Report to the NCCA in response to the Leaving Certificate Biology, Chemistry and Physics Draft Specifications, by the IUA representatives to these Subject Development Groups

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February 2024

Please cite this report as:
Grenon, M., Kennedy, D., and McCauley, V. (2024). Report submitted to the NCCA in response to the Leaving Certificate Biology, Chemistry and Physics Draft Specifications, by the IUA Representatives to these Subject Development Groups. Irish Universities Association, Ireland.

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Executive Summary

This report summarises the response of the Irish University Association representatives on the NCCA Biology, Chemistry and Physics Subject Development Groups and their IUA colleagues to the Leaving Certificate Biology, Chemistry and Physics Draft Specifications (syllabi) published by NCCA in December 2023

Chapter 1 gives a short introduction to the role of IUA representatives and explains how data was gathered for this report. In all a total of 22 University Schools / Departments and individuals submitted responses via the online survey or via written submissions.

Chapter 2 addresses curriculum and syllabus design in Ireland in the past decade. In our role as university academics, we are fully supportive of the concept of learning outcomes and of designing syllabi within a learning outcomes framework. Indeed, as Ireland is a signatory to the Bologna Process, universities are obliged to ensure that teaching, learning and assessment in each institution is carried out within a learning outcomes framework. 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, teachers interpret the learning outcomes differently and the interpretation of learning outcomes by the State Examinations Commission may differ from that of some teachers. The experience of teachers with the new Leaving Certificate Agricultural Science specification is cause for concern. 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 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 a 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. 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 Biology, Chemistry and Physics 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 Biology, Chemistry and Physics 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.
(Oireachtas Committee, 2023 p.19)

Chapter 3 gives an overview of the three draft specifications and discusses a very significant problem with lack of clarity in very large numbers of the learning outcomes across the three specifications. This problem is summarised in the following table:

Subject	No. of learning outcomes	No. of learning outcomes that lack clarity	% of learning outcomes that lack clarity
Biology	99	66	**66.7%**
Chemistry	127	40	**31.5%**
Physics	101	69	**68.3%**

Feedback from IUA colleagues who responded to the survey, also highlighted this lack of clarity. An analysis of the unclear learning outcomes reveal that they fall into various categories:

- Learning outcomes that make no sense in the context in which they are being used.
- 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.
- Learning outcomes that use the term “primary data” when it is not necessary to use it.
- Learning outcomes that use the term “secondary data” when it is not necessary to use it.
- Learning outcomes that are vague and ill defined.
- Learning outcomes that do not clarify what laboratory practical work should be carried out in order to achieve the learning outcome.
- Learning outcomes that overlap

The vagueness of learning outcomes prompted comments on further implications including: student and teacher stress and a drop in student numbers choosing to study the science subjects due to perceived difficulty in preparing for examinations and performing well in the Leaving Certificate examination.

In addition to the lack of clarity in many learning outcomes, there is also a lack of clarity regarding the laboratory practical investigations required in order to achieve the appropriate learning outcomes for the three subjects. A list of mandatory student investigations was not included in any of the three specifications.

The Leaving Certificate Draft specifications in Biology, Chemistry and Physics have been published as ‘stand alone’ bare documents without any information on how the learning outcomes will be assessed and with 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 Biology, Chemistry and Physics. This is not in keeping 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 syllabus.

Analysis of Higher Level and Ordinary Level learning outcomes was carried out and concern is expressed about the balance between learning outcomes at these levels across the three specifications.

Chapter 4 discusses the Additional *Research Investigation* Assessment Component. It is proposed that 40% of the overall marks awarded by the SEC should be allocated for coursework involving a laboratory-based Research Investigation to be carried out by students. A total of 20 hours will be spent by students working in the school laboratory on this research project.

Feedback from university colleagues highlight a number of issues:

- The high percentage of marks (40%) allocated for a research project that takes 20 hours makes no sense given that it is recommended that the entire specification is taught in 180 hours.
- The availability of laboratory equipment / resources in schools to supply all students undertaking their research project.
- The Health and Safety implications of this huge volume of laboratory research investigations being carried out.
- Additional stress on teachers as they face the challenge of managing all their students undertaking individual research projects. Many science teachers teach more than one science subject.
- Additional stress on students. Students typically study 7 subjects for Leaving Certificate and some may take two or three science subjects.
- Adverse effect on uptake of Leaving Certificate Biology, Chemistry and Physics due to the large workload involved in carrying out the research project.
- Problem of cheating using Artificial Intelligence to carry out the coursework.
- Widening of the social divide within schools, and also between fee-paying schools that have additional sources of income and DEIS schools that cater for students from disadvantaged background.
- Importance of the provision of laboratory technicians to all schools. At present, laboratory technicians are mainly confined to fee-paying schools.
- The additional assessment component could 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.

It is clear that considerable funding would have to be provided to schools which are inadequately equipped. In addition, laboratory technicians would have to be appointed to schools – the majority of schools do not have them at present.

The additional stress on teachers may have the unintended consequences of making the profession of science teaching very unattractive to young graduates and hasten the retirement of existing science teachers. This will exacerbate the problems being encountered by school principals in recruiting science teachers.

Chapter 5 discusses the work needed to be carried out in order to bring the draft specifications up to a standard that is in keeping with international best practice in curriculum design so that they can be successfully implemented in the classroom. It is also important that they are brought up to the standard of the current Leaving Certificate Biology, Chemistry and Physics syllabi in order to satisfy matriculation requirements.

The conclusions and recommendations in Chapter 5 may be summarised as follows**:**

1. Lack of clarity in many learning outcomes. There is a lack of clarity in a large number of learning outcomes in the Leaving Certificate Physics, Chemistry and Biology Draft specifications - Physics (68.3%), Chemistry (31.5%) and Biology (66.7%). The three specifications lack the detail required by teachers to successfully implement them in the classroom. It is impossible for universities involved in Initial Teacher Education to adequately prepare student teachers to teach these specifications without more detail being provided.

Recommendation 1: in order to bring clarity to all learning outcomes that are unclear, the three draft specifications need to be brought up to standard by the relevant NCCA Subject Development Groups and revised appropriately for clarity of understanding. The dependence on an additional glossary of terms for interpretation should not be necessary.

2. **Lack of clarity regarding the mandatory laboratory practical investigations**. There is a lack of clarity across the learning outcomes that relate to practical investigation, in terms of specifying which laboratory practical investigations are mandatory, in addition to clarity around what it anticipated in the investigation itself, in order to achieve the appropriate learning outcome. The inclusion of mandatory student laboratory practical work is international best practice in curriculum design of laboratory science subjects. The Leaving Certificate Physics, Chemistry and Biology syllabi being taught in our schools at present contain these clear lists of mandatory student experiments.

Recommendation 2: Clear lists of mandatory student investigations should be drawn up for each specification by the relevant NCCA Subject Development groups and embedded into each of the three specifications.

3. **Additional information on assessment**. The three draft specifications have been published as 'stand alone' bare documents without any information on how the learning outcomes will be assessed. For example, there is 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 not in keeping with international best practice in curriculum design 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.

Recommendation 3: The Department of Education, the NCCA and SEC should publish the full range of syllabus documentation concurrently and not less than 12 months prior to implementation of any new syllabus. The syllabus documentation should include a detailed syllabus which embeds depth of treatment and comprehensive teacher guidelines for the syllabus, sample examination papers and sample marking schemes. New specifications and CPD programmes should not be implemented without all of these materials being available.

4. **Audit of time to implement the three specifications**. It is not clear if the draft specifications as published can be taught within the time period of 180 hours. This is of considerable importance given the time allocation of 20 hours to the Additional Assessment Component Research Investigation

Recommendation 4: When the detail described in recommendation 1 above is written into the draft specifications, an audit should be carried out by 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.

5. **The imbalance between Ordinary and Higher Level**. Concern is expressed at the imbalance between Ordinary and Higher level learning outcomes across the three specifications.

Recommendation 5: Discussions need to be held at NCCA Subject Development Group level to ensure the correct balance between Higher Level and Ordinary Level learning outcomes in all three specifications. Collaboration between the three groups should be initiated to assist in some level of consistency across the three specifications.

6. **Clear linking between learning outcomes and material in the SLA column**. In many cases there is no clear link between individual learning outcomes and material placed in the Student Learn About (SLA) column. This adds to the lack of clarity of the learning outcomes.

