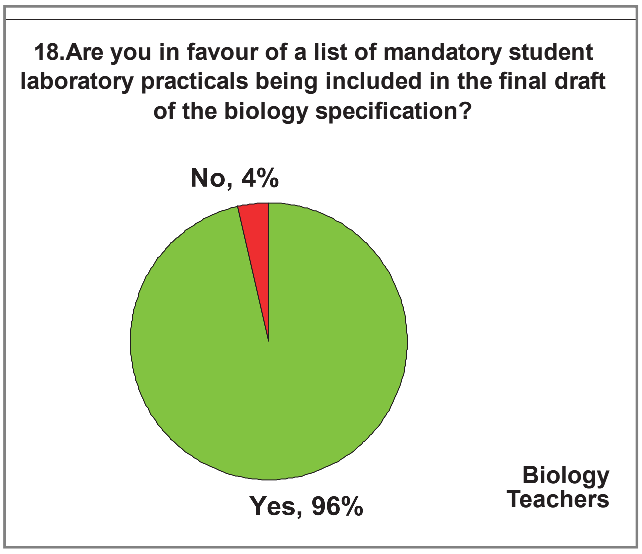
You are asked to analyse primary and secondary data on experiments that are only teacher demonstrations and do not lend themselves to gathering of numeric data. Does that mean that data can be qualitative and quantitative? e.g. analyse diffraction, diffraction? I am confused.

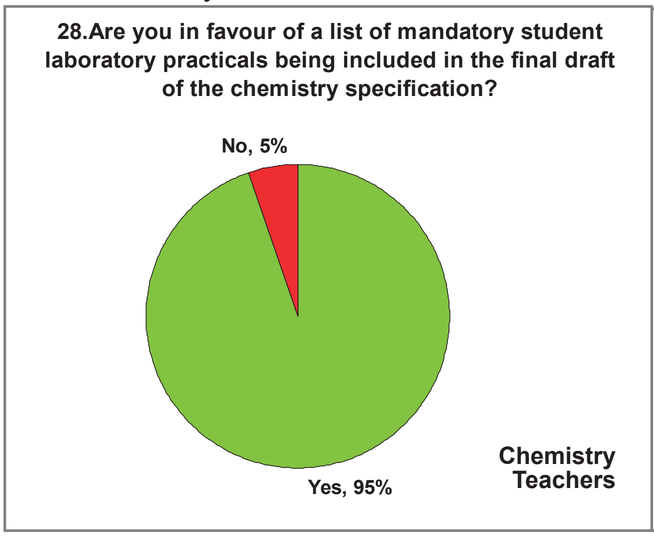
Questions 18, 28 and 38

In questions 18 (biology), 28 (chemistry) and 38 (physics) teachers were asked the following question in relation to the specific subjects of Biology, Chemistry and Physics respectively:

> ***Are you in favour of a list of mandatory student laboratory practicals being included in the final draft of the biology/chemistry/physics specification?***

Teachers were asked to indicate Yes or No to this question. The data obtained from this question are summarised in Figure 7.6. It is clear that the overwhelming majority of teachers wish to have clarity on what laboratory practical work should be carried out by their students.





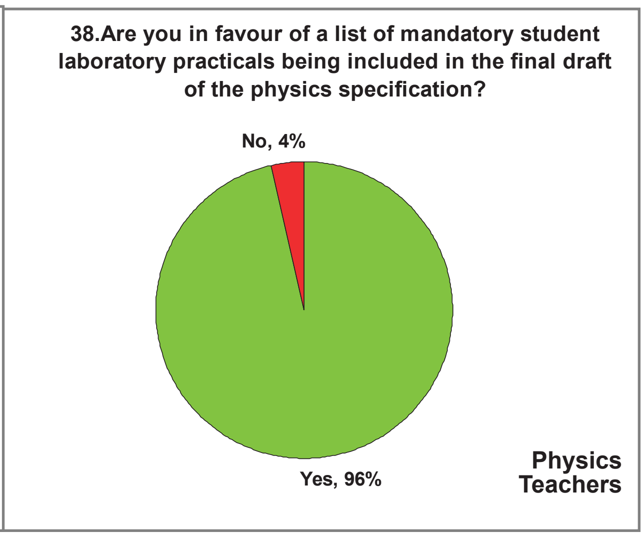


Figure 7.6

Questions 19, 29 and 39

In questions 19 (biology), 29 (chemistry) and 39 (physics) teachers were asked to explain their answer to the previous question.

Typical responses were:

Biology

How else are teachers supposed to know what practical work must be carried out?

Needed to ensure we can plan our teaching efficiently

All students should be proficient in the same investigations.

Clarity good when you have a list of mandatory experiments, vague suggestions only lead to teacher stress and students not all being prepared the same.

Clear to students and teacher what is expected.

Clarity needed on exactly what to investigate for example in the photosynthesis experiment and abiotic factors.

Mandatory practicals are helpful in clarifying issues. I've just done TS of a dicot stem with three separate 5th year classes and they all enjoyed it and got a real sense of what plant tissues are and do.

After working with the JC Science course there is nothing more frustrating than not knowing what exactly am I supposed to teach and to what depth.

It will allow teachers to plan their teaching schemes and give students a better understanding of what to expect on the written paper.

Students need certainty and stability in school. The Leaving Cert. is a high stakes exam and they need to have confidence that they are learning the right content - they have 6 other subjects to complete

A clear list of all practicals is needed so all students face into the exam on an even footing.

Students and teachers need to know what's optional and mandatory

There should be no grey areas in a syllabus.

The time and effort needed to order lab equipment, chemicals and lab timetabling is already high without having to hunt for this information. Clarity is needed in some of the investigations e.g page 26 enzymes in a known enterprise. Known by whom - the NCCA, or the SEC or the teachers and students?

If things aren't mandatory, they won't be done. Have we forgotten pre 2004?

Avoids ambiguity and ensures teachers are adequately preparing students for examination.

I feel that a list of mandatory practicals to be carried out is one of the key components to clearing up the uncertainty

Sme experiments are essential to allow students to get a better understanding of the theory in the LC.

It would be beneficial if students knew which experiments were mandatory as these experiments will be examinable on the paper and its only fair that students know if they can be examined on certain experiments.

It is vital that a clear list of Mandatory Practical Investigations be provided for Biology, Chemistry and Physics. Our Science Department has to fight every year for funding for our labs and the fact that students must carry out a clear list of laboratory work investigations as specified in the current Leaving Certificate syllabi is of enormous help to use in getting this funding. In addition, this mandatory list is very helpful for stock taking and keeping the laboratories as well equipped as possible.

It provides reassurance to students and teachers. Reassurance that we are all learning to the same standard

Lack of list of mandatory investigations is completely unfair to the student - a high stakes exam needs to have a list of what they need to know

I hope they learn from the mess that is the new JC and not repeat the mistakes of the past. We have always felt the Irish education system was fair and transparent.

I am concerned that the course is too long and very vague. The access to the labs and the resources needed will hopefully be provided. Several sample papers should be issued by the SEC before we commence the new curriculum, not at the last minute. The LC is such a high stakes exam for the students. As teachers we need direction as to exactly what they require.

Chemistry

This would make it easier to stock, order and reuse lab equipment. Students and teachers will feel more comfortable and confident if a set list of mandatory experiments is set.

It clarifies what experiments the students must complete. It clearly lays out the practical work required in the course content.

We have to have some idea of those practicals that are likely to be examined. We should not have to be second-guessing specifications just like the JC.

We need a mandatory list to (i) Convince the school principal that money needs to be spent on lab supplies and equipment to fulfil the requirements of the specification and (ii) To make it clear to teachers and students what practical work should be carried out.

Students, and teachers need to know what is expected to be covered in the two-year syllabus. Guessing what has to be taught brings undue stress.

I think a clear guideline is essential to reduce stress for students and teachers. The additional assessment component should allow a small percentage for a completed laboratory notebook at the end of 6th year as it emphasises the importance of practical write ups in senior cycle

As above if left for teachers to decide what experiments to do and how to do them could exacerbate Already existing divide between affluent and disadvantaged schools

It levels the playing field if all students exposed to same material.

I think it is vital! From the proposed plans we do not have much time to prepare. If these are to be introduced in 2025, we have one year to sort through equipment, re organise labs and order new equipment. It takes companies about 6 months recently to send out large orders to us! So we definitely need a definite list so that school can quickly make a move on what they need. I would go a step further and say a list of chemicals and equipment needed for the new specification should also be supplied.

For safety, time, experience and learning opportunities to be fully taken advantage of, a list which keeps all staff and students on track for learning would be beneficial and leave no room for second guessing course requirements and expectation

I have undertaken several courses in the area of Health and Safety and I am very familiar with the legislation requiring teachers to undertake risk assessments for all laboratory activities. The great advantage of the Mandatory Practical Work on the current Leaving Certificate Biology, Chemistry and Physics syllabi, is that these risk assessments have already been done for us - and discussed in CPD courses. If the new specifications do not contain a clear list of mandatory student practical work and it is left to the teacher to decide this, then this will increase the workload of teachers as a risk assessment will have to be carried out by each individual teacher - different schools will be carrying out different practical work. This extra workload will be a source of huge stress for teachers and could result in accidents occurring in our school science laboratories.

Mandatory practical work is a great way of teaching students to develop the skills of following a written set of instructions and taking account of all areas of Health and Safety associated with the laboratory practical work. I frequently attend the BASF Summer School for Chemistry teachers and have visited 6 pharmaceutical plants to date. In every one of these industries, we have been shown the importance of staff being able to follow standard operating procedures in the laboratory by following a clear set of instructions.

Sufficient resources and training must be carried out - more importantly the resources to DO them!!!!!

Clarity on which practicals are mandatory is necessary. Also serves as an easy to find reference when teachers need to check that they have completed all mandatory practicals.

We have to have some idea of those practicals that are likely to be examined. We should not have to be second-guessing specifications just like the JC.

We need a Mandatory List to convince the school principal that money needs to be spent on lab supplies and equipment to fulfil the requirements of the specification.

Vital since now we will be under such time pressure

There is a lot of new experiments on the draft for chemistry, teachers need clarity on how many and what experiments the students are required to carry out. It would also be useful for the teachers to aid in planning to manage time.

Fairness to all should be a priority. Everyone needs to know what to teach.

Need a clear concise list just like the old syllabus for a high stakes exam

It is very important that teachers and students are very clear in terms of what content and investigations needs to be covered. Why is there such resistance to this from the NCCA?

Much easier for teachers and students. Why leave vague details to such a high stakes curriculum.

All students should get the opportunity to explore the same basic mandatory lab practicals. This makes the learning more homogeneous around the country, and ensures validity and reliability of the final written assessment.

If a list of mandatory practical work is not produced, little value will be placed on the importance of practical work. Practical work was decimated in the Junior Cycle Science and students are now board with Science. There is no benefit for carrying out practical work in the JC examination and I feel as I am wasting students' time in doing so. We are much better off *in covering written material, discussions and research but at a cost to the student enjoyment and enthusiasm.*

There should be no fog of confusion about what laboratory practical work is required. The NCCA made a mess of Junior Cycle Science in terms of lack of practical work. The same cannot happen at Leaving Certificate level.

Physics

Ensures all students have completed the minimum number of practicals. Allows teachers to choose to add additional practicals where they feel it is needed.

This would provide a clear structure to base topics on. From experience with JC science students struggle when presented with an experiment that may not have been carried out in class.

The Leaving Cert is obviously very high stakes for students so they need to feel as prepared as possible. We, as their teachers, can only be sure that we are preparing them adequately if we know exactly what to cover.

Anything that can be assessed, must be present, in detail in the spec.

Will ensure that schools have the correct resources to carry these out, will ensure that the students carry these out and they are not just demonstrated by teachers or given secondary data.

From a planning perspective it's good to know the practicals that must be done.

As stated in chemistry if left to teachers to work through and decide which experiments to do and how can make it unfair on schools with more resources.

Mandatory experiments worked well in the current syllabus and ensured certain learning outcomes were achieved. It did not prevent other investigations and demonstrations being asked in other sections of the paper

It is not fair to ask about practical work that some schools may have done and others have not, all due to an unclear specification. It cannot be like the new JC Science specification, as questions have been asked on specific experiments that are not explicitly noted in the curriculum. They should pick some experiments that they feel help to enhance student understanding of the topic at hand and/or enhance understanding of the experience of practical/experimental work in general.

Experiments should be vehicles to deliver learning outcomes

A mandatory list will help us to get funding from our schools and will take the stress off teachers and pupils. Forget about asking us to "unpack" learning outcomes and figure out for ourselves what practical work should be carried out. We will no longer tolerate the nonsense of being asked to "unpack learning outcomes". This is the job of the NCCA subject development group to make it clear to us what mandatory practical work should be carried out.

Need to know what's required when ordering equipment.

Proper experiments properly done should be an integral part of a school physics syllabus. Short-comings in this have been noted as far back as 1898.

Certainty in purchasing of equipment, allocation of resources of class time and laboratory time

We need clarity on what exactly our students should be doing in terms of laboratory practical work. Without specifying a minimum list of laboratory practical work, there is a real danger that little or no laboratory practical work will be carried out and this will really damage the subjects of Physics, Chemistry and Biology at Leaving Certificate level.

It helped students organise their study and revision better without the stress of having a very wide area that 'might' appear as an experiment question

A mandatory list will help us to get funding from our schools and will take the stress off teachers and pupils. Forget about asking us to "unpack" learning outcomes and figure out for ourselves what practical work should be carried out.

7.7 Final comments from teachers

Questions 20, 30 and 40

Questions 20 (biology), 30 (chemistry) and 40 (physics) were sweeper questions inviting teachers to make any other comments.

Biology

A wide variety of responses were made by teachers along themes such as concerns with the second mode of assessment, additional stress on students teachers and teachers, damage to uptake of science subjects at Leaving Certificate, lessons to be learned from the research investigative work in Agricultural Science, lack of clarity in the learning outcomes, increased social inequality and the need for sample papers and other resources to be available before implementation of the new specification.

Concerns with the second mode of assessment

I hope they learn from the mess that is the new JC and not repeat the mistakes of the past. We have always felt the Irish education system was fair and transparent. The AAC and giving 40% for it is opening the door to widespread cheating.

Considering the real possibility of chaos resulting from the implementation of the AAC nationwide in multiple subjects, it would be wise to run a representative pilot for two years to see to what extent the AAC adds value to the courses, improves the quality of education and reduces the stress on students.

Stress on students and teachers

Just exhausted at the thoughts of all the work involved

I do worry that Leaving Cert students will have several projects/investigations to complete which will impact study time and make a busy time with orals etc. even more busy and stressful.

Incredibly disappointing, unrealistic with the lack of resources and lab technicians etc. Dumbing down what were incredible curricula. Adding to the mental health crisis with our young people and quite frankly the teacher shortages. No consultation with those actually on the ground carrying out the work daily. So many unanswered questions and we couldn't even be provided with what's entailed in the actual assessment task or written paper. Disgraceful and disheartening.

I would be very willing to help out in any way with the new Leaving Cert. Biology specification. I don't want to see what has happened to ag science or junior science also happen to a wonderful life subject like biology

Lower uptake of science subjects at Leaving Certificate level

The whole lot seems overloaded. It's a research experimental assessment on top of massive content for the paper. There will be a lower uptake of these subjects as there will be uncertainty until it's well established

Lessons from Agricultural Science

I'm sure I and the rest of the biology teachers would deeply appreciate our opinions to be taken onboard. We are the people delivering the syllabus and we know what is possible and impossible. Please let this consultation be genuine and not lip service as seems it was with regards ag science.

Lack of clarity

Two thirds of the learning outcomes are vague or unclear and need clarification.

There is the ambition like Junior cycle to under-pin this curriculum with Nature of Science with a view develop in our students the habit of Scientific habit of mind which is a nice ambition however just like the Junior cycle there is huge ambiguity time and time again in terms of what dept both teacher and student needs to go in terms of the teaching and learning of the key concepts on the Biology course. The 2 year course is currently very tight as you know in terms of getting it covered however there is a requirement to run essentially an extended CBA, the "Biology in Practice Investigation". This entails 20 hours of class time. And this investigation is to be corrected by the SEC. This makes up 40% of the overall grade. With little be cut off the current course (apart from 3 chapters) it's astounding this Investigation is to take up 11% (20 out of the 180 teaching hours) of class time. I am all on for running class practicals and there remains 13 practicals within the course however to request students to run an extended Investigation over 20 hours is not age appropriate and increases the pressure in terms of covering the curriculum in my view. The ISTA discussion was not a rant but solution based in terms of rewording 66% of the drafted Learning Outcomes for the purposes of clarity in terms of Teaching and Learning for both students and teachers.

New Depth of treatment column included to clarify subject matter. Confirmed list of mandatory experiments. More detail on Additional assessment component. Release sample papers+ MARKING SCHEMES. Grants are needed for new school equipment.

We need to have 100% clear learning outcomes so we can comprehensively prepare our students for their exam. My colleagues have discussed the awful possibility that one of students will leave the exam and say 'but we never covered that question in class'. Also we are not ready for Sept 2025, no inservices so far.

This Biology "specification" lacks depth of treatment . It must not be implemented as it is currently written . We need CLEAR statements & depth of treatment detail in order for us to do our job well. Please do not repeat the dreadful mistakes of the so called Junior Science "specification " . A specification is supposed to be clear with concise instructions & detail. The NCCA is failing teachers by not providing a clear unambiguous syllabus

Social Inequality

Coursework enhances social disadvantage. Impossible to ensure students' work is their own. I have a Biochemistry PhD and industry experience and would love to carry out a variety of *extended practical projects with my students. I would want assessment to be in form of a supervised exam where students answer questions or write a report under supervision in a given timeframe.*

Sample papers and marking schemes prior to introduction

I feel there is not enough time to cover all learning outcomes and complete an additional component. I would hope that the theory content can be reduced to allow adequate time complete the project. I would also hope that there will be sample exam papers and marking schemes available prior to September 2025 when it's being introduced. Teachers need to clear on what they are teaching, and to what level of detail.

Several sample papers should be issued by the sec before we commence the new curriculum, not at the last minute. The LC is such a high stakes exam for the students. As teachers we need direction as to exactly what they require.

Chemistry

A wide range of responses has been received about the revised chemistry specification. Some themes that emerge are, not implementing the three specifications in the one year, rewarding students for practical work and recognising this in the final exam, additional stress on students and teachers in sixth year with the additional assessment component in an already crowded specification, the amount of additional work needed to prepare students for Leaving Certificated chemistry after the implementation of the Junior Cert Science, the necessity of laboratory technicians, how the research project will discourage students from taking up Chemistry and will put a lot of extra work on the teacher, the need for additional resources and proper training,

The length of the specification.

Syllabus is far too long, loads added, little to nothing removed and expected to do a 40% project. No samples of projects/exam papers out yet. No in-service yet. This is a disgrace that we will be expected to teach and prepare students for the unknown in less than 2 years.

I feel there is too much content for the time available. I find it a challenge to finish the current syllabus without doing the units on atmosphere, industrial chem., or crystals/ metals. Now it appears all of this is to be included. I cannot see what if anything has been taken out to make room for this. On top of that we are expected to put 6 weeks aside for the practical investigation???!!!! How is this possible???? Also the timing of the investigation in second term of 6th year seems mad as students are under.