Recommendation 6: A clear method of linking each learning outcomes to information given in the SLA column should be devised to bring clarity to learning outcomes.

7. **Concerns about the Additional *Research Investigation* Assessment Component**. It is clear that requiring students to spend 20 hours carrying out a laboratory-based Research Investigation in Leaving Certificate has huge implications as outlined by our IUA colleagues and ourselves in this report. Among these concerns are:

- The high allocation of 40% of marks.
- Resource implications for laboratory equipment / supplies
- Additional stress on students and teachers.
- Adverse uptake on science subjects at Leaving Certificate level.
- Problems with access to school laboratories
- Widening of the social divide
- Health and Safety implications
- Increased workload on science teachers
- Profession of science teaching becoming less attractive.
- Lack of lab technician support

Recommendation 7: Given the feedback from our IUA colleagues and our experience in initial teacher education and university teaching, we cannot see how the proposed Additional Assessment Component model is feasible without huge investment in our school science laboratories and the employment of laboratory technicians. We recommend that an alternative model be developed to give students credit for carrying out laboratory practical work investigations and that the 40% of marks be reduced to 20%.

We wish to thank the NCCA for all the work that they have done to date in producing the three draft specifications. We look forward to working with them in a spirit of collaboration and partnership to ensure that the highest standards of curriculum specifications are in keeping with international best practice are developed in the areas of Leaving Certificate Biology, Chemistry and Physics.

Chapter 1 Introduction

For over 75 years, the Leaving Certificate has been accepted by Irish universities for matriculation purposes. This indicates that these universities are satisfied that successful completion of the Leaving Certificate curriculum certifies a student has reached a standard of education that prepares him/her for university study. To ensure that the standards of Leaving Certificate subjects meet the requirements of the universities, places have been allocated by the NCCA (and in an earlier era by the CEB and the Department of Education) for university representatives to serve on the individual subject development groups (previously referred to as syllabus committees or course committees).

In the past, two representatives from the Irish Universities Association served on each NCCA subject development group. However, in recent years this number has been reduced to one. Given that we are the sole IUA representative on each NCCA subject development group, we are fully cognisant of the great responsibility that this places on our shoulders. In addition, as representatives of the IUA, we fully appreciate the significance of the role of university subject representatives on each NCCA subject development group in ensuring that standards are maintained in our subjects so that the Leaving Certificate syllabus (specification) is an appropriate syllabus for university entrance.

The Leaving Certificate Physics, Chemistry and Biology Draft Specifications were published in December 2023. To fulfil our role as IUA representatives, we acted in 3 ways to allow IUA members to provide their feedback on the Biology, Chemistry and Physics specifications: (i) we requested that the IUA would inform member institutions of the consultation process that was in operation, (ii) we directly emailed our IUA colleagues in all universities in the various departments of Physics, Chemistry and Biology, alerting them that the consultation process was in operation and inviting them to provide feedback on the NCCA website and (iii) we also offered IUA colleagues the opportunity to provide us directly with their views on the Draft Specifications either directly, or through the online questionnaires to enable us to draft this report.

As December 2023 was a busy time in universities, as it coincides with the end of semester examinations, it was decided to wait until early January to issue a questionnaire to all university Schools / Departments of Biological Sciences, Chemistry and Physics to request feedback on the Leaving Certificate Draft Specifications. Copies of the online questionnaires issued to our university colleagues may be found in Appendices 1, 2 and 3. In all a total of 22 University Schools / Departments and individuals submitted responses via the online survey or via written submissions.

In this report we draw on the very valuable feedback from our IUA university, colleagues, our teaching experience across the sciences, our knowledge of our own specialist areas, our teacher education experience, our research experience in the areas of science and science education, our involvement with curriculum reform at national and international level and our experience of serving on the NCCA subject development groups.

Chapter 2 Syllabus design in Ireland in recent years

2.1 Introduction

As researchers in science and science education, we are acutely aware of reforms that are taking place in science education at national and international level. Indeed, two of the authors are actively involved in preparing student science teachers on their journey to become fully qualified teachers. In addition, we are closely involved in providing continuing professional development (CPD) to practising science teachers around Ireland though our links with various professional organisations such as the Irish Science Teachers' Association, the Royal Society of Chemistry, and the Institute of Physics.

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 raised regarding the syllabus alignment with principals of international best practice, which requires the design team to provide sufficient content detail for successful implementation in the classroom, and evidence of constructive alignment (Biggs 2005), i.e. there must be a clear alignment between learning outcomes, teaching and learning activities, and assessment. See Figure 2.1.

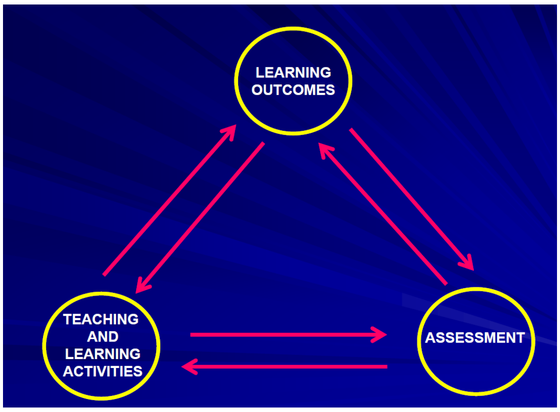

Figure 2.1 Constructive alignment in curriculum design involves the linking of learning outcomes to teaching and learning activities, and also to assessment. Unless all three domains are linked as shown, constructive alignment cannot exist.

In this report the terms 'syllabus' and 'specification' will be used interchangeably. The term 'syllabus' is the more commonly used term at international level.

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 the assessment of learning outcomes.

In short, for constructive alignment to exist, it should be clear to the teacher what teaching and learning activities to select, to ensure that the student achieves each individual learning outcome in their classroom. 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.

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.

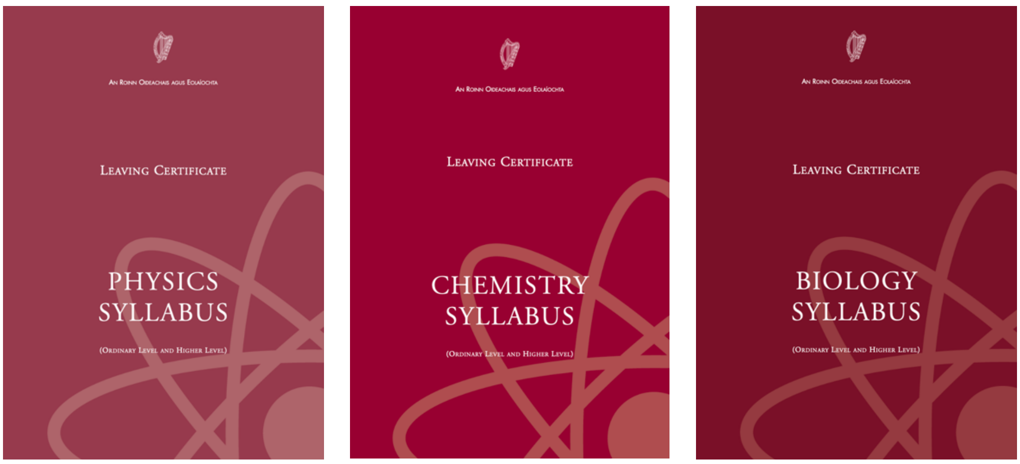

Figure 2.2 The Leaving Certificate Physics, Chemistry and Biology syllabi that are currently being taught in our schools are held in high esteem by teachers due the clarity of depth of treatment of topics being taught.

- **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 a 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. […] 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 their 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 under-statement 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 were:

- 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 Professor Áine Hyland, expert on curriculum design.

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.'

(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 have 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.

In our role as university academics, we are fully supportive of the concept of learning outcomes and of designing syllabi within a learning outcomes framework. Indeed, as Ireland is a signatory to the Bologna Process, universities are obliged to ensure that teaching, learning and assessment in each institution is carried out within a learning outcomes framework. However, 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. We are acutely aware of the problems caused by the "learning outcomes only" approach being adopted in Leaving Certificate Agricultural Science (Gallagher et. al, 2023). As a result, different teachers interpret the learning outcomes differently 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, 2006, p. 15). 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.

We do not see it as the role of the teacher or university lecturers in science education 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 chapter (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.