I feel that the new JC does not prepare students for the LC Chemistry course and that structure is required going forward.

There is way too much content in the draft syllabus. The content as currently laid out cannot be completed in the time allocated to any degree of satisfaction. And that is without an additional assessment to complete.

The course needs to be shorter to compensate for the project work, if anything it has become longer. it just will not be feasible to study chemistry.

While there has been many nice additions to the course there is too much content to be expected to go through and the increase in lab equipment is massive. When will we get more guidance on the investigation?

My biggest worry with the Chemistry specification is the amount of content. New content has been added (options), no content that I can see removed but it is worth less (60%) and needs *to be done in less time that we currently do it. I don't understand how this is expected to happen. Not fair to students.*

I believe the courses should have been trialled to identify what supports should be in place for students and teachers

Concerns with the second mode of assessment.

Students that work hard week by week are then rewarded on an ongoing basis for their efforts, can see the importance of paying attention to the practical work, spread the marks over the two years, and can use this resource when planning their AAC.

I really feel that little has been learned from the instigation of the new JC science programme. Other jurisdictions are now looking at a return to a more knowledge based curriculum again rather than a student-led brief that is now showing signs not working out.

I have a great concern regarding the additional burden that the project will place on students and teachers. I see from my Ag Science colleague who spends on average 40mins to 1 hour reading and making suggestions for improvements on each draft of student's projects and some student will need to submit up to 4 drafts. I am also concerned about uptake of science subjects at senior cycle as currently students in my school would often choose to study 2 or even 3 science subjects and with a weighty project in each, they will no longer do so, and inevitably it will be chemistry and physics numbers that will drop.

I have huge concerns over the availability of computers in our school to complete a project. There is little availability at present not to mind when there are at minimum 3 science subject teachers requiring access to the same. There simply is not enough to go around. I fear these projects will impact greatly on science teachers after school has finished to allow students access to computer rooms to complete project work.

Added teacher and student stress.

Too much stress on students in 6th year already. Additional assignment during second term is madness. The course is far too long to accommodate this assessment piece.

Lab technicians would also be essential.

I think adding research investigations into student's workload in sixth year will increase pressure on them and cause them a great deal more stress. It would be much more beneficial to assess them completing a practical experiment. I.e. give them credit for something they are already doing and should be recognised as part of their Leaving Certificate grade. Instead of putting extra work and stress on both students and teachers.

Lack of Clarity

Please remember that when the Junior Cycle came out there were at least three/four teachers who would be able to give their point of view on what exactly each learning outcome required. In most schools there is only one chemistry and one physics teacher if the learning outcomes remain vague then it is the teacher's interpretation which may be doing a disservice to the student on the final exam.

Please take into consideration the people who are charged with the job of teaching our students. They look to us for clarification and direction. If you decide to leave us without both then we will appear incompetent and unhelpful and their work and enthusiasm will suffer as a consequence. Please make our work easier not harder.

Physics

Other comments of the physics specification range from the removal of the trial, lack of depth of treatment, the vagueness of the practical assessment, the impact of introducing the three syllabuses in the one year, student and teacher stress and the introduction of the PiPi.

Clarity of the Learning Outcomes.

The syllabus lacks depth of treatment and the practical investigation is at best a vague idea that needs serious consideration to impact on students.

We are science teachers, we like clarity and preciseness

The full range of syllabus documentation (including guidelines for teachers, sample exam papers and marking schemes, etc.) should be officially published at the same time as the syllabus itself. The reference to numeracy (P8) needs to be reassessed considering that mathematics is interwoven through Physics more significantly than any other leaving Cert subject. A more substantial and considered statement on the part mathematics plays in Physics would be appropriate. Greater clarity be provided about the depth of treatment in each of the strands, in the final version of the specification.

Clarity of LO's is so important because the stakes at LC are so high. Teachers need to be absolutely sure that they have covered the course fully, especially if there is no choice on the paper

What a vague, muddled, awful set of specifications. Please listen to our feedback.

Unless there is a list of mandatory student practical work, teachers will be very confused as to what should be covered and hence the level of practical work will decline.

Stress

All 3 sciences should not be introduced in the same year. The is unfair on students and teachers.

Makes me feel like quitting. The prospect of a 40% project and the pressure this involves is the reason.

My colleagues who teach Agricultural Science have experienced huge stress and falling numbers of students who take Ag Science for Leaving Certificate. We cannot let the same happen for Physics, Chemistry and Biology.

The workload for teachers will be increased substantially while resources (equipment and facilities) remain the same.

Introduction of Physics in Practice Investigation.

Personally I think the new specification is really missing the mark if its purpose is to give students knowledge and skills that they will use after they leave school. I think the opportunity to encourage more girls into physics is being missed by the omission of astronomy. I think the 40% project will result in endless queries regarding original work and numerous appeals to the DOE.

I would like clarity on the assessment component-what does high, moderate, low level of achievement equate to in terms of marks. Also clarity around the written examination-duration, choice, etc.

Agricultural Science

One teacher gave a detailed account of the Agricultural Science research investigation.

As a teacher of Agricultural Science and Biology, I would like to share my experience of the Individual Investigative Study (IIS) carried out by students. Leaving Certificate Agricultural Science students must design and complete an IIS and write a report on the process, in response to a brief issued by the State Examinations Commission (SEC). Students are generally given the brief in Autumn of 5th year. The IIS is worth 100 marks or 25% of the student's overall grade. The IIS report must be submitted by sixth-year students by a deadline in April. While the theme of the IIS is different every year, the format for completing the IIS remains the same. The IIS report consists of 5 sections:

1. *Background Research and Introduction (and Referencing)*
2. *The Investigative Process*
3. *Results, Analysis and Conclusions*
4. *Reflection on the Study*
5. *Communication and Innovation*

The report must not exceed 2,500 words (excluding references, equations, diagrams, graphs, etc.) and must not include more than 20 images. It is currently not clear if the IIS will remain at 25% or increase to 40% of students overall grade similar to that of the other three science subjects.

The teaching of the IIS has overall been a mixed experience. The positives include students being able to implement the scientific method in Agricultural Science. The IIS facilitates study of particular areas in greater depth and which may be of local or regional agricultural significance and can increase interest for students. It enables students to see at a practical level how science underpins and supports agricultural practices, processes and research. The format of the IIS is relatively straightforward for students and the amount of time to complete the report is appropriate. Another positive is that the IIS project is student centred and allows students to explore specific areas in agriculture in which they have an interest.

However several issues for both teacher and student have arisen:

- *The IIS theme while generally broad does not allow for much variation due to a lack of equipment and/or chemicals in schools.*
- *It is worth noting that the first three thematic briefs were very similar.*
- *A lot of the work for Ag Science has to occur over the summer due to plants having to be grown in a lot of cases.*
- *It is difficult for students to 'unpack' or interpret the theme and this requires a lot of support from their teacher.*
- *The depth of referencing is of a university-level standard and is challenging for students.*
- *There are no marks allocated in the IIS for referencing.*
- *There are serious issues regarding generative AI possibly completing large portions of the IIS report. Teachers are unable to determine if generative AI has been used or not due to the increased sophistication of the software. Teachers, of course, encourage students to be honest with their report but there is a pressure from the student's parents and school management to ensure the student obtains the highest mark possible.*

- *Therefore, it is of my opinion that 25% is an appropriate percentage of a student's grade for the IIS report.*
- *The official CPD training provided for teachers was largely vague and inadequate. The local IASTA branches were very valuable for providing support.*

Thanks

Thank you so much for all your support and the work you are undertaking on this - it is so greatly appreciated!

Thanks for your excellent service to all at the ISTA

Thanks to the ISTA for their work

Thank you for allowing us to give our thoughts and feedback. It's greatly appreciated and thanks for all your hard work on this.

Thank you for all the work done so far, really appreciated

Thank you to ISTA for all your great work in representing the views of teachers. My colleagues who teach Agricultural Science have experienced huge stress and falling numbers of students who take Ag Science for Leaving Certificate. We cannot let the same happen for Physics, Chemistry and Biology.

I would just like to thank you again for all what you are doing.

We have a few very hard years ahead of us. Thank you for trying to make them see sense with this, for science teachers across the country & most importantly our students, who don't even know what's coming their way.

7.8 Summary and Conclusions

This chapter reported on data gathered from questionnaires completed by 320 teachers and from 648 teachers who attended online webinars to discuss the draft specifications.

Over 90% of teachers expressed dissatisfaction with the allocation of 40% to the research investigation component. The most popular choice was 20% with the next most popular option being 10% of marks for coursework.

When asked about the level of laboratory equipment / resources, only a small percentage (7%) described their laboratories as being very well equipped. Over 40% of laboratories were described as being either poorly equipped or very poorly equipped. The majority of teachers (82%) do not feel that they have sufficient resources to support the additional assessment aomponent Research Investigation.

The additional assessment component will impact on the availability of school laboratories and laboratory resources to other classes such as Junior Cycle and Transition Year, e.g. less practical work having to be carried out at Junior Cycle and Transition Year level, students having to be moved out of laboratories to facilitate Leaving Certificate project work, implications of teacher availability for students who wish to participate in BT Young Scientists' Exhibition and Scifest. The perceived rush to introduce the new specifications in schools in 2025 without schools being adequately equipped was also of concern to teachers.

Teachers identified that the proposed model of assessment of Leaving Certificate biology chemistry and physics additional assessment component" by means of a laboratory-based Investigation in sixth year as outlined in the draft specifications would have a number of effects

- Additional stress on teachers and students
- Adverse effect on uptake of Leaving Certificate Physics, Chemistry and Biology.
- Cheating associated with proposed model and alternative models to give credit to students for practical work should be considered.
- Widening of the social divide.
- Timing in sixth year and timescale of introduction were identified as problematic.
- Similar negative consequences as experienced in the Agricultural Science research projects.
- Importance of provision of laboratory technicians.
- Importance of making School Management aware of implications of research investigations in Physics, Chemistry and Biology.

Teachers identified major problems with the clarity of learning outcomes in the Physics, Chemistry and Biology draft specifications. These problem will greatly add to the stress on teachers and students working towards a high-stakes examination like the Leaving Certificate.

Some suggestions for topics which could be included in the draft specifications and excluded from the draft specifications were also made by teachers.

On average, almost 90% of teachers reported that they were unclear on what mandatory laboratory practicals should be carried out by students in school laboratories. An average of 96% of teachers was in favour of a list of mandatory student laboratory investigations being included in the final draft of the Physics, Chemistry and Biology specifications. Among the advantages of mandatory student practical work that emerged from the data were:

1. Mandatory investigations ensure that all students acquired basic key skills in laboratory practical work.
2. Once the basic laboratory skills were acquired, students are then in a position to carry out scientific investigations as required in the second mode of assessment.
3. The list of specified mandatory investigations on the current Leaving Certificate Physics, Chemistry and Biology syllabi help teachers to obtain funding from school principals.
4. Mandatory investigations were liked by students who enjoyed practical work as they were rewarded on the examination paper for carrying out these mandatory investigations.
5. Mandatory experiments allowed student to develop the skill of following a written set of instructions as is demanded in standard operating procedure of industries such as the biopharmachemical and electronics industries.
6. Mandatory experiments are good from a Health and Safety perspective as a risk assessment can be carried out easily for each experiment to be carried out by students.
7. Mandatory investigations assist with lab organisations and management as stock taking is made easier.
8. Mandatory investigation help to have a "level playing pitch" between schools with ample funding and schools with minimum funding.

In final comments made by teachers, issues highlighted were: of increased stress on students and teachers caused by the research investigations, potential for damage to uptake of science subjects at Leaving Certificate level, lack of clarity of learning outcomes, widening of social inequality and the need to have sample examination papers, marking schemes and other documentation available prior to any specification being implemented.

Chapter 8

Conclusions and Recommendations

8.1 Introduction

It is clear from the analysis of the Biology, Chemistry and Physics draft specifications that these drafts are in an unfinished state. Considerable work needs to be done in order to bring them up to the standard of international best practice in syllabus design. This chapter summarised the key conclusions from the data analysed in this and recommends what action is needed.

8.2 Summary of conclusions and recommendations

The main conclusions and recommendations are summarised in Table 8.2

No.	Conclusion	Recommendation
1	One of the main problems in the Leaving Certificate Physics, Chemistry and Biology Draft Specification is the lack of clarity in a significant percentage of learning outcomes in each specification - Physics (68.3%), Chemistry (31.5%) and Biology (66.7%).	Work needs to be initiated by the three NCCA Subject Development Groups to bring the draft specifications up to international standard. This work involves writing into the draft specifications the detail required in order to clarify the learning outcomes highlighted in this report.
2	There is a lack of clarity about the time required to implement the new specifications in Physics, Chemistry and Biology. The time allocated to teach each specification as described in this report involves a lot of estimations due to lack of clarity associated with many learning outcomes.	When the detail described in section 1 above is written into the draft specifications, an audit should be carried out by the practising teachers who serve on the NCCA Subject Development Groups to calculate the time needed to implement each learning outcome in the classroom to ensure that the total time is within the 160 hours of class contact time.
3.	There is a lack of clarity in the laboratory practical investigations that are mandatory in order to achieve the appropriate learning outcomes. Eight reasons for having clear lists of mandatory student investigations emerged from the data analysis (Chapter 7). The fact that 96% of teachers across Physics, Chemistry and Biology requested that clear lists of mandatory practical investigations be provided shows the strength of opinion on this matter.	Clear lists of mandatory student investigations need to be provided – as exist in the Leaving Certificate Physics, Chemistry and Biology syllabi being taught in our schools. These lists should be drawn up by the NCCA Subject Development groups and embedded into each of the three specifications. The lists provided by the ISTA Physics, Chemistry and Biology committees, based on their own teaching experience and feedback from colleagues, included in this report could be used as starting points for working towards the final lists.

4.	It is clear from the analysis of data in Chapter 7 that teachers require more information on assessment. The draft specifications have been published as "bare" documents without any information on how the learning outcomes will be assessed and no information on the structure or format of the examination papers or types of questions that will be given on the Leaving Certificate examination papers in Physics Chemistry and Biology. This is in direct conflict with international best practice where sample examination papers, Teacher Guidelines, sample marking schemes and details of student laboratory practical work are provided in addition to the detailed published syllabi. At the moment the implementation of new specifications is rather haphazard and takes a "make it up as we go along" approach. Teachers cannot effectively prepare and assess students for an examination whose structure they have no idea about until the specification has been largely taught in sixth year.	The ISTA supports the motion passed at the ASTI and TUI Annual Conferences in 2023 that *That the ASTI / TUI demand that, for all future Leaving Certificate syllabi (specifications), the Department of Education, the NCCA and SEC publish the full range of syllabus documentation concurrently and not less than 12 months prior to implementation of the syllabus. The syllabus documentation to include: a detailed syllabus which embeds depth of treatment and comprehensive teacher guidelines into the syllabus, sample examination papers, sample marking schemes, rationale and research-based evidence that underpin the changes to / for introduction of syllabi*
5.	As noted in Chapters 3, 4 and 5, the ISTA is concerned about the imbalance between Ordinary Level and Higher Level in some areas of the specifications. No detailed discussions have been held at NCCA Subject Development Groups about the balance between Higher Level and Ordinary Level topics in the Physics, Chemistry and Biology draft specifications.	To ensure the correct balance between Higher Level and Ordinary Level topics and also balance across teaching times, discussions need to be held at NCCA Subject Development group meetings as part of the review process and appropriate adjustments made in the specifications.
5.	Teachers will be under a lot of stress trying to cover the learning outcomes in the contextual strands of the Physics, Chemistry and Biology specifications without the added stress of having to make sense of the very broad and general learning outcomes in the Unifying Strand.	It is recommended that either the Unifying Strand be deleted from all three specifications or that a clear constructive alignment strategy be drawn up to link the very broad learning outcomes in the Unifying Strand to the appropriate learning outcomes in the contextual strands
6	Additional Assessment Component - Percentage Allocation of marks. It is clear from the data in Chapter 7 that the vast majority of teachers (91%) are unhappy with the allocation of 40% of the marks to the Additional Assessment Component (AAC).	The allocation of marks should be reduced to either 20% or 10%. This could be introduced provisionally for an initial number of years on a trial basis.

7	Additional Assessment Component - Resource Implications. It is clear from the data in Chapter 7 that the majority of schools are ill-equipped to facilitate a model whereby all Leaving Certificate students carrying out research investigations across Physics, Chemistry and Biology. The majority of teachers (82%) do not feel that they have sufficient resources to support the Research Investigations. The lack of access to resources / equipment, lack of lab availability and lack of laboratory technicians in non-fee-paying schools were all cited as major problems.	The proposed model of the Additional Assessment Component as outlined cannot be implemented without funding provided to ensure that all schools have access to the necessary laboratory resources / equipment, access to laboratories and access to technical support from laboratory technicians. If funding is not being provided, then alternative models as suggested in Chapter 7 should be considered, e.g. an oral examination and / or marks being allocated for evidence in students' laboratory notebooks of laboratory practical work being carried out by them.
8	Additional Assessment Component - Stress on Students and Teachers. Analysis of data in Chapter 7 highlighted the additional stress on students and teachers brought about by the implementation of this particular model involving a Research Investigation. Teachers predict that this will lead to adverse uptake of science subjects at Leaving Certificate and make the science teaching profession less attractive to science graduates. Some teachers mentioned that it would hasten their retirement from the science teaching profession.	Remove the stress on students and teachers by considering changing the model. Instead of students carrying out all the Research Investigations over a fixed period in sixth year, devise a model to give students credit for practical work carried out over two years.
9	Additional Assessment Component -Implications for cheating with aid of generative Artificial Intelligence. As highlighted in Chapter 7, the widespread availability of AI tools would make it impossible for teachers to detect cheating. Even if cheating is suspected, teachers expressed reluctance in the online questionnaire completed by them to make accusations against their students.	Modifications need to be made to the proposed model so that the use of Artificial Intelligence does not confer an advantage on students.
10	Additional Assessment Component - Increased Workload on Teachers. In Chapter 7 teachers highlighted the huge increase in their workload caused by the Additional Assessment Component. Teachers were deeply concerned about this.	Modify the model of assessment to give students credit for practical work by other means. Since many teachers teach more than one Leaving Certificate Science subject, consideration should be given to phasing in the three subjects over a number of years instead of introducing them all together in one year.

11	Additional Assessment Component – more clarity. In Chapter 7 teachers expressed frustration at the lack of clarity of the AAC in the draft specifications. Teachers referred to the problems encountered with the Agricultural Science Individual Investigative Study and feared that similar problems would be encountered in Physics, Chemistry and Biology.	Provide teachers with exemplar material including marking schemes to bring clarity to how the Additional Assessment Component will be assessed by the SEC.
12	As noted in Chapter 7, teachers are concerned about the quality of future CPD provision. Experience from Junior Cycle CPD where a lot of time was wasted on group discussions and teachers were told to "unpack" learning outcomes themselves caused great stress and dissatisfaction among teachers.	A new and more effective model of CPD provision needs to be drawn up and implemented by Oide. The model used by the Physical Sciences Initiative and the Biology Support Service which was used to provide CPD for the current Leaving Certificate Physics, Chemistry and Biology syllabi was very effective. Teachers had great confidence in this service, learned a lot about the subject and how to teach it at CPD events and had the ability to have questions about topics on the syllabus answered effectively

Table 8.2 Summary of conclusions and recommendations

The Physics, Chemistry and Biology subject development groups should be closely involved in implementing the above recommendations. Members of these subject development groups contribute invaluable expertise and experience, on a pro bono basis, to Irish education. They help to bridge the gap between theory and practice, between the ideal and the possible. Teachers, in particular, have an important role to play as they are at the chalk-face on a daily basis and bring knowledge of the on-the-ground constraints to the discussion. Third level and employer representatives help to ensure that the revised syllabi prepare students appropriately for further learning and for work. The partnership model has served Irish education well in the past and will hopefully continue to do so in the future.

Since science subjects are less culturally bound than some other subjects, resources developed for science teaching in one country are likely to be relevant and suitable for teachers and students in another country. Consideration should be given by the NCCA Subject Development groups to examining appropriate state-of-the art materials at international level and thus avoiding unnecessary and expensive duplication or "re-inventing the wheel".

It is the earnest wish of ISTA that the above recommendations be implemented in a collaborative and diligent way that is respectful of the views of teachers and of other stakeholders in the world of education. The ISTA looks forward to working in a spirit of cordial cooperation and partnership with the NCCA and all stakeholders represented on the NCCA Subject Development Groups. We hope that all science teachers will be treated with respect and that their opinions valued in this spirit of partnership.

Appendix 1

Analysis of Learning Outcomes in Leaving Certificate Physics Draft Specification

Note: This document covers all the physics learning outcomes. The generic learning outcomes in Strand 1 (which are common to Physics, Chemistry and Biology) are analysed in a separate document in collaboration with the ISTA Physics and Biology committees.

Other documents that should be read in conjunction with this document analysing each learning outcome are:

1. Spreadsheet of estimated time to ensure that students achieve each learning outcome in the specification.
2. Document discussing the breakdown of Higher Level / Ordinary Level learning outcomes.
3. List of Mandatory Student Investigations.
4. Document analysing the "Unifying Strand Learning Outcomes" (first strand that is common to Physics, Chemistry and Biology)

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome	Comment on material in corresponding "Students Learn About (SLA) column.
15	**Strand 1: Forces and Motion: Kinematics and Dynamics (FM)**				
15	1a. model motion of a particle in a straight line with justified assumptions		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome. We have no idea what the term 'justified assumptions' means.	Solve problems involving motion of a particle in a straight line using relevant equations of motion under constant velocity and constant acceleration,	Clear information given.
15	1b. measure constant and varying linear motion using primary data		Clear learning outcome	Measure velocity by experiment. Measure acceleration by experiment. (Mandatory Student Investigation)	Good information given here.

16	1c. derive the kinematic quations of motion		Clear learning outcome		Good information given here clarifying the equations of motion required.
16	1d. verify the law of addition of vectors using primary and secondary data in one and two dimensions		Clear learning outcome		Gives information relevant to vectors and scalars but gives no mention of how students will verify the laws as stated in the learning outcome
16	2a. model real-world situations using Newton's laws of motion		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome. Buoyancy is mentioned in the SLA column but Archimedes Principal is not on the course.	Apply Newton's laws of motion when applied to real-world situations	Clear information given on the list of forces to consider. Reference is made that students will learn about Newton's Second Law of Motion. However, it does not specify that students will study the other two Laws of Motion despite needing to learn how to apply them.
16	2b. verify Newton's 2nd law of Motion by analysing primary and secondary data		Clear learning outcome	Investigate Newton's Second Law by experiment. (Mandatory Student Experiment)	Good information given.
16	2c. model problems involving the motion of a particle under a constant resultant force		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome.	Solve problems involving the motion of a particle under a constant resultant force.	Since $F = ma$ is mentioned, we assume that all problems be solved will be based on Newton's Second Law.
16	2d. model pressure		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome.	Solve problems related to pressure due to solids resting on a surface and pressure within fluids.	Relevant formulae for solving problems are given in the SLA column.

16	2e. relate pressure, force and density of a fluid		Unclear as to how the students should demonstrate this relationship. Is it simply through mathematical relationships? Also, should mention be made here to upthrust and Archimedes principle? If the above learning outcome already includes pressure within fluids then there should be room for these principles here.	Investigate Archimedes' Principle by experiment. (Mandatory Student Experiment).	
16	2f. investigate the principle of conservation of momentum using primary and secondary data		Clear learning outcome.	Investigate the principle of conservation of momentum. (Mandatory Student Experiment).	Good information given here.
16	2g. verify using secondary data that collisions are governed by Newton's laws of motion		Learning outcome is clear though it is not clear why there is no mention of primary data here. Seems inconsistent with the other learning outcomes which include verification.		No additional information given here that is not in the learning outcome.
16	2h. model direct collisions in one and two dimensions		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome. Is it through the use of a mathematical model or through experiment that **this learning outcome** is to be achieved? Do students need to be taught the Cosine rule in fifth year?	Solve problems involving collinear and perpendicular collisions.	More information needs to be given in this column as no additional information that is not in the learning outcome.

16	3a. investigate the force needed to compress or stretch an object using primary and secondary data		The use of the term primary data is unnecessary and confusing. Since this learning outcome clearly involves an investigation to be carried out by the students themselves, of course the data collected will be their own data.	Investigate the force needed to compress or stretch an object. (Mandatory Student Investigation).	Work done is mentioned in this section prior to the learning outcome for work that appears later. This is confusing. There is lack of clarity in the SLA column for this learning outcome and there is overlap with the next learning outcome.
17	3b. verify Hooke's law for elastic objects using primary and secondary data		The use of the term primary data is unnecessary and confusing. Since this learning outcome clearly involves an investigation to be carried out by the students themselves, of course the data collected will be their own data.	Carry out an investigation to verify Hooke's Law for elastic objects. (Mandatory Student Investigation).	There is overlap between the previous learning outcome and this learning outcome and this needs to be clarified.
17	3c. model compressed and stretched objects		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome.	Solve problems involving compressed and stretched objects	
17	4a. define work done by a constant force		Clear learning outcome		Good clear list of equations to be used
17	4b. model authentic situations describing gravitational potential energy, elastic potential energy, work done and the rate of doing work		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome. Use of the word model again. The word "authentic" seems strange here. The phrase "real-world" seems more suitable.	Solve problems involving real world situations describing gravitational potential energy, elastic potential energy, work done and the rate of doing work.	Good clear list of equations to be used

21	4c. investigate the principle of conservation of energy using primary and secondary data		The use of the term primary data is unnecessary and confusing. Since this learning outcome clearly involves an investigation to be carried out by the students themselves, of course the data collected will be their own data. It is unclear exactly what practical work should be carried out; conservation of energy applies to so many situations. Should this be for an object dropped from a height? An elastic collision? A pendulum?	Investigate the principle of conservation of energy for an object moving from a height. (Mandatory Student Investigation).	No additional information given in the SLA column. More information is needed.
17	4d. apply the principle of conservation of energy to authentic situations		Clear learning outcome but again the use of the word authentic. Why not remain consistent and use the phrase ”real-world”?	Apply the principle of conservation of energy to real-world situations.	No additional information given that isn’t in the learning outcome.
17	5a. verify models to determine *g* using primary and secondary data		The use of the term primary data is unnecessary and confusing. Since this learning outcome clearly involves an investigation to be carried out by the students themselves, of course the data collected will be their own data. While the learning outcome does not specify the exact models the information is in the students learn about column.	Carry out investigations to measure ‘*g*’ using a simple pendulum and free fall apparatus. (Mandatory Student Investigations).	The three equations given in the SLA column are helpful. It should be clarified that the third equation involves calculation only.

17	5b. model the gravitational field strength at any point in a gravitational field, including at the surface of a planet	✗	The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome.	Calculate the gravitational field strength at any point in a gravitational field, including at the surface of a planet.	Information given in SLA column is helpful in identifying the equations to be used.
17	6a. explain centripetal force	✓	This is a clear learning outcome.		The appropriate equation given in the SLA column is helpful.
17.	6b. model the dynamics of an object moving in a circle with constant angular velocity.	✗	The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome Is it through the use of a mathematical model or through experiment? This learning outcome is the only mention of angular velocity, are students expected to know how to convert between linear and angular velocity?	Solve problems involving the dynamics of an object moving in a circle with constant angular velocity.	No mention of angular velocity despite learning outcome referencing it. No reference to equation relating angular velocity to linear velocity.
17	6c. verify Kepler's 3rd law using secondary data	✓	A clear learning outcome.		Equation clearly stated.
18	6d. model situations involving the orbits of planets and satellites in near Earth and geostationary orbits	✗	The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome. Is it through the use of a mathematical model or through virtual experiment model?	Solve problems involving the orbits of planets and satellites in near Earth and geostationary orbits.	Reference made to relevant equations to solve these problems.

18	**Strand 2: Wave Motion and Energy Transfer (WMET)**				
18	1a. model thermometric properties		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome. What thermometric properties? These should be listed in the “students will learn about” section.	Discuss the following thermometric properties: EMF of thermocouple. Resistance of wire. Resistance of thermocouple.	List thermometric properties.
18	1b. analyse the suitability of materials for use as thermometers using primary and secondary data		The use of the term primary data is unnecessary and confusing. Since this learning outcome clearly involves an investigation to be carried out by the students themselves, of course the data collected will be their own data.	Investigate the suitability of given materials for use as thermometers. (Mandatory Student Investigation).	More information needs to be provided in the SLA column on the range of materials to be used.
18	1c. determine specific heat capacity and specific latent heat using primary data		The use of the term primary data is unnecessary and confusing. Since this learning outcome clearly involves an investigation to be carried out by the students themselves, of course the data collected will be their own data.	Carry out an investigation to measure the specific heat capacity of a solid and a liquid. (Mandatory Student Investigations). Carry out an investigation to measure the specific latent heat of fusion of ice and the specific latent heat of vaporisation of steam. (Mandatory Student Investigations).	

19	1d. verify models describing the relationships between heat energy, latent heat and temperature change using secondary data	✗	This learning outcome is unclear as it should specify the use of mathematical equations. There is no need to mention secondary data since, of course students will be using secondary data in these calculations as there is no mention of a student investigation where students would collect the data.	Verify with the aid of mathematical equations the relationships between heat energy, latent heat and temperature change	Clarity needs to be given RE the equations given in the SLA column. There should be consistency between all equations given on those equations used the *Formulae and Tables* book.
19	1e. model authentic problems involving heat transfer, change of state and efficiency	✗	The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome. This learning outcome is very confusing as the information given in the SLA column does not clarify the types of problems to be solved. If 'problems' refer to mathematical problems, then the relevant equations should be given in the SLA column.	Discuss real-world examples of heat transfer, change of state, and how they need to be taken into account to improve the efficiency of a system.	Depth of treatment of each authentic problem is not clear "Authentic problems" would read better as "real-world problems/examples"
19	1f. explore the impact of insulation on energy consumption and sustainability using secondary sources	✗	The use of the verb 'explore' is confusing as it is difficult to deduce what students must be able to do in order to carry out this exploration.	Discuss the role of insulation on energy consumption and sustainability using secondary sources.	The SLA column should specify that calculations involving U-values should be carried out by students.
19	2a. model the transfer of energy by waves.	✗	The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome.	Discuss and carry out calculations in the area of the transfer of energy by waves.	The material in the SLA column is helpful.

19	3a. model wave behaviour in a variety of situations		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome. Vague and broad learning outcome. How many situations? Depth of treatment for each?	Discuss the behaviour of waves in situations involving reflection and refraction, interference, diffraction and polarisation. .	The limiting of the discussion to ray models is helpful to the teacher but is confusing when related to the learning outcome. Material needs to be moved to this part of the SLA column from a later learning outcome related to optics.
19	3b. verify models for refraction using primary and secondary data		The use of the term primary data is unnecessary and confusing. Since this learning outcome clearly involves an investigation to be carried out by the students themselves, of course the data collected will be their own data. Does 'model' here refer to mathematical equations?	Carry out an investigation to measure the refractive index of a glass block. (Mandatory Student Experiment) Solve problem related to refractive indices in materials.	Formulae are listed in "students learn about" column but it is not clear to which learning outcomes the formulae relate to. Some of these formulae are not listed in the *Formulae and Tables* booklet
19 to 20	3c. verify models describing the relationship between image and object distances and the focal length of converging lenses using primary and secondary data and diverging lenses using secondary data		The use of the term primary data is unnecessary and confusing. Since this learning outcome clearly involves an investigation to be carried out by the students themselves, of course the data collected will be their own data.	Investigate the relationship between image and object distances and the focal length of converging lenses. (Mandatory Student Investigation). Solve problems involving the relationship between object and image distances and the focal length of the converging and diverging lenses.	Formula given in "students learn about" column.

20	3d. explore the use of optics in a variety of applications using secondary sources		This is a very broad and vague learning outcome which gives no indication of applications to be considered in helping students to achieve this learning outcome.	Discuss the use of optics in following areas (i) The microscope (ii) The astronomical telescope.	The information in the SLA column is very wide ranging. Move SLA material on interference, diffraction and polarisation to the earlier learning outcome on wave motion as indicated above.
20	4a. categorise electromagnetic waves by their wavelength, frequency, ionising ability and everyday use		Clear learning outcome.		The information in the SLA column is helpful in giving the depth of treatment.
20	4b. examine primary and secondary evidence to support the wave nature of electromagnetic energy		Do the students have to collect their own data? If so this should be marked as a Mandatory Student Investigation.	Examine the diffraction pattern formed when monochromatic light is passed through Young's slits or a diffraction grating. (Mandatory Student Investigation).	
20	4c. demonstrate dispersion and explain the phenomenon		Clear learning outcome.		
20	4d. investigate solar irradiance and its impact on life on Earth using secondary sources		Since the formula for irradiance is give in the SLA column, we assume that calculations are required here.	Solve problems in the area of irradiance and discuss the impact of solar irradiance on life on Earth.	Formula for irradiance in this column.
20	5a. examine primary and secondary evidence to support the mechanical wave nature of sound		Do the students have to collect their own data? If so this should be marked as a Mandatory Student Investigation. If not this should be clear that this is a teacher demonstration.	Demonstrate the effect of removal of air on the ability of sound to travel through a vacuum. (Mandatory Student Investigation).	

20	5b. relate the pitch and loudness of sounds to their wave characteristics using primary and secondary data		This learning outcome is very unclear and our members are puzzled as to what students are expected to do to achieve this learning outcome.	Demonstrate the relationship between amplitude of a wave and its loudness and also the relationship between frequency and pitch. (Mandatory Student Investigation).	Suggestions for carrying out this experiment need to be provided in the SLA column.
20	5c. explore the use of ultrasound in technological and medical contexts using secondary sources		What must students be able to do in order to show that they have explored this topic? Since this is clearly not a mandatory student investigation the reference to secondary sources is unnecessary as these are the only sources that can be investigated.	Discuss the use of ultrasound in technological and medical contexts.	If more information is required beyond that of a discussion this additional information needs to be included in the SLA.
20	6a. analyse standing wave patterns using primary and secondary data		Do the students have to collect their own data? If so this should be marked as a Mandatory Student Investigation. If not this should be clear that this is a teacher demonstration.	Demonstrate standing wave patterns using strings. (Teacher Demonstration).	More information needs to be supplied to clarify this learning outcome.
20	6b. model the relationship between harmonics and the standing wave pattern		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome.	Solve problems involving the relationship between harmonics on a string and standing wave patterns.	The appropriate equations should be given in the SLA column.
20	6c. verify the relationship between the length of a string and the frequency of a standing wave using primary and secondary data		The use of the term primary data is unnecessary and confusing. Since this learning outcome clearly involves an investigation to be carried out by the students themselves, of course the data collected will be their own data.	Investigate the variation of the fundamental frequency of a stretched string with length. (Mandatory Student Investigation).	

20 to 21	6d. model standing waves on a stretched string		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome. This learning outcome overlaps with learning outcomes 6a-6d.	Demonstrate standing waves on a stretched string.	A number of these learning outcome need to be merged to avoid in order to avoid overlap.
21	**6e. analyse diffraction using primary and secondary data**		The use of the term primary data is unnecessary and confusing. Since this learning outcome clearly involves an investigation to be carried out by the students themselves, of course the data collected will be their own data.	Examine the diffraction pattern formed when monochromatic light is passed through Young's slits or a diffraction grating. (Mandatory Student Investigation).	Note the overlap between this learning outcome and learning outcome 4b and 6g
21	**6f. model two source interference**		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome. This overlaps with several other learning outcomes.	Explain how interference and diffraction occur.	The overlap between several learning outcomes needs to be addressed.

21	**6g. analyse two source interference using primary and secondary data**		The use of the term primary data is unnecessary and confusing. Since this learning outcome clearly involves an investigation to be carried out by the students themselves, of course the data collected will be their own data. Note the overlap between this learning outcome and the next one.	Carry out an investigation to measure the wavelength of monochromatic light. (Mandatory student Investigation).	
21	**6h. determine the wavelength of light from primary data**		The use of the term primary data is unnecessary and confusing. Since this learning outcome clearly involves an investigation to be carried out by the students themselves, of course the data collected will be their own data. These two learning outcome can be merged into one mandatory student investigation.		
21	7a. investigate the Doppler effect using secondary data.		The term secondary data is unnecessary since, of course teachers will be supplying data to their students in the classroom and for homework.		Supplying the Doppler Effect formula in the SLA column is helpful.
21	7b. model authentic situations involving the relative motion between the source of a wave and the observer		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome. We assume this learning outcome does not involve students solving problems as specified in the previous learning outcome; Therefore a simple discussion should be all that is required.	Discuss real world examples of the Doppler Effect being observed and applied.	
21	7c. Explore the Doppler effect in a variety of applications using secondary sources		This learning outcome has been covered in the previous learning outcome hence it can be deleted.		

21	7d. model real-life situations involving resonance		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome.	Explain the concept of resonance and discus its applications in real world situations.	
21	7e. relate a driving frequency to the natural frequency of an oscillating system, the amplitude of motion and the transfer of energy within the system		Clear learning outcome.		
22	**Strand 3: Electric and Magnetic Fields and their Interactions (EMF)**				
23	1a. demonstrate forces i. between charged objects ii. between charged and neutral objects		Clear learning outcome.		
23	1b. classify materials as conductors or insulators		Clear learning outcome.		
23	1c. model the behaviour of insulators and conductors.		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome.	Describe the properties of insulators and conductors in terms of their ability to conduct an electric charge.	Since no calculations are required at this stage we assume no calculations are required.

23	1d. model static electrical phenomena		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome.	Describe charge distribution on different shaped conductors. Explain how point discharge occurs	More information needs to be provided in the SLA column about what is required.
23.	2a. model the electric force between point charges		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome.	Discuss and analyse the electric force between point charges. Solve problems involving two point charges using Coulomb’s Law.	The information re. Coulombs law in EMF2 should be brought up to the SLA section in EMF1.
23	2b. discuss the electric field as a model for the non-contact interaction between charged objects		Clear learning outcome.		
23	2c. define electric field strength at a point		Clear learning outcome.		
23	2d. use field lines to represent the relative strength and direction of electric fields around charged objects		Clear learning outcome.		