2.3 A Quality Co-Design Process

The co-design process that the NCCA *intends* to enact in terms of curricular design, and the invitation and incorporation of various stakeholder voices is laudable. However, the numerous reports detailed above by practising teachers, university academics and professional bodies, over the last decade (since 2014) have raised many concerns about the current curricular design in second level education, and many have yet to be addressed.

Concerns include:

- A curriculum written within a learning outcomes framework but with insufficient detail regarding depth of treatment of curriculum content,
- Learning outcomes that lack clarity/specificity
- The impact of vague syllabi on the wellbeing of both teachers and students
- Insufficient alignment between learning outcomes, teaching activities, and assessment
- The apparent lack of a transition pathway from junior science topics towards senior cycle
- The lack of evidence of an assessment of the timing allocated for teaching components of the syllabus. For instance a suggested teaching time allocation for strand topics, and additional coursework component.
- The lack of teacher guidance for curricular implementation, regarding a request for teacher guidelines and clarity on the assessment process with sample assessment materials and guidelines to be issued at the time of curricular consultation, prior to the implementation of any new syllabi.

In response, the NCCA has begun the process of responding favourably. In addition to the learning outcomes column (titled ‘Students should be able to’) in the Draft Physics, Chemistry and Biology Specifications, the column ‘Students Learn About’ has been included to allow for clarity regarding depth of treatment of the learning outcomes. This column is developed to different degrees across the three draft specifications, and is a considerable improvement on the Agricultural Science specification (introduced into schools in 2019) where the Students Learn About column is completely blank apart from a title! Therefore, we recommend that further attention is given here to adequately detail the content depth expected across the proposed new science specifications. Further clarity and response is also required regarding the items listed above, and it is hoped that this engagement will arise as a result of this valuable consultation.

In addition to the concerns raised above from multiple reports on curricular reform, the following three chapters offer specific suggestions, from the voices of IUA colleagues across the country, on how to further enhance the quality of these science curricular documents, to maintain and perhaps surpass the quality of standards currently in place.

Chapter 3 Analysis of Leaving Certificate Draft Physics, Chemistry and Biology, specifications

This chapter comments on the general introduction section to the Physics, Chemistry and Biology specifications, the use and quality of learning outcomes, the choice of content topics and the mandatory investigations included in the course. Specific comments relevant to each subject and collected from IUA colleagues are woven throughout.

3.1 General structure of the draft specifications

Introduction

The Introduction section of each of the draft specifications consists of ten or eleven pages (for Physics or Biology & Chemistry respectively) of broad introductory material that is not specific to any of the individual disciplines, and instead addresses the Senior Cycle in general. It details senior cycle Guiding Principles, Rationale & Aims, Continuity with Junior Cycle and Progression, Key Competencies, Teaching and Learning, and a Simplified Description of the Specification Strands.

Key competencies are introduced early on. As these competencies are generic and very general, they are sometimes difficult to interpret in the context of a given subject e.g. *being creative*, *communicatin*g, and *participating in society*. Regarding the Specifications Strands, each specification details the unifying strand called *The Nature of Science*, which is similar across the three science disciplines, in addition to the contextual strands. Table 3.1 gives an overview of the topic titles addressed in the Contextual Strands in Physics, Chemistry and Biology.

Table 3.1 An Overview of the Contextual Strands in Physics, Chemistry and Biology

Subject	Subject specific Contextual stands
Biology	*The Organisation of Life, The Structure and Processes of Life, & The Interactions of Life*
Chemistry	*The Nature of Matter*, *Behaviour of Matter*, *Interactions of Matter, & Matter in our World*
Physics	*Forces and Motion, Waves and Energy transfer, Electricity and Magnetism, & Modern Physics*

Strands of study and learning outcomes

This part of the specification depicts the core of the specifications and is further commented on in section 3.2.

Assessment

This last section of the specification is five pages long and is similar across the three subjects. It presents the assessment for certification, including 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/Chemistry/Biology in Practice Investigation which is also described in this section. The section also addresses the mark descriptor, a brief note on the written examination and reasonable accommodations, as well as a section on leaving certificate grading.

3.2 Learning outcomes across the draft specifications

Analysis of clarity of learning outcomes

An analysis of all the learning outcomes in the contextual strands of the Leaving Certificate Biology, Chemistry and Physics Draft specifications was carried out by the Irish Science Teachers' Association (ISTA 2024). The ISTA report highlighted that a very significant problem with the three draft specifications was the lack of clarity in very large numbers of the learning outcomes. We have carefully studied this analysis (ISTA 2024) and we confirm that we agree with the details of analysis carried out by the ISTA. Details on the lack of clarity in many of the learning outcomes are given in Table 3.2

Table 3.2 An Overview of the Learning outcomes in Physics, Chemistry and Biology, as reported by the Irish Science Teachers Association (ISTA 2024)

Subject	No. of learning outcomes	No. of learning outcomes that lack clarity	% of learning outcomes that lack clarity
Biology	99	66	**66.7%**
Chemistry	127	40	**31.5%**
Physics	101	69	**68.3%**

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

- Learning outcomes that make no sense in the context in which they are being used.
- 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.
- Learning outcomes that use the term "primary data" when it is not necessary to use it.
- Learning outcomes that use the term "secondary data" when it is not necessary to use it.
- Learning outcomes that are vague and ill defined.
- Learning outcomes that do not clarify what laboratory practical work should be carried out in order to achieve the learning outcome.
- Learning outcomes that overlap

The lack of clarity in the learning outcomes was also illustrated by feedback from our IUA colleagues. Details of some of the points made are listed in Appendix 4. The comments express both agreement and disagreement regarding clarity of learning outcomes. The questionnaire did not ask for quantitative data to be supplied. This created difficulty in undertaking a quantitative analysis. In addition, a statistical analysis was difficult as some submissions were made by entire university Schools / Departments and others were individual submissions.

The general themes that arose in the feedback from IUA colleagues regarding the learning outcomes component fell into three categories. There was much frustration regarding the need for clarity in the narrative of the learning outcomes (Direct quotes are available in Appendix 6). Further specific learning outcomes across the three specifications were queried, in some instances with suggestions to aid clarification. These are detailed in Appendix 6 also.

Feedback from IUA colleagues regarding the learning outcomes is summarised below:

- ***Frustration regarding the use of vague action verbs***. The vagueness of learning outcomes prompted comments on further implications including: teacher stress, drop in student numbers due to perceived difficulty and confusion over need for a glossary of action verbs when plain English should be sufficient. The use of the verb "model" in the Physics and Chemistry specifications caused particular difficulty. Information linked to individual learning outcomes should be clearly shown in the *Students learn about* column. Placing each learning outcome in its own row with the corresponding information in the same row of the *Students learn about* column would assist with this clarity.

- **Seeking clarity regarding the mandatory laboratory investigations learning outcomes.** Multiple commentaries were received on whether or not there are any mandatory experiments to be carried out and seeking clarity around whether qualitative or quantitative data is being sought. Some comments received from IUA colleagues on the need to have clarity in the mandatory investigation learning outcomes are summarised in Appendix 5

- **Discipline-specific queries on Learning Outcomes.** In many cases, queries were raised on learning outcomes that were specific to the individual subjects. These are listed individually or Physics, Chemistry and Biology in Appendix 6.

Higher Level and Ordinary Level Learning outcomes

Table 3.3 illustrates the balance of learning outcomes at both Higher Level and Ordinary Level. A review of each of the three draft specifications is needed, and an appropriate assessment of the Ordinary and Higher Level curricula carried out as individual entities – as is the case with the Leaving Certificate Biology, Chemistry and Physics syllabi currently being taught in our schools.

Table 3.3 An Overview of the Learning Outcomes at Ordinary and Higher Level in Physics, Chemistry and Biology

Subject	Number of Learning Outcomes	Number of Learning Outcomes Ordinary level	Additional Higher level Learning Outcomes
Biology	*99*	*82*	*17*
Chemistry	*127*	*92*	*35*
Physics	*101*	*91*	*10*

3.3 Assessment of learning outcomes

As lecturers in the areas of science and science education, we find it strange that the Leaving Certificate Draft specifications in Biology, Chemistry and Physics have been published as "stand alone" 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 not in keeping 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.