23	3a. model • the relationship between work, charge and potential difference the relationship between current and charge • the relationship between electric current, conventional current, power and resistance • series and parallel circuits • the rate of conversion of electrical energy in components of electric circuits • fuses and circuit breakers		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome.	Perform calculations relating the variables as listed in the SLA column. Explain the function and mode of operation of fuses and circuit breakers in electrical circuits.	Calculations involve • the relationship between work, charge and potential difference • the relationship between current and charge • the relationship between electric current, conventional current, power and resistance • series and parallel circuits • the rate of conversion of electrical energy in components of electric circuits All formulae required for this learning outcome should be listed in the same format as they appear in the *Formulae and tables booklet*.
24	3b. use primary and secondary data to verify the relationship between current flowing through and the voltage across an ohmic conductor		The use of the term primary data is unnecessary and confusing. Since this learning outcome clearly involves an investigation to be carried out by the students themselves, of course the data collected will be their own data. There is no need to include reference to secondary data as this is covered in the next learning outcome.	Carry out an investigation to verify the relationship between current flowing through and the voltage across an ohmic conductor. (Mandatory Student Investigation).	We note that resistivity is mentioned in the SLA column but is not mentioned in any of the learning outcomes.
24	3c. determine the resistance of ohmic and non-ohmic conductors		It is not clear if this learning outcome involves the determination of resistance by experiment or by calculations. We recommend it be done by calculation since the investigation to determine resistance is covered in the previous experiment.	Perform calculations using Ohm's law.	

24	3d. investigate the effect of temperature on the resistance of a conductor using primary and secondary data	✗	The use of the term primary data is unnecessary and confusing. Since this learning outcome clearly involves an investigation to be carried out by the students themselves, of course the data collected will be their own data.	Investigate the variation of the resistance of a metallic conductor with temperature. (Mandatory Students Investigation)	
24	3e. model resistances in electrical circuits	✗	The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome.	Discuss series and parallel circuits and carry out calculations involving these two types of circuits.	Since there is no learning outcome involving Kirchhoff's Laws we recommend that it be deleted from the SLA column. This learning outcome overlaps with learning outcome 3a.
24	4a. explore the use of p-n junctions in real-world applications	✓	Again, use of "real-world applications" works here rather than "authentic" in previous learning outcomes.		The material in the SLA column is helpful in indicating the depth of treatment.
24	4b. model an n-p-n transistor	✗	The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome.	Explain how an n-p-n transistor works and discuss their real-world applications.	In what configuration does the student have to model the transistor? In common emitter configuration only or in other configurations? As a switch? As a voltage inverter? As an amplifier?

24	5a. model the relative strength and direction of magnetic fields around • a single permanent magnet and permanent magnets in close proximity • current carrying wire • current carrying solenoid with and without ferrous core		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome.	Describe and represent diagrammatically magnetic fields in a number of different situation. Perform calculations on the force exerted on the magnetic field generated by a moving charge.	The situations to be considered are: • a single permanent magnet and permanent magnets in close proximity • current carrying wire • current carrying solenoid with and without ferrous core.
25	5b. explore the use of permanent and temporary magnets in authentic situations		Explore is a vague term as it is not clear what students must be able to do to demonstrate that they have carried out this exploration.	Discuss the use of permanent and temporary magnets in real-world situations	
25	6a. investigate the relationship between the magnetic field and the electromagnetic force on a current-carrying wire		Clear learning outcome.		The information given in the SLA column is very helpful in indicating the depth of treatment required.
25	6b. model the motor effect		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome.	Explain the principles behind the operation of a motor. Perform calculations on the force on a current carrying conductor in a magnetic field.	The information given in the SLA column is very helpful in indicating the depth of treatment required. Inclusion $F = BIL$ is helpful.

28	6a. model nuclear fission, nuclear fusion and particle–antiparticle interactions		The problem with using model as a verb is covered in an Appendix to this submission. This learning outcome is unclear as it gives no indication as to what students need to be able to do to show they have achieved this learning outcome.	Explain and discuss nuclear fission, nuclear fusion and particle-antiparticle interactions.	In the SLA column reference should be made to the nuclear reactors and nuclear bombs. Calculations involving mass defect only.
28	6b. evaluate evidence about issues related to nuclear fission and fusion in electrical generation using secondary sources		It is not clear what evidence students would have to evaluate in order to achieve this learning outcome.	Compare and contrast nuclear fission and nuclear fusion.	More information needs to be included in the SLA column, e.g. global warming, fuel, waste products,

Appendix 2

Analysis of Learning Outcomes in Leaving Certificate Chemistry Draft Specification

Note: This document covers all the chemistry learning outcomes. The generic learning outcomes in Strand 1 (which are common to Physics, Chemistry and Biology) are analysed in Chapter 6 in collaboration with the ISTA Physics and Biology committees.

Other documents that should be read in conjunction with this document analysing each learning outcome are:

1. Spreadsheet of estimated time required to ensure that students achieve each learning outcome in the specification (section 4.3).
2. Document discussing the breakdown of Higher Level / Ordinary Level learning outcomes (section 4.4).
3. List of Mandatory Student Investigations (section 4.5)
4. As noted above, Chapter 6 analyses the "Unifying Strand Learning Outcomes" (the strand that is common to Physics, Chemistry and Biology)

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome	Comment on material in corresponding "Students Learn About (SLA) column.
19	a. Investigate experimental evidence for the Kinetic Theory of Matter EI		It is not clear what laboratory practical work must be carried out by students in order to achieve this learning outcome.	Investigate experimental evidence for the Kinetic Theory of Matter by observing pollen grains in water or smoke particles in air using a microscope. (Mandatory Student Investigation)	"assumptions and limitations of the model" should read "assumptions and limitations of the kinetic theory of gases model". Reference to the work of the botanist Robert Brown who lived in Ireland for a time and Brownian motion would help to make this topic interesting.

19	b. Analyse the Kinetic Theory of Matter to: • explain the nature and behaviour of matter at the particulate level • model how matter changes state		The problem with using "model" as a verb is covered in an Appendix to this submission. The statement "model how matter changes state" is unclear as it gives no indication what students must be able to do to show that they have achieved this learning outcome.	Draw and interpret models that show what happens to particles (atoms, molecules or ions) as matter changes state.	
19	c. Justify the use of different separation techniques for isolating one or more components of a mixture and conduct experiments using appropriate techniques [EI]		Are students expected to carry out laboratory practical work using all 10 techniques listed in the "students learn about" column? – or simply recognise when it is appropriate to use a particular technique,	This learning outcome should be modified and not indicated by "EI" but rather indicate that students should have an overview of these techniques and only carry them out in lab practicals as they arise when the curriculum content is taught over two years. Including practical work involving all ten techniques in one learning outcome will result in information overload for students and is very poor pedagogical practice. We propose that the LO be reworded as follows: c. Justify the use of different separation techniques for isolating one or more components of a mixture.	Accompanying material should be modified to indicate the overview and point out to teachers that the practical work can be covered as it arises throughout the teaching of the syllabus.
19	d. Distinguish between physical change and chemical change of matter		A clear learning outcome.		

19	e. Verify, using primary data, the law of conservation of mass and explain through the use of models [EI]	✗	The use of the term “primary data” is unnecessary and confusing. Since this is marked as an investigation to be carried out by the students themselves, of course the data collected will be their own data. It is not clear what difference there is (if any) between this laboratory investigation and that already carried out at Junior Cycle.	Carry out an investigation to verify the law of conservation of mass. (Mandatory Student Investigation) Explain your results by drawing and interpreting models of the reactions involved.	Reference to the work of Antoine Lavoisier should be included to help interest the students in this topic. Reference should also be made to the importance of a closed system where gases are generated.
20	a. Outline the development of current atomic theory, including main contributions and refinements by key scientists	✓	A clear learning outcome.		Although this is a broad learning outcome, clarity is brought to it by indicating the depth of treatment (the work of Thomson, Rutherford and Bohr) in the *Students Learn About* column.
20	b. Evaluate previous models of the atom against the current model, **stating the assumptions and limitations in each case**	✓	A clear learning outcome.		Although this is a broad learning outcome, clarity is brought to it by indicating the depth of treatment (the work of De Broglie, Heisenberg, Schrodinger and Chadwick) in the *Students Learn About* column.
20	c. describe the atom using the current model of atomic theory, including subatomic particles	✓	A clear learning outcome.	We propose a slight change in the wording: Describe the **structure of** the atom using the current model of atomic theory, including subatomic particles.	The material in the *Students Learn About* column is very helpful as it lists key terms for which students need to know definitions: atomic number, mass number, relative atomic mass and isotopes.
20	d. **Describe and explain the origin of lines on the atomic emission spectrum of hydrogen**	✓	A clear learning outcome.		In the material in the *Students Learn About* column we propose that $E_m - E_n = hf$ be written as $E_2 - E_1 = hf$ to avoid confusion with the old system of letters to label orbits.

20	e. Identify an element using appropriate primary and secondary data		This learning outcome is unclear. What must students be able to do in order to achieve this learning outcome?	We propose that this learning outcome be split into two separate learning outcomes as follows: 1. Identify the presence of certain metals in compounds using flame tests. [EI] (Mandatory Student Investigation) 2. Identify certain metals from an examination of their emission line spectra.	The information in the *Students Learn About* column is helpful as it specifies the salts of Na, K, Cu, Li, Ba and Sr.
20	f. Describe the electronic structure of elements and associated ions, identifying stable electronic configurations		A clear learning outcome.		Although this is a broad learning outcome, clarity is brought to it by indicating the depth of treatment (number of elements for HL and OL, specifying the types of sublevels as well as specifying the shapes of s and p orbitals) in the *Students Learn About* column.
20	g. Compare chemical and nuclear reactions		A clear learning outcome.		
20	h. Distinguish different forms of radiation		~ A clear learning outcome.		Reference should be made to the work of Marie Curie and Becquerel. Although this is a broad learning outcome, clarity is brought to it by indicating the depth of treatment (types of radiation, properties of radiation and half-life) in the *Students Learn About* column.
21	a. Describe the development of the modern periodic table		A clear learning outcome.		Although this is a broad learning outcome, clarity is brought to it by indicating the depth of treatment (the contribution of Mendeleev and Moseley) in the *Students Learn About* column.

21	b. Identify specific groups of elements and describe physical and chemical properties of elements within each of these groups		This learning outcome is unclear. What must students be able to do in order to achieve this learning outcome?	We propose that this learning outcome be rewritten as follows: Discuss the physical and chemical properties of groups 1, 2, 17 and 18 in the Periodic Table.	The information in the *Students Learn About* column is not very helpful as it gives no information about what physical and chemical properties should be studied for each of the four groups listed. We propose the following be inserted in the *Students Learn About* column: Physical properties to be discussed: state, density, electrical conductivity, melting points and boiling points. Chemical properties (including the Octet Rule) to be discussed: Reaction with air, reaction with water.
21	c. Examine and explain the arrangement of elements in groups, periods and blocks in the periodic table of elements		A clear learning outcome.		
21	d. **Distinguish between d-block elements and transition elements**		A clear learning outcome.		
21	e. Examine trends and relationships in the periodic table		This learning outcome is unclear. What must students be able to do in order to achieve this learning outcome?	We propose that this learning outcome be rewritten as follows: Discuss and evaluate the trends of atomic radius, ionisation energy and electronegativity in the periodic table.	We propose the following be inserted in the *Students Learn About* column: Discussion and definitions of atomic radius (covalent radius), first ionisation energy, second ionisation energy and electronegativity to be covered.

21	f. **Explain trends in first ionisation energies, including exceptions, and in successive ionisation energies and atomic radii**		This learning outcome overlaps with the previous learning outcome.	We propose it be rewritten as: Explain and evaluate exceptions to the general trend of ionisation energy across a period.	The information in the *Students Learn About* column is not very helpful as the information is presented in a jumbled fashion which does not follow the order of the learning outcomes and repeats the topics of atomic number and relative atomic mass already covered in previous learning outcomes. We propose the following be inserted: Exceptions to general trend of ionisation energy across a period and additional evidence for existence of energy levels to be discussed and evaluated.
21	a. Define and explain the mole in terms of the Avogadro constant, and relate the mole to how the amount of a substance can be quantified		A clear learning outcome.		
22	b. Solve problems involving relative atomic mass and percentage abundance		It is not clear what "percentage abundance" refers to.	We propose the following wording: Solve problems involving relative atomic mass, percentage abundance of each isotope in an element and percentage composition of elements in a compound.	.
22	c. State Avogadro's law and deduce the molar volume of a gas		A clear learning outcome.		Since density is mention in the *Students Learn About* column for the previous learning outcome we propose that the following be inserted for this learning outcome: Calculations involving density, volume and relative molecular mass of gases.

22	d. **Conduct an experiment to determine the relative molecular mass of a gas**		A clear learning outcome.	Since cylinders of gases are not normally available in school science laboratories, we propose that the word “gas” be changed to a “volatile liquid”. Also, the term “EI” should be inserted to indicate that this is a Mandatory Student Investigation.	
22.	e. Model a range of solution concentrations and use knowledge to prepare solutions, including primary standard solutions		The problem with using “model” as a verb is covered in the introductory notes to this submission. The statement “model a range of solution concentration” is unclear as it gives no indication what students must be able to do to show that they have achieved this learning outcome.	We propose this learning outcome be rewritten as follows: Explain the concept of concentration of a solution and outline how to prepare a range of solutions of different concentrations including primary standard solutions.	
22	f. Convert between units of concentration		A clear learning outcome.		Although this is a broad learning outcome, clarity is brought to it by indicating the depth of treatment (g/L, mol/L, %w/v, %v/v and ppm) in the *Students Learn About* column.
22	g. Use the concept of a mole to: • determine empirical and molecular formulae • balance equations for reactions where reactants and products are specified • analyse and solve quantitative problems based on balanced Equations		A clear learning outcome.	The wording of the learning outcome is fine but some editing is required in the *Students Learn About* column.	The term “simple unit analysis” is used in the *Students Learn About* column. We propose that this term either be removed or clarified as there are already ample examples of types of problems in the *Students Learn About* column on which our students can be tested: *The concept of a mole as applicable to stoichiometry and to the analysis of quantitative problems, including: gravimetric analysis, percentage composition, theoretical and actual yields, percentage yields, volume of gases, exact stoichiometric amounts, limiting reagents and reagents in excess.*

23	a. Describe and compare different types of chemical bonding		It is not clear from the learning outcome or the information SLA column what types of bonding on the continuum should be studied.	We propose that this learning outcome be rewritten as follows: Describe and compare ionic, polar covalent and pure covalent bonding.	We propose that the information in the SLA column be modified to read: These three types of bonding should be studied as part of a bonding continuum indicating relative strengths of bonds.
23	b. Predict the nature of chemical bonds between atoms, using trends in electro-negativity values		A clear learning outcome.		Reference should be made to the work of Linus Pauling on chemical bonding to add interest to what can be a boring topic for students.
24	c. Model different types of bonding to predict chemical formulae and **outline the limitations in predicting bonding between atoms**		The problem with using “model” as a verb is covered in the introductory notes to this submission. The statement “model different types of bonding” is unclear as it gives no indication what students must be able to do to show that they have achieved this learning outcome.	We propose this learning outcome be rewritten as follows: Represent different types of bonding in diagrammatic form to represent bonds and hence predict chemical formulae. We propose reference to the limitation in predicting bonding between atoms be deleted be deleted as this is a very complex area (especially for relatively large molecules). If only a simple treatment is required for specific molecules, then this needs to be clarified.	The information given in the SLA column is very good as it clarifies the depth of treatment by referring to the use of Lewis diagrams, sigma bonding, pi bonding and delocalised bonding.
24	d. Relate the properties of simple compounds to the nature of bonding present		A clear learning outcome.		Although this is a broad learning outcome, clarity is brought to it by indicating the depth of treatment (electrical conductivity, thermal conductivity, melting and boiling points, solubility in water and state of matter) in the *Students Learn About* column.

24	e. **Compare the nature of metallic bonding with the nature of bonding along the continuum, accounting for differences and similarities in properties**		A clear learning outcome.		The material in the SLA column is very helpful in guiding teachers on the key points to be covered.
24	f. Investigate, using primary data, the presence of ions in salts and in solutions, and identify an anion and cation in an unknown salt EI		There appears to be overlap between this LO and that of p.20e learning outcome. The use of the term “primary data” is unnecessary and confusing. Since this is marked as an investigation to be carried out by the students themselves, of course the data collected will be their own data.	Since flame tests for cations have already been carried out by students in achieving learning outcome 20e, we propose this learning outcome be reworded as follows: Carry out an investigation to test for a range of anions in aqueous solution and identify an anion and cation in an unknown salt. EI	The information in the SLA column is helpful in clarifying the depth of treatment as it lists the anions (chlorides, nitrates, phosphates, sulfates, sulfites, carbonates and hydrogencarbonates) to be included in this student investigation.
24	g. Compare the properties and structures of allotropes of carbon		A clear learning outcome.		Although this is a broad learning outcome, clarity is brought to it by indicating the depth of treatment (diamond, graphite, graphene and fullerenes) in the *Students Learn About* column.
24	h. Discuss the use of carbon allotropes in society		A clear learning outcome.	We propose that this learning outcomes and the previous one could be combined into one learning outcome: Compare the properties and structures of allotropes of carbon and discuss their uses in society.	This area is an ideal opportunity to add interest to the topic of chemical bonding (found to be dull and difficult by many students) and also to highlight modern scientific discoveries. Reference should be made to the discovery of graphene by Geim and Novoselov, and the Nobel Prize in Physics awarded to them in 2010. Reference should be made to the discovery of buckminsterfullerene by Kroto, Smalley and Curl and their award of the Nobel Prize in Chemistry in 1996.
25	a. Distinguish between intramolecular bonding and a range of intermolecular forces		A clear learning outcome.		Although this is a broad learning outcome, clarity is brought to it by indicating the depth of treatment (London dispersion forces, permanent dipole-dipole and ion-dipole forces) in the *Students Learn About* column. It is also helpful that it is clarified that dipole moments are not required.

25	b. Relate observed physical properties for a range of compounds to the type of intermolecular forces, **accounting for trends**		It is not clear what students must be able to do in order to achieve this very broad learning outcome.	We propose that the learning outcome be reworded as follows: Investigate the effect of hydrogen bonding on the rate of evaporation of some organic compounds and analyse the resulting trends. [EI]	We propose that the information in the SLA column be edited as follows: How the nature of intermolecular forces such as Hydrogen bonding can influence physical properties such as boiling points. Additional evidence for trends in boiling points can be obtained by studying appropriate secondary data. (The range of compounds includes water and appropriate inorganic and organic compounds).
25	c. **Explain qualitatively the influence of polarity, and symmetry, on intermolecular forces**		A clear learning outcome.		The information provided in the SLA column is very helpful as it clarifies that symmetry can give rise to non-polar compounds even in the case where individual polar bonds exist within the molecule.
25	d. Use the shapes of molecules of simple compounds to predict physical properties		As the physical properties have not been given in the SLA column, it is not clear what students must be able to do in order to achieve this learning outcome.		We propose that the physical properties to be studied should be boiling point, melting point and solubility.
25	e. **Use VSEPR theory to predict and model the shapes of molecules**		A clear learning outcome.	We propose that the wording of the learning outcome could be improved further as follows: Use the VSEPR theory to predict the shapes and construct models of molecules	The information provided in the SLA column is very helpful as it clarifies molecules of the form AB_n for up to four pairs of electrons around a central atom, single bonds only.
25	f. Distinguish between the structures of amorphous and crystalline solids		A clear learning outcome.		The work of William and Laurence Bragg, Dorothy Hodgkin and Kathleen Lonsdale should be highlighted in the *Students Learn About* column.