In November 2023 the authors of this report wrote to the Irish Universities Association to request that it formally supports the policy of teachers, raised by their ASTI and TUI union representatives in the Biology, Chemistry and Physics Subject Development Groups as follows:

> *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*

Having studied the three draft specifications, we feel that it is more important than ever to reiterate our support for the above ASTI and TUI policy in order to bring this level of clarity to the assessment of learning outcomes. The above policy of the teachers' unions is based on international best practice for syllabus design. In addition, it is clear from research reports (IASTA 2019, 2021) that vague syllabi can cause huge stress among teachers and their students and can damage the subject in terms of numbers choosing to study the subject.

3.4 Topic coverage in the specifications

Although it is difficult to agree on the ideal topic coverage, feedback was collected from IUA members regarding topics missing from the three draft specifications. Answers focused on topics coverage and are summarised below thematically. Details comments are also added. Physics, Chemistry and Biology topics that IUA colleagues suggested to be included or reviewed are listed in Table 3.4. Further details are given in Appendix 6

Table 3.4 An Overview of the Topics in Physics, Chemistry and Biology, that IUA members suggested could be included or reviewed in the associated specification.

Discipline	Topics
Physics Topics to be included	Blackbody radiation, Sustainable energy, solar energy, Energy storage, Greenhouse effect, Radon gas and levers/moments.
Chemistry Topics on draft specification to be included/reviewed	Electrochemistry, Atomic Structure, Chemical Bonding, Sustainability, Analytical Chemistry and Macromolecules, analytical chemistry and nanotechnology, New Developments in Chemistry, Options A and B
Biology Topics on draft specification to be included/reviewed	Plant Science, Biodiversity, climate, Parasites, Ecology, Immunology, , Biotechnology and Molecular genetics, Sustainability and Technology and associated Ethical Concerns, Skeleton, senses and muscles

3.5 Mandatory Student Investigations

Lack of clarity of experimental work to be performed

There is a lack of clarity regarding the laboratory practical investigations required in order to achieve the appropriate learning outcomes for the three subjects. A list of mandatory student investigations was not included in any of the three specifications. It is recommended that this list is drawn up by each NCCA development group to bring clarity to what laboratory practical work is needed in order to successfully implement the specification in the classroom. This clarification is essential in helping teachers securing resources for the correct equipment of their laboratory.

About three quarter of the respondents noted that they were not clear following their review of the specifications, about what laboratory work was expected.

Table 3.6 An Overview of IUA colleagues feedback regarding whether they felt that there was clarity in the specifications in terms of what laboratory work should be carried out by students.

From reading the draft specifications, are you clear on what laboratory work should be carried out by students in school laboratories?		
	% Yes	% No
Biology	30	70
Chemistry	29	71
Physics	0	100
Average	24	76

Subject specific comments from submissions received from IUA colleagues regarding the mandatory experiments are summarised in Table 3.6 below and detailed in Appendix 5.

Table 3.6 An Overview of specific comments from submissions received from IUA colleagues regarding the mandatory experiments

Discipline	Identified issues
Physics	Not clear what laboratory work is intended, lack of clarity in learning outcomes relating to laboratory work, lack of a list of experiments to be carried out, issues with equality across schools.
Chemistry	Lack of clarity about what investigation is expected from the learning outcomes, the need for a list of mandatory experiments and how they will be examined, teacher guidance needed on lab work, details of school equipment needed for lab experiments is required, lack of clarity of lab work will lead to increased stress for teachers and students.
Biology	Lack clarity on laboratory work, need for specific list of experiments, need for mandatory experiments to be clarified, clarification needed on school equipment, lack of field work.

Chapter 4 Additional Assessment Component - Research Investigation

4.1 Introduction

In each of the Biology, Chemistry and Physics Draft Specifications it is proposed that 40% of the overall marks awarded by the SEC should be allocated for coursework involving a laboratory-based Research Investigation to be carried out by students. A total of 20 hours will be spent by students working in the school laboratory on this research project. A similar research project called an *Individual Investigative Study* (IIS) is currently in operation in Agricultural Science and is worth 25%. Precise details have not been provided in the Leaving Certificate Biology, Chemistry and Physics Draft Specifications but it is felt that the coursework may be broadly similar to that in Agricultural Science.

In 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 fifth year. The IIS report must be submitted by sixth-year students by a deadline in April.

4.2 Perspectives from Science Teacher Education

As lecturers in Science Education, we frequently visit a wide variety of schools in which our student teachers are on teaching placement. Whilst the concept of Leaving Certificate students carrying out their own research projects is an excellent one, we have some concerns as to the feasibility of this model of giving credit to students for carrying out practical work.

The number of students who sat for the Leaving Certificate Physics, Chemistry and Biology examinations in 2023 may be summarised in Table 4.1

Table 4.1 An Overview of the number of students who sat for the Leaving Certificate Physics, Chemistry and Biology examinations in 2023

Subject	Number of students
Biology	**34,602**
Chemistry	**9,750**
Physics	**7,526**
Total	**51,878**

Many students study more than one subject. Hence, there could be as many as 70,000 Leaving Certificate students undertaking laboratory-based research projects in sixth year in schools throughout Ireland. This is in addition to the 7460 students undertaking Agricultural Science research projects.

Based on our experience as science education lecturers, we have serious concerns about the following:

- The high percentage of marks (40%) allocated for a research project that takes 20 hours makes no sense given that it is recommended that the entire specification be taught in 180 hours.

- The availability of laboratory equipment / resources in schools to supply all students undertaking their research project.

- The Health and Safety implications of this huge volume of laboratory research investigations being carried out.

- Additional stress on teachers as they face the challenge of managing all their students undertaking individual research projects. Many science teachers teach more than one science subject.

- Additional stress on students. Students typically study 7 subjects for Leaving Certificate and some may take two or three science subjects.

- Adverse effect on uptake of Leaving Certificate Physics, Chemistry and Biology due to the large workload involved in carrying out the research project.

- Problem of cheating using Artificial Intelligence to carry out the coursework.

- Widening of the social divide between fee-paying schools that have additional sources of income and DEIS schools that cater for students from disadvantaged background.

- Importance of provision of laboratory technicians to all schools. At present, laboratory technicians are mainly confined to fee-paying schools.

- The additional assessment component could 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.

We share the Health and Safety concerns highlighted by our IUA colleagues of the implications of large numbers of different research projects being carried out without any support of lab technicians.

Many of our concerns align with the feedback on the Agricultural Science Individual Investigative Study (ISTA 2024) summarised here:

- 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 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.
>
> (ISTA, 2024)

It is clear that considerable funding would have to be provided to schools which are inadequately equipped. In addition, laboratory technicians would have to be appointed to schools – the majority of schools do not have them at present. At third level, in a laboratory of 24 students, it is common practice to have two laboratory tutors present and also the assistance of a laboratory technician. How can one expect a single teacher to manage this huge workload on their own? The Health and Safety implications are considerable and risk assessments need to be carried out for each individual research investigation project.

The additional stress on teachers may have the unintended consequences of making the profession of science teaching very unattractive to young graduates and hasten the retirement of existing science teachers. This will exacerbate the problems being encountered by school principals in recruiting science teachers.

Therefore, we recommend that an alternative model be developed to give students credit for carrying out laboratory practical work and that the 40% of marks be reduced to 20%.

4.3 Perspectives from IUA Colleagues

Feedback was invited from IUA colleagues on the inclusion and impact of the proposed Research Investigation component. Responses were collated through the online questionnaire and some emailed submissions from various university Departments/ Schools. Quotes illustrating each of these themes are detailed in Appendix 7.

The general themes regarding the assessment component include:

- ***inappropriate percentage weighting of the coursework component,*** e.g. such a large weighting given to coursework question around adequate time to teaching curriculum content within the time allocated

- **broadening social division**, e.g. unfair advantage of some students regarding resources and social capital heightened with high weighted coursework component, laboratory technicians only available in schools with private funding, more laboratories available in private schools and higher levels of equipping of laboratories.

- **questioned whether there would be sufficient resourcing of the coursework component**, e.g. funding to pay for technician support, Health and Safety support, costing of materials (equipment/chemicals) for carrying out such a wide variety or research investigations

- **stress impact on teachers and students**, e.g. pressure of large assessment weighting, time to complete core course content, students opting out of science, volume of content to be taught in 160 hours. Clarity of guidance on what the coursework entails. Students carrying out several research investigations across many subjects, high percentage of 40% for each investigation in a high-stakes examination,

- **integrity issues with recent access to AI*,*** e.g. integrity issues that arise with ubiquitous access to AI

Chapter 5 Conclusions and Recommendations

5.1 Introduction

There is a consensus that updating and revising the existing Leaving Certificate Curricula in Physics, Chemistry and Biology is welcomed. A lot of thought and effort has been expended in bringing new draft specifications forward for consideration, as well as in the modernising and broadening of the topics under consideration.

It is clear from the feedback received from our IUA colleagues and from our own analysis of the Leaving Certificate Draft Biology, Chemistry and Physics specifications that these drafts are in an unfinished state. A considerable amount of work needs to be carried out in order to bring them up to a standard that is in keeping with international best practice in curriculum design so that they can be successfully implemented in the classroom. It is also important that they are brought up to the standard of the current Leaving Certificate Biology, Chemistry and Physics syllabi in order to satisfy matriculation requirements.

5.2 Conclusions and Recommendations

The conclusions and recommendations may be summarised as follows:

1. Lack of clarity in many learning outcomes. There is a lack of clarity in a large number of learning outcomes in the Leaving Certificate Physics, Chemistry and Biology Draft specifications - Physics (68.3%), Chemistry (31.5%) and Biology (66.7%). The three specifications lack the detail required by teachers to successfully implement them in the classroom. It is impossible for universities involved in Initial Teacher Education to adequately prepare student teachers to teach these specifications without more detail being provided.

Recommendation 1: in order to bring clarity to all learning outcomes that are unclear, the three draft specifications need to be brought up to standard by the relevant NCCA Subject Development Groups and revised appropriately for clarity of understanding. The dependence on an additional glossary of terms for interpretation should not be necessary.

2. **Lack of clarity regarding the mandatory laboratory practical investigations**. There is a lack of clarity across the learning outcomes that relate to practical investigation, in terms of specifying which laboratory practical investigations are mandatory, in addition to clarity around what it anticipated in the investigation itself, in order to achieve the appropriate learning outcome. The inclusion of mandatory student laboratory practical work is international best practice in curriculum design of laboratory science subjects. The Leaving Certificate Physics, Chemistry and Biology syllabi being taught in our schools at present contain these clear lists of mandatory student experiments.

Recommendation 2: Clear lists of mandatory student investigations should be drawn up for each specification by the relevant NCCA Subject Development groups and embedded into each of the three specifications.

3. **Additional information on assessment**. The three draft specifications have been published as 'stand alone' bare documents without any information on how the learning outcomes will be assessed. For example, there is 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 not in keeping with international best practice in curriculum design 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.

Recommendation 3: The Department of Education, the NCCA and SEC should publish the full range of syllabus documentation concurrently and not less than 12 months prior to implementation of any new syllabus. The syllabus documentation should include a detailed syllabus which embeds depth of treatment and comprehensive teacher guidelines for the syllabus, sample examination papers and sample marking schemes. New specifications and CPD programmes should not be implemented without all of these materials being available.

4. **Audit of time to implement the three specifications**. It is not clear if the draft specifications as published can be taught within the time period of 180 hours. This is of considerable importance given the time allocation of 20 hours to the Additional Assessment Component Research Investigation

Recommendation 4: When the detail described in recommendation 1 above is written into the draft specifications, an audit should be carried out by 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.

5. **The imbalance between Ordinary and Higher Level**. Concern is expressed at the imbalance between Ordinary and Higher level learning outcomes across the three specifications.

Recommendation 5: Discussions need to be held at NCCA Subject Development Group level to ensure the correct balance between Higher Level and Ordinary Level learning outcomes in all three specifications. Collaboration between the three groups should be initiated to assist in some level of consistency across the three specifications.

6. **Clear linking between learning outcomes and material in the SLA column**. In many cases there is no clear link between individual learning outcomes and material placed in the Student Learn About (SLA) column. This adds to the lack of clarity of the learning outcomes.

Recommendation 6: A clear method of linking each learning outcomes to information given in the SLA column should be devised to bring clarity to learning outcomes.

7. **Concerns about the Additional *Research Investigation* Assessment Component**. It is clear that requiring students to spend 20 hours carrying out a laboratory-based Research Investigation in Leaving Certificate has huge implications as outlined by our IUA colleagues and ourselves in this report. Among these concerns are:

- The high allocation of 40% of marks.
- Resource implications for laboratory equipment / supplies
- Additional stress on students and teachers.
- Adverse uptake on science subjects at Leaving Certificate level.
- Problems with access to school laboratories
- Widening of the social divide
- Health and Safety implications
- Increased workload on science teachers
- Profession of science teaching becoming less attractive.
- Lack of lab technician support

Recommendation 7: Given the feedback from our IUA colleagues and our experience in initial teacher education and university teaching, we cannot see how the proposed Additional Assessment Component model is feasible without huge investment in our school science laboratories and the employment of laboratory technicians. We recommend that an alternative model be developed to give students credit for carrying out laboratory practical work investigations and that the 40% of marks be reduced to 20%.

We wish to thank the NCCA for all the work that they have done to date in producing the three draft specifications. We look forward to working with them in a spirit of collaboration and partnership to ensure that the highest standards of curriculum specifications are in keeping with international best practice are developed in the areas of Leaving Certificate Biology, Chemistry and Physics.

Appendix 1

IUA Online Questionnaire
Feedback on Draft Biology Specification (Syllabus)

1. Your Name ______________________________

2. Name of Institution _____________________________________

3. Your email address: ____

4. Please comment on the learning outcomes listed in the draft specification (p. 14 – 30).

____

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

____

6. What topics, if any, have been included in the draft specification which you feel should <u>not</u> be included? Please state your reasons why these topics should not be included

____

7. From reading the draft specifications, are you clear on what laboratory work should be carried out by students in school biology laboratories?

☐ Yes ☐ No

Please explain

____

8. Please comment on the proposed model of assessment of Leaving Certificate biology as outlined on p. 31 – 37 of the draft specification.

____

9. Any other comments?

____

Thank you for completing this questionnaire. Your help is very much appreciated.

Appendix 2

IUA Online Questionnaire
Feedback on Draft Chemistry Specification (Syllabus)

1. Your Name ______________________________

2. Name of Institution _____________________________________

3. Your email address: ____

4. From reading the learning outcomes in the draft specification, are you clear about what is expected to be taught for each topic?

☐ Yes ☐ No

Please explain with reference to the relevant learning outcomes listed in the draft specification (p. 14 – 30).

____

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

____

6. What topics, if any, have been included in the draft specification which you feel should <u>not</u> be included? Please state your reasons why these topics should not be included

____

7. From reading the draft specifications, are you clear on what laboratory work should be carried out by students in school Chemistry laboratories?

☐ Yes ☐ No

Please explain

____

8. Please comment on the proposed model of assessment of Leaving Certificate Chemistry as outlined on p. 43 – 49 of the draft specification.

____

9. Any other comments?

____

Thank you for completing this questionnaire. Your help is very much appreciated.

Appendix 3

IUA Online Questionnaire
Feedback on Draft Physics Specification (Syllabus)

1. Your Name ______________________________

2. Name of Institution _____________________________________

3. Your email address: ____

4. From reading the learning outcomes in the draft specification, are you clear about what is expected to be taught for each topic?

☐ Yes ☐ No

Please explain with reference to the relevant learning outcomes listed in the draft specification (p. 14 – 30).

____

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

____

6. What topics, if any, have been included in the draft specification which you feel should not be included? Please state your reasons why these topics should not be included

____

7. From reading the draft specifications, are you clear on what laboratory work should be carried out by students in school Physics laboratories?

☐ Yes ☐ No

Please explain

____

8. Please comment on the proposed model of assessment of Leaving Certificate Physics as outlined on p. 29 – 34 of the draft specification.

____

9. Any other comments?

____

Thank you for completing this questionnaire. Your help is very much appreciated.

Appendix 4

Comments from IUA colleagues regarding lack of clarity in learning outcomes in the Draft Biology, Chemistry and Physics Draft Specifications

***Frustration regarding the use of vague action verbs**:*

The draft specification consists of a series of learning outcomes. There is not enough depth given so there will be a lot of ambiguity amongst teachers. There will be no consistent standards across classrooms due to this lack of clarity.

The NCCA must review the design of this syllabus. It requires much more detail. It is a shambles compared to international syllabi

From my in depth reading of the draft, I would estimate that about half of all of it lacks clarity. There is a serious lack of depth of treatment as well as a lack of purpose.