26	g. Model ionic, molecular, **metallic** and covalent crystalline structures and relate the structure to the physical properties	✓	A clear learning outcome.	We propose that the wording of the learning outcome could be improved further as follows: Build and analyse models of ionic, molecular, metallic and covalent crystalline structures and relate the structure of each type to its physical properties.	We propose that iodine be added to the list of crystalline solids as it is a good example of a molecular crystal and one with which students are familiar in the school laboratory. We propose that the physical properties to be studied should be melting point, hardness, electrical conductivity and solubility.
26	a. Outline the development of the gas laws and **the ideal gas equation**	✓	A clear learning outcome.		Although this is a broad learning outcome, clarity is brought to it by indicating the depth of treatment (Boyles Law, Charles Law, Gay-Lussac's Law and Avogadro's Law) in the *Students Learn About* column.
26	b. Explain what is meant by the ideal gas, **accounting for deviations of real gases from ideal gas behaviour**	✓	A clear learning outcome.		The information in the *Students Learn About* column the fact that van der Waal's equation is not required is very helpful. .
26	c. Solve and interpret quantitative problems using the gas laws	✓	A clear learning outcome.		In the *Students Learn About* column we propose that the heading "Modelling" be removed as modelling cannot be interpreted as meaning to solve quantitative problems using the gas laws. We also propose "how to verify and use the gas laws" in the SLA column be changed to "How to use the gas laws to solve problems involving gases". Otherwise, teachers may interpret this as having to verify all the gas laws by experiment and this would be very time consuming.
26	a. Outline the main sources of hydrocarbons and their uses in industry and society	✓	A clear learning outcome.		The information in the *Students Learn About* column is very helpful as it provides the depth of treatment listing the main sources (fossil fuels, living matter and synthesis) to be covered.

26	b. Identify and research one major impact on society of the extensive use of hydrocarbons. RI	✓	A clear learning outcome.	We note that this learning outcome is marked as a research-based investigation (as describe on p. 14 of the draft specification)	Although the learning outcome is clear, information needs to be provided on what exactly students must do to achieve the learning outcome. For example, would a homework assignment be sufficient? This information is needed to calculate the time required to teach the entire syllabus.
27	c. Prepare ethene, observe its physical properties, and investigate some of its chemical properties EI	✓	A clear learning outcome.		The information in the *Students Learn About* column is very helpful as it gives the required depth of treatment since it lists the tests to be carried out (combustion, tests for unsaturation using bromine water and acidified $KMnO_4$).
27	d. Describe and compare different groups of hydrocarbons, including composition, bonding and structure, and relate these to their characteristic properties	✓	A clear learning outcome.		The information in the *Students Learn About* column is very helpful as it gives the required depth of treatment
27	e. Explain and predict differences in properties of: • straight chain alkanes of different carbon number • alkanes of the same carbon number • mono-unsaturated straight chain alkenes	✗	As the properties have not been given in the SLA column, it is not clear what students must be able to do in order to achieve this learning outcome.	Describe and explain differences in physical properties of straight chain alkanes and monounsaturated straight chain alkenes. Delete second bullet point. (d) and (e) could be combined.	Physical properties [physical state, solubility (qualitative only) in water and in non-polar solvents]. Structures, but not isomers, of hexane, heptane, octane, cyclohexane and 2,2,4-trimethylpentane (iso-octane) to be considered. Systematic names, structural formulas and structural isomers of alkenes to C-4.
27	f. Explain the relative chemical stability of alkanes	✓	A clear learning outcome.		

27	g. Construct and examine 3 dimensional models of hydrocarbon molecules and explain how bonding and isomers influence the spatial arrangement of atoms for these molecules	✔	A clear learning outcome.		
27	h. Explain and compare the shapes of ethane, ethene, ethyne **and benzene molecules in terms of sigma and pi bonds, including delocalised pi bonding**	✔	A clear learning outcome.		The information in the *Students Learn About* column is very helpful as it gives the depth of treatment in terms of condensed and expanded molecular formulae.
27	i. **Distinguish between structural and geometrical isomerism, including how isomerism gives rise to different properties**	✔	A clear learning outcome.		The information in the *Students Learn About* column is very helpful as it gives the depth of treatment in terms of structural isomers for alkanes and alkenes up to C6 and cis-trans geometric isomers in butane.
29	a. define bond enthalpy and explain enthalpy changes in a reaction in terms of making and breaking bonds	✔	A clear learning outcome.		
29	b. Explain, and model diagrammatically, processes of energy transfer using exothermic and endothermic reactions	✘	It is not clear what students must be able to do in order to achieve this learning outcome.	We propose that this learning outcome be reworded as follows: Explain with the aid of simple energy diagrams the concepts of exothermic and endothermic reactions.	The information given in the *Students Learn About* column is helpful. We propose the following sentence be added: Enthalpy changes are quoted relative to a standard set of conditions of temperature and pressure.

29	c. Investigate, using primary data, how to determine ΔH for a suitable neutralisation reaction. [EI]	✗	As this learning outcome is clearly marked as a student laboratory investigation, the use of the term “primary data” is unnecessary and confusing since the data collected by students is primary data.	We propose that this learning outcome be reworded as follows: Carry out a laboratory investigation to determine the enthalpy of neutralisation of a suitable strong acid – strong base reaction and discuss your result with reference to the standard data.	
29	d. Calculate ΔH for a chemical reaction and describe the energy transfer through a simple energy profile diagram	✗	It is not clear what calculations students must be able to perform in order to achieve this learning outcome.	We propose that this learning outcome be reworded as follows: Calculate (i) the heat of formation of a compound using other heats of formation and heat of reaction and (ii) calculate the heat of reaction using heats of formation of reactants and products.	We propose that the following be added to the Students Learn About column Energy transfer may be explained using simple Hess’s Law energy cycle diagrams.
29	e. **Analyse a given reaction, involving covalent molecules, to explain and predict the value of ΔH using average bond enthalpy values**	✓	A clear learning outcome.		
29	f. **Calculate and predict enthalpy changes using Hess’s Law**	✓	A clear learning outcome.		We propose that the wording in the *Students Learn About* column be clarified as follows: State Hess’s Law and represent it in diagrammatic form. * See Bond Energy questions in previous syllabus (not current one)

30	g. Construct balanced equations for the complete combustion of hydrocarbons and primary alcohols, **and explain trends in the associated standard ΔH values**		A clear learning outcome.		We propose that the wording in the *Students Learn About* column be clarified as follows: The combustion of hydrocarbon compounds up to C6 containing no more than one double bond and primary alcohols up to C6.
30.	h. Investigate, using primary data, the energy change of combustion and compare experimental values to standard values, accounting for differences EI		As this learning outcome is clearly marked as a student laboratory investigation, the use of the term "primary data" is unnecessary and confusing.	We propose that this learning outcome be reworded as follows: Carry out a laboratory investigation to measure the enthalpy of combustion of a liquid and compare your result to standard values accounting for differences.	As spirit burners are readily available, we propose that reference to these be retained in the SLA column but reference to measuring enthalpy of combustion of food samples be deleted as a recommendation. Instead we propose the following sentence be inserted: The use of bomb calorimeters to accurately measure enthalpies of combustion.

30	a. Investigate, using primary data, the factors that affect rates of a reaction and interpret rate of reaction graphs, using primary and secondary data [EI]	✗	This is a very vague learning outcome and it is impossible to deduce from it what students must be able to do in order to achieve this learning outcome. As already pointed out, the use of the term “primary data” is unnecessary since students are collecting their own data (i.e. primary data) in the investigations.	The notes in the STA column propose three examples of investigations that students could carry out. Each of the experiments is quite different and cause different learning outcomes to be achieved by students. Hence, we recommend that these three investigations be listed as three separate investigations as follows: 1. To investigate the effect of particle size on the rate of reaction when hydrochloric acid reacts with marble chips and interpret rate of reaction graphs. 2. To investigate the effect of concentration on reaction rate when sodium thiosulfate solution reacts with hydrochloric acid and interpret rate of reaction graphs. 3. To investigate the effect of a catalyst (e.g. manganese dioxide) on the decomposition of hydrogen peroxide and interpret rate of reaction graphs.	The reference to initial, average and instantaneous rates of reactions in the SLA column is good. We recommend the words “but are not limited to” be removed as this will undermine the confidence of teachers and students if the list of investigations to be performed by students is left wide open.
30	b. Describe collision theory, and give examples of slow and fast reactions	✓	A clear learning outcome.		The points listed in the SLA column are very helpful in indicating the depth of treatment.
30	c. Define rate of reaction	✓	A clear learning outcome.		

31	d. Compare the energy profile diagrams of catalysed and uncatalysed reactions, for both exothermic and endothermic reactions		A clear learning outcome.		
31	e. Outline two general catalytic mechanisms		Names of theories re mechanisms of catalysis need to be given.	Outline Surface Adsorption (heterogeneous) and Intermediate Formation (homogeneous) theories of catalysis.	
31	a. Appreciate that some reactions tend to be reversible and explain the concept of dynamic chemical equilibrium		Since the verb “appreciate” is not an active verb, we propose that this learning outcome be rewritten to make it clear what students must be able to do in order to show that they appreciate this concept.	We propose the following wording: Explain that some reactions tend to be reversible and discuss the concept of dynamic chemical equilibrium	The notes in the SLA column are helpful in indicating the depth of treatment.
31	b. Explain the factors that affect the value of the equilibrium constant *Kc*, **and use the mathematical model of *Kc* to describe and predict how given reactions would proceed**		A clear learning outcome.	The word model is used in such a confusing manner throughout the draft specification that we propose the term “mathematical model” be replaced by the simpler term “mathematical expression”.	
31	c. **Solve problems involving the mathematical model for the equilibrium constant *Kc***		This is a vague learning outcome and it is difficult to deduce from it what types of problems students must be able to solve in order to achieve this learning outcome.	Once again, we propose the term “mathematical model” be replaced by the simpler term “mathematical expression”.	We propose that the following information be given in the SLA column to indicate the required depth of treatment: Students should be able to solve problems (i) to calculate the value of Kc given equilibrium concentrations and (ii) to calculate equilibrium concentrations given the value of Kc. In all cases the balanced chemical equation will be provided to students.

31	d. Apply Le Chatelier's principle to a variety of processes to predict responses to disturbances to the equilibrium and **to predict conditions for optimising yields of product**	✓	A clear learning outcome.		The additional information in the SLA column is very helpful in indicating the depth of treatment.
32	e. Investigate, using primary and secondary data, how changes in temperature and concentration can affect the state of equilibrium [EI]	✗	This is a very vague learning outcome and it is impossible to deduce from it what students must be able to do in order to achieve this learning outcome. As already pointed out, the use of the term "primary data" is unnecessary since students are collecting their own data (i.e. primary data) in the investigations.	We propose that this learning outcome be reworded as follows: Carry out a laboratory investigation to study how changes in temperature and concentration can affect the state of equilibrium. If students are required to study secondary data using digital simulations, this is best left to the SLA column as it is not a laboratory investigation but can be carried out in an ordinary classroom or at home.	The information provided in the SLA column is helpful as it specifies the reaction that should be investigated. Note that the name of one of the chemicals should be written as iron(III) chloride.
32	f. Explain the Haber process as an industrial application of chemical equilibrium, and how chemical equilibrium principles can be applied to the production of ammonia	✓	A clear learning outcome.		The list of items in the SLA column is very helpful in indicating the depth of treatment.
32	g. Outline the impact of the Haber process on society and consider its ongoing role	✓	A clear learning outcome.		

32	h. **Outline the importance of a compromise between yield and rate of reaction for the industrial use of the Haber process**		A clear learning outcome.		
32	a. Justify categorisation of commonly used substances as acid or base, based on the display of certain properties and discuss common everyday examples of neutralisation		A clear learning outcome.		The examples given in the SLA column are helpful in providing depth of treatment to ensure that students achieve this learning outcome.
32	b. Predict the products of, and write balanced equations for, acid base reactions		A clear learning outcome.		Although this is a broad learning outcome, clarity is brought to it by indicating the depth of treatment (the three types of acid-base reactions) in the *Students Learn About* column. We propose that acid-hydrogencarbonate be added to the list.
33	c. Compare two theories of acid-base systems and justify why Brønsted-Lowry theory is a more extensive model for explaining behaviour		A clear learning outcome.		The depth of treatment note in the SLA column is very helpful for clarifying the two theories (Bronsted-Lowry and Arrhenius)
33	d. **Apply Brønsted-Lowry theory to identify, in chemical equations:** **• conjugate acid-base pairs** **• species acting as acids and bases**		A clear learning outcome.		
33	Explain the self-ionisation of water **and deduce a mathematical representation for the ionic product of water (K_w), accounting for its temperature dependence**		A clear learning outcome.		The material provided in the SLA column is very helpful in highlighting the mathematical equation required.

33	f. Measure pH, and explain the pH scale **and its limitations**	✓	A clear learning outcome.		The depth of treatment (ways of measuring pH) provided in the SLA column is very helpful.
33	g. **Investigate, using primary data, factors that affect the pH of a solution** EI	✗	This is a vague learning outcome and it is difficult to deduce from it what students must be able to do in order to achieve this learning outcome. As already pointed out, the use of the term "primary data" is unnecessary since students are collecting their own data (i.e. primary data) in the investigation.	We propose that this learning outcome be reworded as follows: Carry out a laboratory investigation to study the factors that affect the pH of a solution.	Information needs to be provided in the SLA column on the factors that need to be studied. We propose that wording along the following lines should be included. Students should investigate the effect of strong acids, strong bases, weak acids, weak bases, concentration and temperature on pH.
33	h. Distinguish between: • weak and strong acids (and bases) • concentrated and dilute acids (and bases)	✓	A clear learning outcome.		
33	i. **Solve mathematical problems involving pH for dilute aqueous solutions**	✓	A clear learning outcome.		The depth of treatment (two types of calculations) provided in the SLA column is very helpful.
33	j. **Deduce mathematical representations for weak acid dissociation constant (*Ka*) and weak base dissociation constant (*Kb*)**	✓	A clear learning outcome.		The depth of treatment (two mathematical representations) provided in the SLA column is very helpful.
33	k. Compare degrees of dissociation of strong and weak acids, and strong and weak bases, **using *Ka* and *Kb* values**	✓	A clear learning outcome.		

34	l. **Explain how weak acid and weak base acid-base indicators function**		A clear learning outcome.		
35	m. Investigate pH titration curves, using primary and secondary data from acid-base reactions, justifying appropriate indicators for each titration [EI]		This is a vague learning outcome and it is difficult to deduce from it what students must be able to do in order to achieve this learning outcome. As already pointed out, the use of the term “primary data” is unnecessary since students are collecting their own data (i.e. primary data) in the investigation.	The study of secondary data is not part of a laboratory investigation as this activity can be done as homework or studying past examination papers. Reference to secondary data analysis could be included in the SLA column or as a separate learning outcome. We propose that this learning outcome be reworded as follows: Carry out a laboratory investigation to investigate pH titration curves.	The depth of treatment (three types of titration curves) provided in the SLA column is very helpful.
34	a. Describe oxidation and reduction, using suitable examples and applications, identifying oxidising and reducing agents in given chemical reactions		A clear learning outcome.		The depth of treatment (suitable examples and applications) provided in the SLA column is very helpful.
34	b. **Apply oxidation numbers to balance redox reaction equations**		A clear learning outcome.		

34	c. **Investigate, using primary data** [EI]**:** • **redox reactions, using simple experiments involving halogens** • **displacement reactions of metals, relating them to the electro-chemical series**	✗	This is a vague learning outcome and it is difficult to deduce from it what students must be able to do in order to achieve this learning outcome. As already pointed out, the use of the term “primary data” is unnecessary since students are collecting their own data (i.e. primary data) in the investigation.	We propose that this learning outcome be reworded as follows: Carry out an investigation of oxidation-reduction reductions using simple experiments involving (i) halogens and (ii) displacement reactions of metals, relating them to the electrochemical series.	We propose that the following guidance be inserted into the SLA column: Halogens as oxidising agents: • Oxidation of bromide ions to bromine by chlorine. • Oxidation of iodide ions to iodine by chlorine. • Oxidation of iodide ions to iodine by bromine. Displacement reactions of metals: • Displacement of Cu^{2+} ions out of solution as copper metal using zinc. • Displacement of Cu^{2+} ions out of solution as copper metal using iron. • Displacement of Ag^{+} ions out of solution as silver metal using copper. The sentence currently included in the SLA column “The use of the electrochemical series as a guide to the relative tendency of metals to be oxidised” is very helpful in indicating the depth of treatment.
34	d. Compare a primary and secondary cell	✗	This needs clarification as to what is required.	We propose that this be reworded as: Distinguish between a primary and secondary cell.	
34	e. Conduct an experiment to create a simple galvanic cell and explain its operation	✓	A clear learning outcome.	This is a very worthwhile activity and we propose it be labelled EI to indicate that it is a student laboratory investigation.	The information in the SLA column is very helpful as the copper-zinc system recommended works very well.

35	f. Conduct experiments in electrolysis, and explain the operation of the electrolytic cells		"neutral salt solution" is unclear"	Electrochemistry is found to be a difficult topic by many students. We propose that this investigation be labelled "EI" as student voltameters are readily available and will help to bring this subject to life for students.	The information in the SLA column is very helpful as it clarifies what electrolysis experiments are required to be carried out. We propose that the sentence "reactions at electrodes required" be changed to "half-reactions at electrodes required" and that neutral salt solution be replaced by sodium chloride solution.
35	g. Research the role of electrochemistry in an area related to sustainability and technology in everyday life [RI]		The term "Research" is unclear on what is expected of students.	We note that this learning outcome is marked as a research-based investigation (as describe on p. 14 of the draft specification). We propose it be reworded as "Describe the role of electrochemistry in an area related to sustainability and technology in everyday life"	Information needs to be provided on what research students must do to achieve the learning outcome. For example, would a homework assignment be sufficient. This information is needed to calculate the time required to teach the entire syllabus.
36	a. Recognise the importance of primary standards and standard solutions		A clear learning outcome.	To help students achieve this learning outcome we propose that it be included as one of the five recommended investigations in the next learning outcome.	The depth of treatment (acid base and redox volumetric analysis) provided in the SLA column is very helpful.

36	b. Determine the concentration of analytes by titration, using primary standard solutions and/ or solutions standardised using primary standards EI		This is a vague learning outcome and it is impossible to deduce from it what students must be able to do in order to achieve this learning outcome.	The broad headings of (i) strong acid- strong base, (ii) strong acid –weak base and (iii) weak acid- strong base investigations is of no help to teachers in preparing students to achieve the learning outcome in the laboratory. It is vital that clarity be brought to this learning outcome as shown in the proposed wording in the SLA column.	The following is the proposed new wording to be inserted in the SLA column: Investigations should include the following: (i) Investigate the use of a standard solution of sodium carbonate to standardise a given hydrochloric acid solution. (ii) Investigate the concentration of ammonia solution in a household cleaner by titration. (iii) Investigate the concentration of ethanoic acid in vinegar. (iv) Investigate the amount of iron in an iron tablet. (v) Investigate the amount of dissolved oxygen in a sample of water by means of a titration.
37	c. **Solve and analyse volumetric problems**		This is a vague learning outcome and it is impossible to deduce from it what type of volumetric problems students must be able to solve in order to achieve this learning outcome.		We propose the following information be provided in the SLA column: Solving volumetric problems, using the formula method. (Higher Level and Ordinary Level) **Solving volumetric problems from first principles, where the formula method is not applicable. Either method may be used when both methods are applicable. (Higher Level only)** Balanced equations will be given in all volumetric problems.
37	a. Outline sources of organic compounds and the use and impact of products based on organic compounds		A clear learning outcome.		The depth of treatment (list of sources) provided in the SLA column is very helpful.
37	a. Apply rules for nomenclature and classify each functional group in terms of general formula & structure		A clear learning outcome.		The depth of treatment (list of functional groups) provided in the SLA column is very helpful in providing clarity to this learning outcome.

37	c. Construct and compare representations of organic molecules	✓	A clear learning outcome.		The depth of treatment (list of ways of representing organic molecules) provided in the SLA column is very helpful in providing clarity to this learning outcome.
38	d. Conduct qualitative analysis tests: • to distinguish between aldehydes and ketones • for the presence of carboxylic acid and alcohol functional groups	✓	A clear learning outcome.	We propose that this learning outcome be labelled "EI" as it is an excellent investigation for students to carry out in the laboratory.	The depth of treatment (list of tests to be carried out) provided in the SLA column is very helpful in providing clarity to this learning outcome.
38	e. **Relate the physical properties of organic molecules to molecular size, type of bonding present and intermolecular forces**	✓	A clear learning outcome.		The depth of treatment (list of physical properties) provided in the SLA column is very helpful in providing clarity to this learning outcome.
38	f. Describe **and discuss** five types of reactions **and analyse a given reaction in terms of the type(s) of reaction taking place**	✓	A clear learning outcome.		The depth of treatment (list of five types of reactions) provided in the SLA column is very helpful in providing clarity to this learning outcome.
38	g. Analyse an organic reaction scheme and predict possible reactions and reaction products	✗	This is a vague learning outcome and it is impossible to deduce from it what type of reaction schemes should be covered in the classroom by teachers so that their students achieve this learning outcome.		We propose the following wording be included in the SLA column for clarification: Reaction schemes will be limited to those involving addition, substitution, redox, acid-base and elimination reactions. Students will not be expected to know conditions of temperature and pressure.

38	h**. conduct experiments to:** **• prepare an ester** **• synthesise benzoic acid, determining purity, melting point and yield**	✓	A clear learning outcome.	We propose that this learning outcome be labelled "EI" as the two experiments are excellent investigation for students to carry out in the laboratory.	The depth of treatment (reflux method for ester preparation and oxidation of phenylmethanol method for benzoic acid) provided in the SLA column is very helpful in providing clarity to this learning outcome.
39.	i. Describe reaction mechanisms involving movement of electrons, including supporting evidence	✓	A clear learning outcome.		The depth of treatment (list of eight reactions) provided in the SLA column is very helpful in providing clarity to this learning outcome.
39	j**. Discuss redox reactions and acid-base reactions of organic compounds**	✓	A clear learning outcome.		The depth of treatment (listing details of redox reactions) provided in the SLA column is very helpful in providing clarity to this learning outcome.
39	k. **explain the acidity of carboxylic acid and alcohol functional groups**	✓	A clear learning outcome.		The depth of treatment (inductive effect, resonance, polarity) provided in the SLA column is very helpful in providing clarity to this learning outcome.
39	l. Outline how a soap works, as an example of a surfactant, and the applications of surfactants in everyday life	✓	A clear learning outcome.		The depth of treatment (health and sanitisation) provided in the SLA column is very helpful in providing clarity to this learning outcome.
39	m. Conduct an activity to prepare soap, with NaOH either limiting or in excess	✓	A clear learning outcome.		The depth of treatment provided in the SLA column indicating that this is a simple activity rather than a full laboratory experiment is very helpful.
39	n. Compare the manufacture and basicity of a simply-made soap product with a commercial product	✓	A clear learning outcome.		

40	o. Illustrate the use of organic compounds in pharmaceutical products		A clear learning outcome.		The depth of treatment provided in the SLA column is very helpful in providing clarity to this learning outcome. We propose that the phrase "not limited to" be removed as this is quite a complex area of organic chemistry.
40	p. **Investigate, using primary data, how to find percentage aspirin in an aspirin tablet** [EI]		As already pointed out, the use of the term "primary data" is unnecessary and confusing since students are collecting their own data (i.e. primary data) in the investigation.	We propose that this learning outcome be reworded as follows: Carry out a laboratory investigation to find the percentage aspirin in an aspirin tablet.	
40	q. describe the structure and applications of addition polymers		A clear learning outcome.		The depth of treatment provided in the SLA column is very helpful in providing clarity to this learning outcome. We propose that the phrase "not limited to" be removed as a knowledge and understanding of three addition polymers is sufficient
40	r. **Relate the physical properties of addition polymers to their structures, and how non-bio-degradability is related to chemical stability**		A clear learning outcome.		
40.	a. Discuss our chemical environment for each of the three domains and consider the interconnections across domains		This is a very broad and vague learning outcome and it is impossible to deduce from it what should be covered in the classroom by teachers so that their students achieve this learning outcome.		More information on depth of treatment needs to be provided in the SLA column

40	b. Research, individually or collaboratively, one area of each of the three domains regarding the impact of humans on our chemical environment RI		This is a very broad learning outcome and it is impossible to deduce from it what should be covered in the classroom by teachers so that their students achieve this learning outcome. How can this research be assessed?		Information needs to be provided on what exactly students must do to achieve the learning outcome. For example, would a homework assignment be sufficient? This information is needed to calculate the time required to teach the entire syllabus.
41	c. Relate aspects of the Nitrogen, Oxygen and Carbon cycles to climate change and sustainability		A clear learning outcome.		
41	d. Describe the natural greenhouse effect and explain its significance		A clear learning outcome.		
41	e. Discuss the evidence for the enhanced greenhouse effect and possible solutions to anthropogenic influences on the atmosphere		A clear learning outcome.		
41	f. Outline the water cycle, including its significance		A clear learning outcome.		
41	g. Describe the steps necessary in the treatment of drinking water and appreciate the impact of providing clean water for human use		Since the verb “appreciate” is not an active verb, we propose that this learning outcome be rewritten to make it clear what students must be able to do in order to show that they appreciate this concept	We propose the following wording: Describe the steps necessary in the treatment of drinking water and discuss the impact of providing clean water for human use.	The depth of treatment (list of stages of water treatment) provided in the SLA column is very helpful in providing clarity to this learning outcome.

41	h. Analyse water samples, both qualitatively and quantitatively [EI]	✗	This is a very broad learning outcome and it is difficult to deduce from it what laboratory investigations should be covered in the classroom by teachers so that their students achieve this learning outcome.	Give that students have already carried out investigations to test for anions and measure levels of dissolved oxygen, perhaps this learning outcome could be rewritten as: Carry out a laboratory investigation to measure (i) the pH and (ii) concentration of free chlorine in water samples using a comparator and a colorimeter.	
41	i. Discuss causes of water contamination, biochemical consequences and possible solutions to one of the causes	✓	A clear learning outcome.		The depth of treatment provided in the SLA column is very helpful in providing clarity to this learning outcome. We propose that the phrase “but are not limited to” be removed as a lot of topics are already specified.
42	j. Outline methods for the extraction of metals from their natural states based on their positions in the electro-chemical series	✗	This is a very broad learning outcome and it is impossible to deduce from it what metal extractions should be covered in the classroom by teachers so that their students achieve this learning outcome.	We propose this learning outcome be rewritten as: Outline a method for the extraction of sodium from molten sodium chloride, aluminium from bauxite and iron metal from iron ore.	Extraction of sodium and aluminium by electrolysis and extraction of iron metal from iron ore by carbon (coke).
42	k. Discuss the recycling of aluminium and plastics	✓	A clear learning outcome.		
42	l. Discuss the impact on sustainability of reduced dependence on energy sourced from fossil fuels, and sustainable alternatives	✓	A clear learning outcome.		The depth of treatment provided in the SLA column is very helpful in providing clarity to this learning outcome. We propose that the phrase “but not limited to” be removed as many alternative energy sources topics are already specified.

Appendix 3

Analysis of Learning Outcomes in Leaving Certificate Biology Draft Specification

Note: This document covers all the Biology learning outcomes. The generic learning outcomes in Strand 1 (which are common to Physics, Chemistry and Biology) are analysed in Chapter 6 in collaboration with the ISTA Physics and Chemistry committees.

Other documents that should be read in conjunction with this document analysing each learning outcome are:

1. Spreadsheet of estimated time required to ensure that students achieve each learning outcome in the specification (section 5.3).
2. Document discussing the breakdown of Higher Level / Ordinary Level learning outcomes (section 5.4).
3. List of Mandatory Student Investigations (section 5.5)
4. As noted above, Chapter 6 analyses the "Unifying Strand Learning Outcomes" (the strand that is common to Physics, Chemistry and Biology)

5.

Strand 1 - The Organisation of Life

Page	Learning Outcome	Clarity	Comment	Proposed rewording of learning outcome (where applicable)	Comment on material in corresponding "Students Learn About (SLA) column
18	OrgL1 a.evaluate the characteristics of living things		Clear learning outcome	Describe the characteristics of all living things.	Clear and concise.
18	OrgL1 b. explain how viruses replicate within cells		Clear learning outcome.		No SLA comment … stages of viral replication could be added. Explain the stages of viral replication including: attachment, penetration,

Page	Learning Outcome	Clarity	Comment	Proposed re-wording of learning outcome	Comment on material in SLA column
18	OrgL1 c. discuss the difficulty of defining viruses, their economic and medical importance	✓	Clear learning outcome.		
18	OrgL1 d. use classification principles to identify and classify living things in known and unknown contexts; examine the importance of classification systems in biology	✗	Not a clear learning outcome. The depth required is very difficult to assess here. To what level are the living things classified? As animals, plants, fungi, protist or bacteria? Do animals need to be classified as vertebrates and invertebrates, or into their phyla / classes? Plants in their families? SLA detail does not help provide clarity.	Outline the importance of classification systems in biology. Classify organisms according to the three domains of life.	Greater depth of treatment required on 'Phylogeny - classification based on evolutionary development'. Clades are a key feature of phylogenetic classification but are not mentioned here - difficult to teach phylogeny without mentioning them. Depth on three Domains?
18	OrgL2 a. describe the complexity of multicellular organisms	✓	Clear but missing an opportunity to relate to LO OrgL1a and the use of the term 'organisation'.	Describe the organisation of cells in multicellular organisms.	Cellular basis of life already mentioned in OrgL1a.
18	OrgL2 b. compare the ultrastructure of prokaryotic and eukaryotic cells	✓	Clear learning outcome		Detail on 'microstructure' and 'ultrastructure' should be provided in the SLA section here.

18	OrgL2 c. investigate, using primary and secondary data, the structures and organelles of animal and plant cells and relate them to their functions	✗	Clarity can be improved in SLA section.	Investigate, using a light microscope, the structures and organelles of animal and plant cells and relate them to their functions.	Do schools have sufficient microscopes, with enough magnifying power, to formulate primary data on organelle structure?
18	OrgL3 a. outline a nutritional source, and the structural and metabolic roles, of carbohydrate, lipid and protein	✗	Learning outcome is unclear and related SLA is confusing.	Describe carbohydrates, lipids and proteins in terms of their basic units, sources, metabolic and structural roles.	Decent clarity, although functions could be elaborated. No mention of saccharides as the unit of carbohydrates - the only biomolecule whose unit is not stated?
18	OrgL3 b. recognise the roles of vitamins and minerals in biological processes	✗	Unclear learning outcome	Recognise the roles of vitamins and minerals in biological processes; describe the role of one water soluble and one fat soluble vitamin in humans, and outline their deficiency diseases.	Water and Fat Soluble mentioned but no specifics - any one of each? Two of each? Specific vitamins?
18	OrgL3 c. outline the main roles of water in living organisms	✓	Clear learning outcome		SLA could outline acceptable roles.
19	OrgL3 d. investigate qualitatively the level of any one constituent in a range of food samples, use primary data to support conclusions	✗	Unclear. The "level" of a food constituent cannot be measured qualitatively - level implies quantitative data.	Investigate qualitatively the presence of any one constituent in a range of food samples, using primary data to support conclusion.	List of acceptable chemical tests should be provided.

Page	Learning Outcome	Clarity	Comment	Proposed re-wording of learning outcome	Comment on material in SLA column
20	OrgL3 e. describe the role of ATP and NAD+/NADP+ in metabolic pathways		Clear learning outcome		Could also include proton transfer, along with energy and electrons, in the SLA text.
20	OrgL3 g. describe the basic structure and function of DNA and RNA		Learning outcome is unclear. SLA seems incomplete and could create confusion.	Describe the structure of a DNA and RNA nucleotide.	No reference to sugar (ribose or deoxyribose) or phosphate in the structure of DNA or RNA. Nucleotides mentioned earlier - should be referenced here.
20	**OrgL3** **h. relate genes, proteins and traits in organisms; outline the concept of the genetic code**		Unclear learning outcome. Difficult to unpack the depth required here - the SLA detail is grossly insufficient ("the concept of the genetic code" is far too vague)	Describe the relationship between genes, proteins and traits. Define the term 'genetic code'	Considering that this is a HL learning outcome, greater clarity needed on the depth and meaning of "the concept of the genetic code". Is this second statement even required, considering that protein synthesis is outlined in greater detail later?)
20	OrgL4 a. describe the structure of a chromosome and the role of a gene; compare nuclear and non-nuclear inheritance		Unclear learning outcome. Greater detail needed on what is required in the "structure of a chromosome". This is due to the addition of epigenetics in Org L4b which causes changes to chromosome / chromatin structure.	This learning outcome should be split into separate parts.	Detail required on "chromosome structure" - which parts need to be mentioned? Centromere, telomere, chromatin, histones, methyl groups?

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20	OrgL4 b. compare genetic and epigenetic mechanisms		Unclear learning outcome. Difficult to unpack the depth required here - which genetic and epigenetic mechanisms? Typically, epigenetics works in one of three ways: DNA methylation, histone modification and non-coding RNA action. It's not clear in the previous LO if methyl groups and histones are even required in chromosome structure. This needs a rethink.	Compare genetic mechanisms (deletions and mutations) with epigenetic mechanisms (methylation and histone modification).	Key concepts are useful but far greater detail needed. Genetic and epigenetic mechanisms should be separated in this section for clarity. Detail on specific mechanisms should be provided.
20	OrgL4 c. predict inheritance to the first generation of a single unlinked trait in crosses involving homozygous and heterozygous parents		Clear learning outcome		The key concepts are useful although it would be useful to have a separate SLA section for each of these learning outcomes.
20	OrgL4 d. predict a cross involving incomplete dominance		Clear learning outcome		

20	**OrgL4 e. illustrate Mendel's Laws of Segregation and Independent Assortment**		Unclear learning outcome. Inappropriate use of the verb 'illustrate'. Illustrate suggests that a student will not be asked to define either or both laws?	Define Mendel's Laws of Segregation and Independent Assortment.	The SLA content opposite this learning outcome (non-nuclear inheritance) does not apply to it. It's confusing and not related to any specific learning outcome.
20	**OrgL4 f. predict inheritance to the second generation of two unlinked traits in crosses involving homozygous and heterozygous parents**		Clear learning outcome		
20	**OrgL4 g. explain how linkage affects Mendel's Law of Independent Assortment (knowledge of crossing over not required)**		Clear learning outcome		Crossing over not required is mentioned twice, in the LO and SLA.
20	OrgL4 h. describe sex determination by X and Y chromosomes in humans		Learning outcome is unclear and no SLA detail provided. Clarity on depth required ... suggest removing "in humans".	Describe sex determination by X and Y chromosomes in mammals / animals.	Previously, (well constructed) questions appeared on sex determination in other animals (including birds where the XX gives rise to maleness). Perhaps change this to mammals or animals to provide greater challenge?
20	OrgL4 i. develop and use models to explain and predict the inheritance of sex- linked traits from known examples		Unclear what "develop and use models" refers to here and how it could be applied to sex-linked traits.	List two examples of sex-linked characteristics Carry out a genetic cross to show the inheritance of sex-linked characteristics in the F1 generation.	SLA should provide some examples, as a starting point. Elaborate on meaning of 'develop models'.

20	OrgL5 a. explain the variations that come from sexual reproduction and mutations		Unclear learning outcome. No clarity on depth of treatment on types of mutations, causes of mutations, meiosis. Although crossing over was not required in OrgL4, it is a significant source of variation in sexual reproduction.	Define the term ‘variation’. List the two causes of variation - i.e. mutations and sexual reproduction	SLA section should be used to provide greater clarity here.
20	OrgL5 b. discuss the rationale for, and basis of, the theory of evolution by natural selection		Unclear. No depth of treatment.	Discuss the theory of evolution by natural selection.	Depth of treatment should be provided in SLA.
20	OrgL5 c. consider evidence that supports the theory of evolution by natural selection; recognise the value of the theory of evolution in understanding the modern world		Clear learning outcome		SLA detail is very good; a model for all learning outcomes.
20	OrgL5 d. evaluate the practical applications of artificial selection; discuss ethical and societal issues		Unclear learning outcome. The use of ‘practical applications’ is unnecessarily vague. It should be more specific e.g. agriculture, dog breeding etc	Compare natural selection and artificial selection; discuss the ethical and societal issues of artificial selection in agriculture and animal breeding.	No SLA content here at all, which seems lacking. Examples of practical applications required should be listed here.
22	SPL1 a. explain how enzymes function to facilitate the catalysis of biochemical reactions		Unclear learning outcome. SLA content could be improved.	Explain how enzymes lower the activation energy of biochemical reactions, facilitating their catalysis.	No SLA content provided. Is knowledge of activation energy required, for example? If so, it should be mentioned in the SLA section.

Page	Learning Outcome	Clarity	Comment	Proposed re-wording of learning outcome	Comment on material in SLA column
22	**SPL1** **b. illustrate enzyme specificity using the Induced Fit model.**		Clear learning outcome		3D structure ... does this mean the term 'globular' is not required?
22	SPL1 c. investigate factors that affect the rate of enzyme-catalysed reactions, use primary and secondary data to support conclusions		Unclear learning outcome. Not specific enough - the factors to be investigated should be listed here. How many do students have to investigate? Use of 'primary data' here is unnecessary.	Investigate the effect of pH and temperature on the rate of enzyme-catalysed reactions, use data to support conclusions.	The use of 1/t isn't suitable for many enzyme investigations. For example, the catalysis of H2O2 by catalase (used by most teachers) uses height of foam to measure the rate of enzyme action. Is this no longer suitable? SLA should list suitable factors to investigate: temperature, pH, surface area, enzyme conc, substrate conc etc.
22	SPL1 d. evaluate the use of enzymes in a known enterprise; appreciate the central role of enzymes in industrial applications		Needs to be more specific. SLA should provide greater detail on acceptable examples. Evaluate seems an inappropriate action verb in this case; explain seems cleaner and more relevant, considering the spec's own explanation of the action verbs.	Explain the use of enzymes in industry, giving examples.	SLA should give examples of acceptable enterprises / applications. By saying, know enterprise in the LO, it leaves little flexibility of the SEC to assess this.
22	SPL2 a. outline the processes of anaerobic respiration, aerobic respiration and photosynthesis		Unclear learning outcome. Grossly insufficient. While 'outline' means restrict to essentials, the essentials need to be provided in the SLA.	Distinguish between anaerobic and aerobic respiration. Define photosynthesis.	Depth of treatment required here. For example: are balanced chemical equations required? Reactants and Products?