This draft specification is certainly not ready for release and will need significant refinements and teacher buy-in.

Details are very vague in certain instances. Learning outcomes need to be more specific.

Many learning outcome are not clear.

There is a serious lack of detail and clarity in the new Syllabus

I have concerns about the use of the term “DISCUSS” in the “specifications”. While this is a fine use of students’ time in the classroom – and indeed I’m sure is already carried out in most classrooms as things stand – I’m not so sure how it can be assessed properly; open-ended questions have not been a feature of chemistry exams. The glossary of action terms defines “discuss” as “to offer a considered, balanced review that includes a range of arguments, factors or hypotheses; opinions or conclusions should be presented clearly and supported by appropriate evidence”. In this context, if a question such as “Discuss causes of water contamination” MW3 (f) appear in an exam, how is a student meant to know what exactly is being asked for, and in what detail?

There are numerous learning outcomes where wording is quite vague and needs to be more carefully specified and/or using correct scientific terminology. Some of these include 22 e, 23 a, 25 b, 30 a, 37 c. All learning outcomes containing an 'RI' component are vague; what needs to be done to properly complete these 'research investigation' learning outcomes? How much time/effort should students spend on these?

In many cases, there is no issue because of the similarity to the topics as they are already being taught and examined at the moment. However, in other instances, it is not stated specifically what detail is required, e.g. MW 3 "analyse water samples, both qualitatively and quantitatively", is far too broad.

Physics is perceived as a difficult subject. Writing the specification in riddles is not helping teacher to be clear to the pupils on what they need to know, understand and be able to do. Unless the teacher is clear on what they have to do, they cannot provide clarity to their students. I am very concerned that prospective physics students of this University will not choose physics for fifth year as there will be easier, more reliable ways to get points. In addition I do not think that many physics graduates go into teaching, so it is important that a very good teacher education system be in place so as interested but perhaps less qualified teachers can learn the necessary physics for school and inspire the next generation!

There should be a clear linking of each learning outcome to the material in the "Students Learn About" column. Each learning outcomes should be in its own specific row and the material in the Students Learn About column placed in the row next to it. Keep it simple and clear!

However, concerning the more detailed Learning Outcomes in the draft, we believe there is a serious lack of information concerning the details of their implementation, and more generally a lack of direction to both the teacher and student as to how these outcomes will be achieved. Many of the Outcomes appear to be weakly or even poorly formulated.

We urge that the entire text be appropriately adjusted and clarified across all Strands of the new Syllabus. More direct terminology and clarification is key, otherwise we have no doubt that this will seriously affect the uptake of LC Physics in the immediate term.

As an aside, a note on the "Glossary of Action Verbs" in the appendix of the Draft Specification. In contrast to the level of technical detail that we believe is missing outlined above, this seems un-necessarily burdensome and (frankly) somewhat pedantic, which we fear will also act to put people off the course, teachers and students alike.

I've no idea what "students should be able to model pressure" means on p.16. Probably says more about me but I find a lot of learning outcomes pretty meaningless.

Model pressure? What does that mean? Even the explanation of model is confusing. 'Use words, diagrams, numbers, graphs and equations to describe phenomena make justified predictions and solve problems'. Why not just make a clear statement of what you want students to know, understand and be able to do. Also 'explore the use of optics in a variety of applications using secondary sources' Some teachers may do Polaroid glasses and reading glasses and other may do the Newtonian Telescope or a camera. How can this be assessed?

***Physics Specific Comments on Learning Outcomes**:*

There is a somewhat peculiar emphasis on the importance of “modelling”, when what the student is really being asked to first develop an understanding of the key concepts, most likely with the accompanying mathematical interpretation, before applying this in the context of modelling, verification and real world cases, for example.

The action verb "measure" is only used once in the context of "constant and varying linear motion"

I do not understand at all how for a physics curriculum the action: Measure is used only once in the entire curriculum. Clearly the entire concept of physics/physical science is that any model/information/theory is backed up by actual measurements. The way this curriculum is defined the student will not be measuring anything themselves, which in my opinion is one of the most crucial part. We can teach them a lot of theory but at one stage a student needs to experience the connection between a hand-on doing things/getting measurements to the underlying theory.

Physics tends to be a traditional subject and should be straightforward to understand. However some of the areas of the course are very open ended and some seem impossible to do. e.g. model pressure? What does that mean? Even the explanation of model is confusing. 'Use words, diagrams, numbers, graphs and equations to describe phenomena make justified predictions and solve problems'. Why not just make a clear statement of what you want students to know, understand and be able to do. Also 'explore the use of optics in a variety of applications using secondary sources' Some teachers may do Polaroid glasses and reading glasses and other may do the Newtonian Telescope or a camera. How can this be assessed?

How can you take proper measurements for the following experiment? : 'relate the pitch and loudness of sounds to their wave characteristics using primary and secondary data' Is this quantitative data or qualitative data? As loudness depends on both frequency and pitch, this is not a fair test. They are many more examples where the physics behind some investigations is naive at best.

Some lab work is very clear, but some is not clear and simply unclear how each student can collect primary data. e.g. 'Relate the pitch and loudness of sounds to their wave characteristics using primary and secondary data'. e.g. analyse diffraction using primary and secondary data. the quality of the data for some of these experiments may not mount to much. Would the diffraction grating be satisfactory for this instead of Young's Slits?

We are also concerned that several aspects of the mandatory experiments are very poorly specified - for example, “Analyse diffraction, two source interference, Measure the wavelength of light…” how are these to be carried out ? There is a real danger that the teacher will be at a loss to know how to run these experiments without more detail.

Chemistry Specific Comments on Learning Outcomes:

In many cases, there is no issue because of the similarity to the topics as they are already being taught and examined at the moment. However, in other instances, it is not stated specifically what detail is required, e.g. MW 3 "analyse water samples, both qualitatively and quantitatively", is far too broad.

I have concerns about the use of the term "DISCUSS" in the "specifications". While this is a fine use of students' time in the classroom – and indeed I'm sure is already carried out in most classrooms as things stand – I'm not so sure how it can be assessed properly; open-ended questions have not been a feature of chemistry exams. The glossary of action terms defines "discuss" as "to offer a considered, balanced review that includes a range of arguments, factors or hypotheses; opinions or conclusions should be presented clearly and supported by appropriate evidence". In this context, if a question such as "Discuss causes of water contamination" MW3 (f) appear in an exam, how is a student meant to know what exactly is being asked for, and in what detail?

There are numerous learning outcomes where wording is quite vague and needs to be more carefully specified and/or using correct scientific terminology. Some of these include 22 e, 23 a, 25 b, 30 a, 37 c. All learning outcomes containing an 'RI' component are vague; what needs to be done to properly complete these 'research investigation' learning outcomes? How much time/effort should students spend on these?

Would the analysis of dissolved oxygen not be better carried out using oxygen electrodes and data logging rather than via the Winkler method? This would certainly require less class time and would be more up-to-date.

Why have they extended the number of carbon atoms in hydrocarbons, and particularly alkenes, to C-10?

The return of bond energy calculations seems unnecessary

Why require the term enthalpy? I know it is more correct, but it is very tricky to explain it without introducing the concept of entropy and I think it is unnecessary to replace "heat of reaction" with "enthalpy within the system".

In IM2, when discussing the effect of concentration on rate of reaction, why are the students being confused with the idea of concentration not always having an effect on rate? A proper explanation of this requires an introduction to the concept of order of reaction, which is surely not intended. •There is enough material in organic chemistry without adding stereoisomerism

***Biology Specific Comments on Learning Outcomes**:*

Under SPL4 Response, one of the areas is Immunity but there is no information as to what the students will learn about (it is blank). The information as to what the students will be able to do is not sufficient to know what will be covered.

Under OrgL1 The characteristics of life, the learning about should refer to "domains of life" and not three domains of life" as this is still an area where such detail is debated as more phylogenomic data become available.

SPL4 Response, Immunity. It is not clear what will be covered under innate and acquired immunity. This needs to include the non-specific innate system (TLR, inflammatory response, etc). The information on what the students will be able to do looks limited. There is also a lack of information as to what will be covered under infectious diseases.

Under IL2 (Nutrient Cycles), it is not clear why "Common mechanisms of molecular genetics in microorganisms and humans" is here. Looks misplaced?

Under IL3 The information of life - biotechnology, there needs to be a specific mention of CRIPSR technologies and genome engineering (under what students will learn about)

The draft specification consists of a series of learning outcomes. There is not enough depth given so there will be a lot of ambiguity amongst teachers. There will be no consistent standards across classrooms due to this lack of clarity. The majority of the biology specification is unclear for example SPL2a, SPL2b, SPL1c, SPL4, ILIe, OrgL4b

Many learning outcome are not clear. For example; use classification principles to identify and classify living things in known and unknown contexts; examine the importance of classification systems in biology. 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?

Using models to explain the two stage process of photosynthesis -students will find this very difficult.

Appendix 5

Comments from IUA colleagues regarding lack of clarity in learning outcomes regarding the Mandatory Student Investigations

***Frustration regarding the clarity in learning outcomes related to mandatory student investigations**:*

Seeking clarity regarding the mandatory experiment learning outcomes - is qualitative or quantitative data expected?:

There is no clear lab studies that I can determine, experiment is referenced several times with only one mention of laboratory

To me the practical laboratory work is not immediately clear in the draft document & it would be beneficial if particular experiments could be described in more detail.

The verb 'investigate' is present in some of the learning outcomes, I would presume this is the practical work the question refers to. If this is the case, there is very limited practical work expected of students. It would be better to have a mandatory list of practicals.

The only thing that is clear is that there are no mandatory laboratory experiments. This is a frightening prospect and a backward step. I would have real concerns that some schools will not do experiments if they are not prescribed and mandatory. This in turn would have very serious implications for those students as they progress to 3rd level.

I would worry about the amount of equipment that will be needed by schools. There will be to be a lot of funding allocation needed for this. It is not clear what experiments are actually mandatory.
There is no information regarding laboratory work given in the document.

Is there a list of experiments? I can't dig out from all the blurb what experiments they will do. Maybe I'm missing something.

How can you take proper measurements for the following experiment? : 'relate the pitch and loudness of sounds to their wave characteristics using primary and secondary data' Is this quantitative data or qualitative data? As loudness depends on both frequency and pitch, this is not a fair test. They are many more examples where the physics behind some investigations is naive at best.

Some lab work is very clear, but some is not clear and simply unclear how each student can collect primary data. e.g. 'Relate the pitch and loudness of sounds to their wave characteristics using primary and secondary data'. e.g. analyse diffraction using primary and secondary data. the quality of the data for some of these experiments may not mount to much. Would the diffraction grating be satisfactory for this instead of Young's Slits?

We are also concerned that several aspects of the mandatory experiments are very poorly specified - for example, “Analyse diffraction, two source interference, Measure the wavelength of light…” how are these to be carried out ? There is a real danger that the teacher will be at a loss to know how to run these experiments without more detail.

In many cases, there is no issue because of the similarity to the topics as they are already being taught and examined at the moment. However, in other instances, it is not stated specifically what detail is required, e.g. MW 3 "analyse water samples, both qualitatively and quantitatively", is far too broad.

I’m presuming that the specified experiments that we can identify as “mandatory experiments” will be examined in the same way that they are at the moment, looking for specific details and observations etc of the practical. However, what is going to be the case with the other, unspecified “primary data” investigations that are mentioned?
The “specification” states: “Whilst the contextual strands set out situations where students are required to gather primary data to verify observations and mathematical relationships, this is a minimum requirement and it is not expected that practical opportunities would be limited to these situations”.
If the questioning of these in the exam is open-ended, this would likely lead to significant uncertainty as to the detail required. They also lead to more preparatory work and time, and therefore stress, for teachers. If the case is to be that these unspecified experiments are not to be examined at all, then they are likely to be ignored in many instances as the course is long enough as it is.

A clear list of mandatory experiments needs to be created, with further detailed guidance for teachers. At the moment it is very unwieldy to find in the specification what the 'EI' experiments are, and for some of them the descriptions give too little detail.

Subject Specific Comments related to Mandatory Practical Investigations are summarised below

Biology

Biology Feedback on lab work & mandatory experiments **included** : Lack or scarcity of laboratory work, need of specific list of experiments, need of mandatory experiments, school equipment need, lacking field work

*There are **no clear lab studies** that I can determine, experiment is referenced several times with only one mention of laboratory*

*To me the practical **laboratory work is not immediately clear** in the draft document & it would be beneficial if **particular experiments could be described** in more detail.*

*The verb 'investigate' is present in some of the learning outcomes, I would presume this is the practical work the question refers to. If this is the case, there is **very limited practical work expected of students**. It would be **better to have a mandatory list of practicals**.*

*The only thing that is **clear is that there are no mandatory laboratory experiments.** This is a frightening prospect and a backward step. I would have real concerns that some **schools will not do experiments if they are not prescribed and mandatory. T**his in turn would have very serious implications for those students as they progress to 3rd level.*

*I **would worry about the amount of equipment that will be needed by schools**. There will be to be a lot of funding allocation needed for this. It is **not clear what experiments are actually mandatory**.*

*It is clear but **the lack of expected field work is disappointing**. Field work should not be optional or the preserve of wealthy schools. Certainly, plant-based field studies can be conducted virtually anywhere e.g. pavement botany/urban ecology etc and virtual field classes are now more available if physical ones are not possible. This also increases inclusivity in the area.*

Chemistry

Chemistry Feedback on lab work & mandatory experiments **included** : Lack of clarity on lab investigation learning outcomes, clarity on lab experiment, need of mandatory experiments and how they will be examined, teacher guidance, details school equipment need, increased prep and stress for teachers

All learning outcomes containing an 'RI' component are vague; ***what needs to be done to properly complete these 'research investigation' learning outcomes****? How much* ***time/effort should students*** *spend on these?*

A clear list of ***mandatory experiments needs*** *to be created, with further detailed* ***guidance for teachers****. At the moment it is very unwieldy to find in the specification what the 'EI' experiments are, and for some of them the descriptions give too little detail.*

I'm presuming that the specified experiments that we can identify as "mandatory experiments" will be examined in the same way that they are at the moment, looking for specific details and observations etc of the practical. However, what is going to be the case with the other, unspecified "primary data" investigations that are mentioned?

The "specification" states: "Whilst the contextual strands set out situations where students are required to gather primary data to verify observations and mathematical relationships, this is a minimum requirement and it is not expected that practical opportunities would be limited to these situations".

If the ***questioning of these in the exam is open-ended, this would likely lead to significant uncertainty as to the detail required****. They also lead to* ***more preparatory work and time, and therefore stress, for teachers. I****f the case is to be that these unspecified experiments are not to be examined at all, then they are likely to be ignored in many instances as the course is long enough as it is.*

Physics

Physics Feedback on lab work & mandatory experiments **included** : Lack or scarcity of laboratory work, lack of clarity on learning outcomes relating to lab work, lack of list of experiment,

*There is **no information regarding laboratory work** given in the document. The action verb "measure" is only used once in the context of "constant and varying linear motion"*

*I've no idea **what "students should be able to model pressure" means** on p.16. Probably says more about me but I find a lot of learning outcomes pretty meaningless.*

***Is there a list of experiments?** I can't dig out from all the blurb what experiments they will do. Maybe I'm missing something.*

***How can you take proper measurements for the following experiment**? : 'relate the pitch and loudness of sounds to their wave characteristics using primary and secondary data' Is this quantitative data or qualitative data? As loudness depends on both frequency and pitch, this is not a fair test. They are many more examples where the physics behind some investigations is naive at best.*

***Some lab work is very clear, but some is not clear and simply unclear how each student can collect primary data**. e.g. 'Relate the pitch and loudness of sounds to their wave characteristics using primary and secondary data'. e.g. analyse diffraction using primary and secondary data. the quality of the data for some of these experiments may not mount to much. Would the diffraction grating be satisfactory for this instead of Young's Slits?*

*Concerning the experimental aspects of the new LC Physics Programme:
We are also concerned that several aspects of **the mandatory experiments are very poorly specified** - for example, "Analyse diffraction, two source interference, Measure the wavelength of light…" how are these to be carried out ? There is a real danger that the teacher will be at a loss to know how to run these experiments without more detail.*

Appendix 6

Comments from IUA colleagues on suggested Physics, Chemistry and Biology topics to be included or reviewed

Chemistry

Suggested **Chemistry Topics on draft specification to be included/reviewed** are: Electrochemistry, Atomic Structure, Chemical Bonding, Sustainability, Analytical Chemistry and Macromolecules, analytical chemistry and nanotechnology. New Developments in Chemistry, Options A and B.