22	SPL2 b. investigate factors that affect the rate of photosynthesis, use primary and secondary data to support conclusions	❌	Unclear learning outcome. How many factors need to be investigated? Why not add other factors, e.g. colour of light?	Investigate how light intensity, CO2 concentration of temperature affect the rate of photosynthesis.	Traditionally, Elodea was used for photosynthesis investigations but is almost impossible to source now. Advice on alternatives should be provided here e.g. immobilised microalgae (algal balls).
22	SPL2 c.investigate the conditions necessary for fermentation, use primary and secondary data to support conclusions	❌	Unclear learning outcome. Which conditions should the student investigate? Temperature, sugar concentrations, pH? Greater clarity needed here.	Hard to provide an alternative when so little detail is provided initially.	This could be a lovely investigation but greater detail required here. Information on all investigations should be detailed and concise.
22	SPL2 d.examine how leaf structure is adapted for photosynthetic efficiency; discuss the role that manipulation of photosynthesis can play in horticulture	❌	Unclear learning outcome. The 'manipulation of photosynthesis' is a clunky and confusing statement.	Examine how leaf structure is adapted for its role in photosynthesis; discuss the role of photosynthesis in horticulture	No SLA content provided.
22	**SPL2** **e. develop and use models to explain the two-stage processes of photosynthesis and respiration; make particular reference to the role of transfer molecules**	❌	Unclear learning outcome. Grossly insufficient. No depth of treatment provided here. Simplifying respiration into two stages is oversimplification and arguably just plain wrong.	In truth, this should be a series of separate learning outcomes: Outline the process of the Light Stage and dark stage of photosynthesis. Outline the stages of Aerobic Respiration. Outline the process of Anaerobic Respiration	SLA detail is insufficient in providing any clarity on the depth required. Respiration has more than two stages. The mention of 'concentration gradients' makes the depth of treatment even more confusing; suggests greater detail than in previous syllabus without providing clarity. Grossly insufficient. The use of key concepts here, like in Orgl4, could be used.

Page	Learning Outcome	Clarity	Comment	Proposed re-wording of learning outcome	Comment on material in SLA column
23	**SPL2 f. recognise the significance of the internal structures of mitochondria and chloroplasts in facilitating the processes of photosynthesis and respiration**		Unclear learning outcome. Greater clarity needed here. It is unclear what a student has to do to achieve this learning outcome.	Relate the stages of photosynthesis to the internal structure of the chloroplast. Relate the stages of respiration to the internal structure of the mitochondria.	SLA needs far more detail here. What detail is required on 'concentration gradients' or the 'electron transport chain' for example?
23	SPL3 a. describe simply the process of mitosis and meiosis; compare the roles of mitosis and meiosis		Unclear learning outcome. "Describe simply" is a confusing statement. Using the action verbs available, outline seems more appropriate. Detail to be covered should be specified.	Suggest making this separate learning outcomes: Outline the process of mitosis; illustrate the four stages (prophase, metaphase, anaphase and telophase). Define the terms 'mitosis' and 'meiosis'. Compare the roles of mitosis and meiosis in unicellular and multicellular organism.	SLA section should provide detail on the depth required for both mitosis and meiosis for this comparison. Is is unclear whether any detail on the stages of mitosis or meiosis are required at all. Not mentioning the cell cycle here, or before, seems a mistake.
23	SPL3 b. explain the role of DNA replication and mitosis in the cell cycle		Unclear learning outcome. The lack of a learning outcome specifically on the cell cycle, when mentioned here, seems remiss. Suggest adding additional learning outcome.	Outline the cell cycle: interphase, mitotic phase. Explain the role of DNA replication to the cell cycle.	SLA provides little clarity on depth of treatment in the cell cycle. Is knowledge of the stages of Interphase needed? **Note: Interphase not mentioned anywhere in the specification.**

23	SPL3 c. describe how DNA is replicated and the flow of information through mRNA to protein		No detail on depth required here ... LO is vague and unclear. No reference to depth needed in DNA replication or ‘flow of information through mRNA to protein’.	Describe the stages of DNA replication, making reference to the role of enzyme Helicase and DNA Polymerase. Outline, in simply terms, how information is copied from DNA as mRNA and transferred to ribosomes to form specific proteins.	No SLA detail at all, which seems inappropriate. Detail on DNA replication should be provided - is knowledge of helicase and DNA polymerase required? Polymerase is referred to in a later LO so really should be mentioned here. e.g DNA Replication - Helicase unzips DNA - Free Nucleotides - DNA Polymerase Builds New Strand - Reforming of double helix (half old, half new)
23	SPL3 d. describe how gene and chromosomal mutations occur, making reference to known examples of both		Clear learning outcome		SLA should provide clear depth here.
23	**SPL3** **e. describe the processes of transcription and translation**		Unclear learning outcome. No detail on the depth of treatment required. It is very confusing. Note: For HL learning outcomes, the depth should be even more specific.	Describe the processes of transcription and translation in protein synthesis; outline the roles of mRNA and tRNA in the process of protein synthesis. Describe the codon nature of the genetic code; relate the structure of tRNA to the codon nature of the genetic code.	SLA makes no mention of codons or anticodons ... does that mean students do not need knowledge of them. It’s very difficult to explain the process without knowledge of these terms, in a practical sense.

Page	Learning Outcome	Clarity	Comment	Proposed re-wording of learning outcome	Comment on material in SLA column
23	SPL3 f. outline how uncontrolled cell growth and proliferation can lead to development of cancers		Unclear learning outcome. Should be rephrased. Missed opportunity to relate to previous LOs.	Relate mitosis and meiosis to the development of cancers.	It is unclear how the SLA information provided relates to the learning outcome.
23	SPL3 g. examine the role of infectious agents, environmental factors and/ or genetic susceptibility in the development of different cancers in an organism; evaluate solutions to address the development of cancers		Clear learning outcome, although there is room for further clarity in the SLA. Consider separating into two distinct learning outcomes, considering the weight of the term 'evaluate'.	Examine the role of infectious agents, environmental factors and/or genetic susceptibility in the development of different cancers in an organism. Evaluate solutions to address the development of cancers.	SLA content is relevant here ... is detail on metastasis required?
23	SPL4 a. relate the structure of the parts of the central nervous system and the peripheral nervous system to their functions; compare nervous and hormonal coordination		Unclear learning outcome. Consider separating into two learning outcomes?	Distinguish between the CNS and PNS in terms of their function and parts. Compare the nervous system and endocrine system in the way they carry out their functions.	SLA should contain the parts of the CNS and PNS the LO refers to.
24	SPL4 b. describe the roles of the main parts of the brain		Clear learning outcome		Good use of SLA to provide clarity on LO.

24	SPL4 c .describe the structure of a neuron and the mechanisms of impulse transfer		Clarity required: - The structure of which neuron type should be described? Motor, sensory, both? - What depth is required under the mechanism of impulse transfer i.e. through the axon or from one nerve to the next? Consider replacing the term impulse with 'action potential' - the more widely recognised phrase for impulse. This will also provide clarity here.	Compare the structure of the motor and sensory neuron. Outline the role of endorphins and dopamine in the human body. Outline how an action potential forms in an neuron. Describe how an impulse travel across a synaptic cleft; outline the role of neurotransmitters and enzyme inhibitors at the synapse.	Far greater detail required here.
24	**SPL4** **d. develop and use models to explore the interaction of the hormonal and nervous systems to maintain homeostasis**		An incredibly vague learning outcome; impossible to ascertain the depth required. Must give specific examples in the SLA to make this LO workable.	Describe homeostasis; relate homeostasis to metabolism and enzyme reactions. Describe how the endocrine and nervous systems interact to maintain homeostasis.	A missed opportunity to relate to learning outcomes on enzymes. Almost no concrete information provided here. Specific examples should be provided here e.g. water levels, body, temperature, pulse etc.
24	SPL4 ie. illustrate the location and function of the major glands in the endocrine system and their associated hormones		Unclear LO. Llist of "major glands" must be provided in the SLA.	Locate the pituitary gland, thyroid, parathyroid, adrenal, pancreas, testes and ovaries in the human body. Explain the role of each of these endocrine glands.	SLA must provide the list of what is deemed a "major gland" and the hormones associated with them.

Page	Learning Outcome	Clarity	Comment	Proposed re-wording of learning outcome	Comment on material in SLA column
24	SPL4 f. recognise the impact of hormonal manipulation on organisms		Unclear learning outcome. Should be rephrased. Consider rephrasing 'hormonal manipulations'; or give specific examples i.e. contraceptive pill, ethylene to ripen fruits etc.	Discuss the use of artificial hormones in sport, health, agriculture and commercial enterprises.	Consider adding agriculture to that list.
24	SPL4 g. distinguish between innate and acquired immunity; outline the strategies applied to prevent and treat microbial diseases		Unclear. Greater depth needed in the SLA section. More specific mention of vaccination should be made.	Distinguish between innate and acquired immunity; outline the strategies applied to prevent disease (including vaccination); outline methods to treat microbial diseases.	SLA should provide examples of acceptable strategies to prevent and treat microbial diseases. **Missed opportunity to reference RNA vaccines.**
24	**SPL4** **h. distinguish between the roles of B and T lymphocytes in the body's immune response**		For a HL learning outcome, this needs more clarity. Knowledge of which B and T cells is needed? What about monocytes and natural killer cells?	Compare the roles of different types of white blood cell (monocytes, natural killer cells, B lymphocytes and T lymphocytes) in immune response. Outline the role of the different kinds of T lymphocyte (helper, killer, suppressor and memory) in the immune response.	SLA is completely blank for the immunity learning outcomes, which seems strange. Greater depth of treatment can be provided here.
24	SPL4 i. explore how new diseases emerge; discuss the importance of emerging diseases for society		Unclear; a missed opportunity to relate to mutations and evolution in previous learning outcomes.	Outline how mutations and environmental change result in the emergence of new diseases. Discuss the importance of a knowledge of emerging diseases is society, including autoimmune diseases.	Again, no SLA which seems inappropriate. No reference to autoimmune diseases.

24	SPL5 a. relate the general structure of the male and female mammalian reproductive systems to their functions		Unclear learning outcome. There is confusion as to why not 'human' reproductive system rather than mammalian; seems an unnecessary addition. No detail on which parts of the systems are required.	Relate the general structure of the male and female human reproductive systems to their functions.	SLA should provide details on the parts of the reproductive system required.
24	**SPL5** **b. outline the relationship between hormonal levels and stages of the menstrual cycle**		No depth of treatment, which seems remiss in a HL learning outcome. Which hormones are to be considered? SLA content should be elaborated on.	Outline how hormone levels (Oestrogen, Progesterone, LH and FSH) change during the menstrual cycle. Relate the changes in the level of these hormones to stages of the menstrual cycle.	SLA needs more detail. Considering adding: Make reference to the following: - FSH - Graafian Follicle - Oestrogen - LH - Corpus Luteum - Progesterone
24	SPL5 c. describe pregnancy from the development of fertilised embryo to birth; relate the structure of the placenta to its functions		Grossly Unclear. This could take minutes or weeks to study, as it stands. Far greater detail required on the depth needed at each stage of development. Should there be a separate learning outcome on the functions of the placenta or by mentioning them here, is it implied detail is needed on these? Note: a "fertilised embryo" makes no sense, it should be a fertilised egg.	This learning outcome should be split into separate parts.	SLA should contain detail on the stages required, and to what depth. e.g. Zygote (as fertilised egg), Morula (solid ball of cells), Blastocyst (hollow ball of cells - detail of inner cell mass and germ layers), Embryo, Foetus, Birth, Lactation). Some of the items listed in the SLA here don't relate to any learning outcome e.g. copulation, milk formation.
25	SPL5 d. develop and use models to illustrate the role of hormones before, during and after pregnancy		Which hormones are being related to in the learning outcome?	Illustrate the role of hormones (oestrogen, progesterone, oxytocin and prolactin) before, during and after pregnancy.	Need specific detail relating to this learning outcome. Which hormones are being related to?

25	SPL5 e. appreciate the impact of advancements in modern technology on prenatal and postnatal care		Unclear learning outcome. Since the verb “appreciate” is not an active verb, we propose that this learning outcome be rewritten to make it clear what students must be able to do in order to show that they appreciate this concept.	List the advantages that modern technology has had on prenatal and postnatal care	Good detail provided here.
25	SPL5 f. discuss the use and medical implications of strategies to control fertility and treatments for infertility		Unclear. Perhaps this could be easily simplified ‘strategies to control fertility’ seems like a long winded way of saying contraception.	Discuss the use of different methods of contraception; discuss the use and medical implications of fertility treatments.	Could elaborate on the three words provided here. Seem insufficient.
25	SPL5 g. investigate the structures of insect and wind pollinated plants and relate them to their functions, use primary and secondary data to support conclusions		Clear learning outcome		No detail provided on the structures to be compared.
25	SPL5 h. investigate the digestive activity of seeds during germination, use primary data to support conclusions		Clear learning outcome		Some guidance on methodologies should be provided here; it should not be assumed that knowledge of the current investigation is available.
25	SPL6 a.distinguish between diffusion, osmosis and active transport; examine the role of osmosis in food preservation and plant health		Good learning outcome		

25	SPL6 b. investigate factors affecting rates of osmosis across semi-permeable membranes, use primary data to support conclusions	✗	It would be useful to have a list of acceptable factors to be investigated. How many factors need to be investigated, especially considering primary data is required.	Investigate how temperature, concentration gradient or surface area affects the rate of osmosis across semi-permeable membranes, use primary data to support conclusions.	SLA should provide detail on factors to be investigated and how many.
26	SPL6 c. relate the macrostructure of the urinary system to its function in filtering and removing waste; outline the filtration of blood in the nephron	✗	Unclear. Much more detail is needed in the SLA column on the depth required on the filtration of blood at the nephron. Is reabsorption of nutrients not required? Or osmoregulation?	Suggestion is to split up this learning outcome into multiple parts.	It seems remiss to not reference ADH here; it is practically impossible to explain the role of the nephron without referencing ADH and it's a missed opportunity to not reference previous learning outcomes. e.g. SPL4 d, e and homeostasis.
26	SPL6 d. describe how the macrostructure of the human digestive system and associated organs and glands carry out the process of digesting fats, carbohydrates and proteins	✗	Not clear on depth required; information is contrary to SLA. Which organs and glands? Which enzymes?	Needs to be broken into multiple learning outcomes to provide clarity. Describe the macrostructure of the human digestive system and associated organs and glands. Relate the organs and glands to the physical and chemical digestion of carbohydrates, fats and proteins.	SLA is grossly inadequate here and is contrary to learning outcomes. Only enzyme mentioned is amylase, yet reference to digestion of fats and proteins is within the learning outcome. Needs far greater expansion. Hepatic portal vein mentioned but no mention of the liver. Are the functions of the liver outside of digestion required?
26	SPL6 e. describe the absorption, transport and storage of the products of digestion	✓	Clear learning outcome		Assuming the products of digestion relate to carbohydrates, fats and proteins, and not just those of amylase and starch?

Page	Learning Outcome	Clarity	Comment	Proposed re-wording of learning outcome	Comment on material in SLA column
26	SPL6 f. consider the biological implications of dietary choices	✔	Clear learning outcome		SLA content useful to provide context to LO. Consider adding a 'wellbeing flag' here as this issue can be sensitive.
26	SPL6 g. relate the anatomy and physiology of the breathing system to its role in gaseous exchange in the lungs	✘	No depth of treatment. The LO or SLA should provide details on the detail required within the anatomy and physiology of the breathing system. No mention of alveolus - does that mean it doesn't need to be learned?	Draw and label the parts of the human breathing system. Outline how gaseous exchange occurs between the alveoli and the capillaries.	SLA should be used to provide detail here.
26	SPL6 h. outline the role of carbon dioxide concentration as a controlling factor in stomatal opening and in the human breathing system	✔	Clear learning outcome		
26	SPL6 i. investigate the structures of the heart and relate them to their functions, use primary and secondary data to support conclusions	✔	Clear learning outcome		Some clarity on the structures within the heart would be useful here.

26	SPL6 j. develop and use models to describe the interaction between the circulatory and other human body systems in facilitating transport of materials around the body		The use of ‘develop and use models to describe’ is unnecessary here.	Describe the interactions between the circulatory and other human body systems in facilitating transport of materials around the body	SLA should provide detail on which materials should be referenced. Currently no SLA content.
26	SPL6 k. explain heartbeat and its control by the pacemaker, pulse, blood pressure and the cardiac blood supply		Unclear. Also, a missed opportunity to relate this LO to SPL4 d and e. Greater clarity on depth required on blood pressure and cardiac blood supply needed.	Explain the stages of the heartbeat (systole and diastole) and its control by the brain and SA and AV nodes. Distinguish between pulse and blood pressure.	No SLA content supplied.
27	SPL6 l. relate the composition of the blood to its functions; appreciate the value of knowledge on blood grouping for human health		Unclear learning outcome. Since the verb “appreciate” is not an active verb, we propose that this learning outcome be rewritten to make it clear what students must be able to do in order to show that they appreciate this concept.	Describe the structure and role of red blood cells, white blood cells and platelets.	ABO Blood grouping System Rhesus Factor
27	SPL6 m. distinguish between arteries,veins and capillaries based on their macrostructures and role in the circulatory system of humans		Clear learning outcome		Why no detail on macrostructure for comparison?

27	SPL6 n. relate the structure of the lymphatic system to its functions		Lacks clarity - like many learning outcomes, it assumes the same level of detail is required as in the old syllabus. Which structures within the lymphatic system need to be referred to? Which functions? How much detail on these structures is required? e.g. there is no mention of the lacteal in the digestive system learning outcomes - should this be referenced here?	It doesn't need rephrasing, just elaboration.	SLA should provide the detail required here.
27	SPL6 o. relate the structure of the root, stem and leaf and their associated tissues with their functions		Unclear. There is an assumption that we know which structures and tissues the LO is referring to - needs greater clarity. Missed opportunity to relate to LOs on tissues / cell organisation.	Relate the main structure of the root, stem and leaf to their basic functions. Describe the associated tissues within the root, stems and leaves that contribute to their roles.	SLA provides no detail on depth required. Should reference structures within all three plant organs and which tissues need to be referred to.
27	SPL6 p. describe the transport of water, minerals, carbon dioxide and photosynthetic products in the plant		Grossly Unclear. No depth provided. Is knowledge of Cohesion-Tension model needed? Is knowledge of xylem and phloem needed? How much detail is required on the transport of sugars in the phloem?	Describe the cohesion-tension model of water transport; relate mechanisms for movement of materials in cells (diffusion, osmosis and active transport) to water transport. Outline how carbon dioxide is transported within the plant; compare CO_2 levels in a plant during the day and at night. Outline the movement of the products of photosynthesis through phloem tissue.	SLA provides very basic information, mainly on water transport and none on CO_2 or sugar transport. Much more detail needed here.

28	IL1 a. discuss the ways in which science interacts with social, economic, cultural and ethical factors to inform the making of decisions on local ecological issues		Unacceptable. Extremely vague, open ended and open to multiple interpretations. While the LO has value, the depth required needs to be clearly presented. In truth, this learning outcome could be a Leaving Certificate course in itself. Which social, economics, cultural and ethical factors. What decisions are being referred to? Legal, research, legislative?	Not sure where to start.	Currently, the SLA content opposite (although useful for the wider topic) provides little clarity on this learning outcome. Detail on which factors and how many factors in each interaction the students are required to discuss.
28	**IL1** **b. analyse evidence of species diversity in ecosystems using a mathematical model**		Learning outcome unclear Significant clarification needed on SLA content.	Analyse methods of determining diversity in ecosystems. Use the Simpson's Species Diversity Index to calculate species diversity.	The model provided is the Simpson's Diversity Index - is this the only model that can be used, as the learning outcome suggests any model can be used? Do the students have to be able to use the Simpson's Index i.e. make calculations? Do they need to know the formula by heart, or just use it? Do they need to source the data themselves?

Page	Learning Outcome	Clarity	Comment	Proposed re-wording of learning outcome	Comment on material in SLA column
28	**IL1** **c. interpret pyramids of biomass to explain and make predictions about the carrying capacity of ecosystems at different scales**		This is a Inadequately constructed learning outcome. There is no other mention of carrying capacity in the specifications, but clearly a knowledge is required to treat this outcome fully. To what depth is carrying capacity explored to? It can be a large topic in itself, pertaining to various species including humans. Far greater detail needed here; in truth, this should be a series of learning outcomes.	Compare the use of pyramids of numbers and pyramids of biomass in ecosystem study. Use data from pyramids of biomass to make quantitative predictions of energy transfer in food chains. Explain the term carrying capacity and relate it to pyramids of biomass.	The SLA shown has little to do with carrying capacity or pyramids of numbers.
29	IL1 d. interpret primary or secondary data relating to the effects of human activity on species diversity; evaluate associated benefits and risks		The inclusion of primary data here makes the learning outcome generally unworkable in a school setting. It is difficult to ascertain what is meant by the 'benefits and risks' of human impact on species diversity. It makes little sense, to be honest.	Using secondary data, evaluate the effects of human activity on species diversity; discuss the impact of biodiversity loss in ecosystems.	The SLA should provide suggestions on how to find secondary data relating to human impact on biodiversity.

29	IL1 e. construct a model of the ecosystem illustrating species, relevant biotic and abiotic factors e1. construct a model of the ecosystem illustrating species, relevant biotic and abiotic factors		Unclear what 'construct a model' means in this context. Is it simply to gather qualitative and quantitative on an ecosystem and then write a report summarising the findings? This needs to be clarified.	Investigate an ecosystem, qualitatively and quantitatively, and illustrating species present, biotic factors and abiotic factors.	Detail on meaning of 'model of an ecosystem' should be provided here. The use of 'collection methods' is unsuitable; a list of suitable methods and then number required would be helpful. What does the term 'classifications systems' refer to? Classification of species, classification of abiotic factors, classification of ecosystems? List of acceptable abiotic factors; how many do students need to measure? What is meant by 'ground' abiotic factors? (soil already mentioned) The content of the SLA section here, in general, is vague and ambiguous.
29	IL1 e2. investigate the influence of a range of abiotic factors on the distribution of a species		Firstly, e2 and e3 are practically the same; the use of both is needless. How many abiotic factors constitute a "range"? We would question the use of 'distribution of species' in both these learning outcomes; it would make more sense to investigate the effect of abiotic factors on the abundance of species in an ecosystem, which can be measured quantitatively while distribution cannot.	Suggest dividing into two learning outcomes: Describe how to measure abiotic factors: Air temperature; Wind speed Water temperature; pH; salinity Soil Temperature, pH. * the key is to provide specific information in the specification	The SLA section is not sufficient for providing detail in this learning outcome; in fact, there seem to be factual errors.

Page	Learning Outcome	Clarity	Comment	Proposed re-wording of learning outcome	Comment on material in SLA column
29	IL1 e3. investigate **quantitatively** the impact of variation in abiotic factors on the distribution of a species	✗	As above, practically the same apart from the addition of **quantitatively.** Needs greater clarity and distinction from the previous one.	Suggested replacement for both these LOs. Investigate the effect of variations in an abiotic factor on the abundance and distribution of a named species; use **primary** and secondary data to support conclusions.	The SLA provides no clarity to the depth required.
29	IL1 e4. describe the transfer of matter and energy from producers to at least 3 trophic levels	✗	This is unclear. Also, does it have to relate to the ecosystem study only and not to unknown scenarios? Perhaps aligning it to the ecosystem study leaves little room for the SEC to assess it?	Describe how different nutrients are transferred from one trophic level to the Explain why there is energy loss from one trophic level to the next.	The only concern here is that there is no learning outcome on energy transfer outside of the investigation of the ecosystem, where primary data is the only source allowed.
29	IL1 e5. describe how an organism's adaptations enable it to exploit a niche in the ecosystem	✗	Unclear. This LO leaves no room for exploring adaptation of organisms outside of the studied ecosystem.	Explain the concept of the niche using examples as it applies to adaptations in an ecosystem.	
29	IL1 e6. explain the feeding and symbiotic relationships that occur between organisms	✗	Same as above.	Describe two examples of a symbiotic relationship	
29	IL2 a. distinguish between bacteria and fungi in terms of structure, nutrition, reproduction and **cellular nature**	✗	Unclear. Why is **cellular nature** in bold? The previous LO distinguishing between prokaryotic and eukaryotic is not HL only.	Outline the structure of a bacterial cell. Describe the process of binary fission. Distinguish between the process of asexual and sexual reproduction in fungi.	Again, not sure why prokaryotic and eukaryotic are HL only here but not in previous LOs.

29	IL2 b. investigate factors affecting the growth of microorganisms, use primary and secondary data to support conclusions		Clear learning outcome	Suggest adding: Illustrate how the bacteria growth curve can be used to model the population growth of microorganisms.	SLA provides a list of factors that can be investigated; how many need to be completed by the student? SLA mentions bacteria growth curve but no learning outcome.
29	IL2 c. discuss the economic, medical and pharmaceutical importance of microorganisms		Learning outcome is unclear. The SLA content is ambiguous and potentially confusing.	List two ways in which bacteria and fungi play a role in the economy, medicine and the pharmaceutical industry	No relation to learning outcome opposite; separate learning outcome on genetic engineering in next section.
30	IL2 d. illustrate and explain the carbon and nitrogen cycles		No detail on depth required, except that names of microorganisms are not needed.	Describe the carbon cycle; make reference to the role of photosynthesis, respiration, decomposers, fossil fuels and carbon sinks. Describe the stages of the nitrogen cycle, making reference to the types of bacteria involved: nitrogen fixation, nitrification, decomposition, denitrification.	
30	**IL2** **e. evaluate ethical and sustainability issues associated with the cycling of nutrients**		Very difficult to judge the depth of treatment here. The addition of ethical issues seems unnecessary.	Evaluate the stability of the carbon and nitrogen cycles; discuss the role of sustainable practices in the carbon and nitrogen cycles.	No SLA information provided.

Page	Learning Outcome	Clarity	Comment	Proposed re-wording of learning outcome	Comment on material in SLA column
30	IL2 f. discuss the link between atmospheric carbon dioxide, methane and climate change; evaluate biological strategies to reduce atmospheric levels of these gases		Clear learning outcome		Suggest adding the phrase 'carbon sequestration' along with carbon sinks.
30	IL3w a.describe the principles and processes involved in genetic engineering		The learning outcome and supporting SLA material seem outdated. Even the phrase 'genetic engineering' is more commonly referred to as 'gene editing' or 'genome engineering'.. **No reference to CRISPR in either the learning outcome and SLA seem like a missed opportunity to bring a modern technique into the course.** No reference to the ethical or societal issues associated with genome engineering again seems like a missed opportunity.	Describe mechanisms of common gene editing technologies, including CRISPR; evaluate the ethical and societal effects of genome engineering.	The SLA material is based on just one form of genome engineering, which seems outdated considering the rise of CRISPR as a gene editing tool.
30	IL3 b. describe the process of DNA profiling and its potential uses		Unclear. Only issue is reference to PCR when DNA Polymerase is not mentioned in the DNA replication learning outcome SPL3c previously. You cannot explain PCR without reference to DNA Polymerase in DNA replication.	Define the process of DNA Profiling and describe the steps involved in generating a DNA profile.	SLA should include Definition of DNA profiling. Gel Electrophoresis. Analysis of pattern generated. Reference to Polymerase Chain Reaction changes interpretation of LO SPL3c.

30	IL3 c. outline the principle of DNA sequencing and its use in bioinformatics	✔	Clear learning outcome.		SLA could be expanded here.
30	IL3 d. use a genome database to search for alleles that are known to cause (or be responsible for) specific genetic diseases	✔	While clear, it is difficult to understand the rationale for this learning outcome. What is the end point here? In addition, gene databases are extremely complex environments to navigate.		SLA can be used to provide specific examples of genes to search for.
30	IL3 e. investigate patterns using a DNA profile, use primary and/ or secondary data to support conclusions	✘	Unclear. The addition of 'primary data' here should be removed. It is unfair to include an 'and/or' option as most schools simply will not be able to afford Gel Electrophoresis equipment.	Investigate patterns using a DNA profile, use secondary data to support conclusions	SLA provides no depth here.
30	IL3 f. discuss the ethical and sustainability issues arising from advancements in genetic technologies	✘	Unclear.	Discuss the ethical issues arising from advancements in genetic technologies.	SLA should make reference to specific genetic technologies to discuss here.

Appendix 4

The use of the verb *model* in writing learning outcomes

The use of the word model as a verb has caused considerable confusion in many learning outcomes in the Physics and Chemistry Draft Specifications. The word model is not used as a verb in any of the Learning Outcomes in the Biology Draft Specification.

The correct use of the word model should not cause problems as the word is clearly defined in dictionaries. The information in this Appendix is drawn from the following online dictionaries:

https://dictionary.cambridge.org/dictionary/english/model?q=Model

https://www.collinsdictionary.com/dictionary/english/model

https://www.oxfordlearnersdictionaries.com/definition/english/model_1?q=model

Model as a noun

Meaning: Something that a copy can be based on because it is an extremely good example of its type:

- *The educational system was a model for those of many other countries.*
- *They created an education system on the European model.*
- *I worked as an artist's model when I was a college student.*

Model as an adjective

Model is used as an adjective to express approval of someone when you think that they perform their role or duties extremely well.

- *She really is a model (= perfect) student.*
- *As a girl she had been a model pupil.*
- *Hospital staff members say he is a model patient.*
- *It is a model farm (= one that has been specially designed to work well).*

Model as a verb

Meaning: to make a model of something or to wear fashionable clothes, jewellery etc in order to advertise them:

- *She modelled the clay into a sculpture.*
- *Tatjana is modelling a Versace design.*
- *I used to model when I was younger.*
- *If someone models for an artist, they stay still in a particular position so that the artist can make a picture or sculpture of them.*

Definition of model in Glossary of Action Verbs published in Leaving Certificate Physics and Chemistry Draft Specifications

In the Glossary of Action Verbs published in the Physics Draft Specification the verb model is defined as follows:

> **Use words, diagrams, numbers, graphs and equations to describe phenomena make justified predictions and solve problems.**

In the Chemistry Draft Specification the verb model is defined differently:

> **Generate a mathematical representation (e.g. number, graph, equation, geometric figure) or physical replica for real world or mathematical objects, properties, actions or relationships.**

The above definitions are completely different from any of the definitions of the verb model found in dictionaries. It is not surprising that teachers have found learning outcomes using the verb model to be very confusing. Teachers who teach both Leaving Certificate Physics and Chemistry would be even more confused!

In all cases where the verb model is used in writing learning outcomes in the Leaving Certificate Physics and Chemistry Draft Specifications, in Appendices 1 and 2 we have indicated alternative action verbs as understood in dictionaries written by professional lexicographers, e.g. explain, solve, predict, apply, calculate, discuss, describe, demonstrate and interpret.

One of the basic rules for writing learning outcomes is that they should be simple sentences using language that is easily understood by teachers and students.

Recommendation

All learning outcomes containing the word model when used as a verb should be replaced by action verbs whose meanings are clearly defined in standard English dictionaries.

Appendix 5

Copy of online questionnaire completed by science teachers

Irish Science Teachers' Association
Eolaithe na hÉireann

2/2/'24

ISTA Online Questionnaire

Feedback on Draft Physics, Chemistry and Biology Specifications

When completing this questionnaire, please pay particular attention to the clarity of learning outcomes listed in each draft specification (syllabus). It is essential that the specification is as clear as possible since problems have been encountered in interpreting the learning outcomes of the Leaving Certificate Agricultural Science syllabus introduced in 2019.

Please complete this form by midnight on ***Sunday 11 February 2024*** *as the data from this questionnaire will be analysed over the mid-term break in order to meet the deadline set by NCCA for receipt of submissions.*

1. Are you a member of ISTA?

☐ Yes ☐ No

2. Please indicate which of the following Leaving Certificate subjects that you teach.

☐ Biology ☐ Chemistry ☐ Physics

3. The proposed breakdown of marks awarded to students in the draft specifications is 60% for the written paper and 40% for the additional assessment component research Investigation as described in the draft specifications. Are you happy with this breakdown?

☐ Yes ☐ No

4. Please explain your answer to the previous question.

____

5. If you answered "no" to question 3, please indicate your preferred allocation of marks to the additional assessment component Investigation.

☐ 10% ☐ 20% ☐ 30% ☐ Greater than 40%

6. Please indicate the level of laboratory equipment / resources that best describes those found in your school?

☐ Very well equipped ☐ Fairly well equipped ☐ Poorly equipped ☐ Very poorly equipped

7. Please explain your answer to the previous question.

____

8. Do you believe that your school laboratories have sufficient resources to support your students in completing to the best of their ability the additional assessment component research Investigation?

☐ Yes ☐ No

9. Please explain your answer to the previous question.

____

10. Please outline any concerns that you may have regarding the impact that the additional assessment component might have on the availability of school laboratories and laboratory resources to other classes such as Junior Cycle and Transition Year.

____

11. Have you any other comments on the proposed model of assessment of Leaving Certificate biology chemistry and physics additional assessment component" by means of a laboratory-based Investigation in sixth year as outlined in the draft specifications?

____

Biology Draft Specification

If you do not teach Leaving Certificate Biology, please move to the next section

12. **Clarity of learning outcomes**. From reading the learning outcomes in the draft biology specification, please estimate the percentage of learning outcomes that you feel are unclear.

Percentage ____________________

13. Please explain your answer to the previous question with reference to the relevant learning outcomes listed in the draft biology specification. You need not rewrite learning outcomes in full but simply refer to the page number and letter assigned as examples of learning outcomes that are unclear to you, e.g. "p. 19 LO c"

____

14. What topics, if any, have **not** been included in the draft biology specification which you feel should be included to cover the knowledge, skills and values required of Leaving Certificate biology students? Please state your reasons why these topics should be included

____

15. What topics, if any, have been included in the draft biology specification which you feel should **not** be included? Please state your reasons why these topics should not be included

____

16. From reading the draft specifications**,** are you clear on what mandatory laboratory practicals should be carried out by students in school laboratories**?**

☐ Yes ☐ No

17. Please explain your answer to the previous question.

____

18. Are you in favour of a list of mandatory student laboratory practicals being included in the final draft of the biology specification?

☐ Yes ☐ No

19. Please explain your answer to the previous question.

____

20. Any other comments?

____

21. Thank you for your feedback. If you are willing to share further insights into your answers, please provide your email address.

____

If you do not teach Leaving Certificate Chemistry or Physics you have now finished completing the questionnaire. Thank you for taking the time to complete this questionnaire. Your assistance in helping the ISTA to reflect the views of its members is very much appreciated

Chemistry Draft Specification

If you do not teach Leaving Certificate Chemistry, please move to the next section.

22. **Clarity of learning outcomes**. From reading the learning outcomes in the draft chemistry specification, please estimate the percentage of learning outcomes that you feel are unclear.

Percentage ______________________

23. Please explain your answer to the previous question with reference to the relevant learning outcomes listed in the draft chemistry specification. You need not rewrite learning outcomes in full but simply refer to the page number and letter assigned as examples of learning outcomes that are unclear to you, e.g. "p. 19 LO c"

____

24. What topics, if any, have **not** been included in the draft chemistry specification which you feel should be included to cover the knowledge, skills and values required of Leaving Certificate chemistry students? Please state your reasons why these topics should be included

____

25. What topics, if any, have been included in the draft chemistry specification which you feel should **not** be included? Please state your reasons why these topics should not be included

____

26. From reading the draft specifications**,** are you clear on what mandatory laboratory practicals should be carried out by students in school laboratories**?**

☐ Yes

☐ No

27. Please explain your answer to the previous question.

____

28. Are you in favour of a list of mandatory student laboratory practicals being included in the final draft of the chemistry specification?

☐ Yes ☐ No

29. Please explain your answer to the previous question.

____

30. Any other comments?

____

31. Thank you for your feedback. If you are willing to share further insights into your answers, please provide your email address.

____

If you do not teach Physics you have now finished completing the questionnaire. Thank you for taking the time to complete this questionnaire. Your assistance in helping the ISTA to reflect the views of its members is very much appreciated

Physics Draft Specification

32. **Clarity of learning outcomes**. From reading the learning outcomes in the draft physics specification, please estimate the percentage of learning outcomes that you feel are unclear.

Percentage _____________________

33. Please explain your answer to the previous question with reference to the relevant learning outcomes listed in the draft physics specification. You need not rewrite learning outcomes in full but simply refer to the page number and unique number assigned as examples of learning outcomes that are unclear to you, e.g. "p. 19 LO c is unclear because….."

____

34. What topics, if any, have **not** been included in the draft physics specification which you feel should be included to cover the knowledge, skills and values required of Leaving Certificate physics students? Please state your reasons why these topics should be included

____

35. What topics, if any, have been included in the draft physics specification which you feel should **not** be included? Please state your reasons why these topics should not be included

____

36. From reading the draft specifications, are you clear on what mandatory laboratory practicals should be carried out by students in school laboratories?

☐ Yes ☐ No

37. Please explain your answer to the previous question.

____

38. Are you in favour of a list of mandatory student laboratory practicals being included in the final draft of the physics specification?

☐ Yes ☐ No

39. Please explain your answer to the previous question.

____

40. Any other comments?

____

41. Thank you for your feedback. If you would be willing to share further insights into your answers, please provide your email address.

____

Thank you for taking the time to complete this questionnaire. Your assistance in helping the ISTA to reflect the views of its members is very much appreciated.

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