Electrochemistry
This submission on the need to modernise the Electrochemistry section in the draft specification was made by a university lecturer with great expertise in the area of Electrochemistry. He suggests the following changes be made to section IM5 Electrochemistry (p. 34) in the Chemistry Draft Specification.

- *Replace the galvanic cell with a more interesting example., e.g. metals stuck into a lemon.*
- *Replace Cu electrolysis with KI electrolysis in a student voltameter*
- *Replace electrolysis of copper sulfate solution with an experiment to measure the voltage of a primary and a secondary cell.*

Dear IUA colleague,
This submission is with respect to the revised curriculum for Leaving Certificate Chemistry. I am the lead author of a university textbook on electric vehicles [1]. The book has been translated into Chinese and has been adopted globally at scores of universities for the teaching of electric vehicles and related environmental, mechanical, electrochemical, and electrical technologies.
One of the key technologies underpinning electric vehicles is the lithium-ion (Li-ion) battery cell. This cell has transformed our daily living and has had a very significant impact on secondary-school children and their families. Smart phones, tables, laptops, scooters, drones and electric vehicles are all embedded in their world. Thus, the Li-ion battery is a wonderful technology for the Leaving Certificate. It brings together the everyday applications, and their energy storage wonders and limitations with which we are all familiar, and the fundamentals of chemistry. Over the past two years, I have been working on developing the second edition of the textbook with a particular focus on electrochemistry and the Li-ion cell. Working with a PhD student, we have strived to understand and develop a revised Li-ion curriculum that covers Leaving Certificate pass and honours chemistry, and further extends the material to introduce and cover electrochemistry for university engineering and science students. We have presented visions for this material to the ISTA in 2022 and 2023, and also developed a new sub-module for CM1203 Teaching Chemistry Concepts here at UCC. We presented this material in late 2023. The key learning outcomes are presented below. In this sub-module, we integrated the history, the key energy storage units, the everyday applications, and the safety and environmental challenges, with the fundamentals of

chemistry, where we explored the key elements, the periodic table, oxidation-reduction, half-cell reactions, and estimated the mass of the various elements we require for a cell or application. We also delved into the wonderful relationship between the Nernst equation, the Law of Chemical Equilibrium and mass transfer within a cell during charge and discharge.
In conclusion, the electrochemistry section of the Leaving Certificate Chemistry can be substantially based on the Li-ion battery with key chemistry learnings on one of the most transformative and impactful technologies which our students experience today and will for the foreseeable future.

[1] ***Electric Powertrain*** *Energy Systems, Power Electronics and Drives for Hybrid, Electric and Fuel Cell Vehicles*, John G. Hayes and G. Abas Goodarzi, ISBN: 978-1-119-06364-3, John Wiley & Sons, January 2018.
Chinese language edition, ISBN 978-7-111-67290-6, China Machine Press, May 2021.: 电驱动系统——
混动、纯电动与燃料电池汽车的能量系统、功率电子和传动、功率电子和传动,

Student learn about	Learning outcomes
Students should be aware of the contributions of Volta, Galvani, Planté, Leclanché and 2019 Nobel Prize winners Goodenough, Whittingham and Yoshino.	• Describe the development of electrochemistry from Volta's pile to modern lithium ion batteries.
Students should be able to explain the importance of oxidation and reduction reactions in the context of electrochemistry as well as clearly defining these terms.	• Explain the meaning of the terms electrochemistry, voltaic cell, anode, cathode, electrolyte, primary cell and secondary cell.
Students should be able to define, convert and use the units of energy storage (joule, kilowatt-hour), battery capacity (coulombs and amp-hours), voltage (volt), and current (ampere).	• Discuss and apply the units of energy storage, battery capacity and electrical voltage, current and charge.
Students need only write the half equations at each cell for charging and discharging (see slide 36 of Hayes UCC CM1203 presentation))	• Describe the structure of a lithium-ion cell and explain how current is generated during discharge and also the process of recharging.
Students should study how battery packs are configured in series and in parallel for applications such as electric vehicles, electric scooters, laptops and mobile phones.	• Calculate energy storage, capacity and voltage for various applications of lithium-ion batteries.
Students can relate electrochemistry to the key elements of Li, Ni, Co, Mn, Fe, Al, C and O in the Periodic Table.	• Outline the metals and non-metals in the Periodic Table that are used in the manufacture of lithium-ion cells and relate these to sustainability issue.
Students understand the safety hazards of batteries, such as fire and contact with water,	• Discuss safety issues related to lithium-ion cells.
Given the rating of a lithium-ion cell students should be able to perform calculations to calculate the mass of active lithium required in that cell. Students should then be able to calculate the mass of cobalt and other metals required in the cathode.	• Calculate the quantity of lithium and other elements which are required in a cell in order to have the required energy storage.
Students should be able to apply the Nernst equation and the Law of Chemical Equilibrium. Students are not required to learn off the equation but to explain the use of this equation to show why the voltage drops as the battery is discharged and why the voltage rises as the battery is charged.	• Use the Nernst equation to relate the cell voltage to the quantity of reactants within the cell using the Law of Chemical Equilibrium.

Atomic Structure
A Senior Lecturer in Organic Chemistry made the following comment about the need to stress the limitations of the Bohr model and requested clarification on the learning outcome on the current model of atomic theory (p. 20 c)

It seems counterproductive to teaching by solely using the Bohr model of the atom. It may be easier to explain than the more current models, but it is wrong after all, and the textbooks don't make that clear. On the contrary they seem to rely on it. It doesn't help the education of chemists at third level if students arrive from secondary school with an image of the atom that is based solely on the Bohr model without awareness of the limitations of this model.
With regard to this specification, it says they will describe the atom using the current model of atomic theory but it's not clear what is meant by this. Is this solely the Bohr model or more current models that students will study in 3rd level?

Chemical bonding
The lack of clarity of some aspects of chemical bonding was highlighted by a chemistry lecturer as follows:
One point I would highlight is a possible lack of clarity in BM2: it is unclear if lone electron pairs should be considered in the application of VSEPR model to molecular shape - under 'physical properties', interactions between water molecules are highlighted to be studied, but without considering lone-pairs this could be concluded to be non-polar.

Sustainability, Analytical Chemistry and Macromolecules
The following submission was made by a chemistry lecturer:
- Within the theme of Sustainability, it would be worthwhile to include reference to combustion of hydrogen in IM1 alongside hydrocarbons, and to consider pollution concerns around lithium mining in MW3.
- Under NM1 it would be worthwhile to include theoretical aspects of HPLC or other silica chromatography methods which have been standard in pharma industry and research for decades - as an extension of the paper chromatography currently taught.
- There is no learning outcome that touches on macromolecules key to Health, despite health being a cross-cutting theme. Some basic awareness of the chemical structures of DNA, sugars and amino acids (or proteins) is vital to understanding the behaviour of many drugs, the chemical processes involved in life and connection to diet, citizenship and integration with other subjects. Complete omission from the chemistry specifications seems like a shortcoming.

Overall this seems a comprehensive set of specifications, albeit quite modest in terms of updates to core chemical concepts.

Another lecturer also commented on the removal of **analytical chemistry**
•*It seems odd that modern analytical techniques have been removed, and not actually augmented with even newer techniques such as X-ray fluorescence*

The case was also made for the inclusion of more information on **nanotechnology**.
A greater inclusion of nanotechnology, rather then just a brief mention, might be both more interesting and more up-to-date

*It seems there are relatively few **new developments in chemistry** that have been added onto the new specification (e.g. in the fields of quantum chemistry/organic chemistry), which is unfortunate considering that the specification is now far more overloaded than it was before.*

There is simply too much content and this needs to be corrected. I think it's hard to pick particular topics to completely remove, rather I think that numerous topics need to be 'trimmed' so that that the specification is less heavy.

*The current **options A and B should be retained** as options and not amalgamated into the course as the draft course is extremely long*

Physics

Suggested **Physics Topics to be included** are: Blackbody radiation, Sustainable energy, solar energy, Energy storage, Greenhouse effect, Radon gas and levers/moments.

***Blackbody radiation** (including Wien's law and Stefan's law). Pretty fundamental physics and you couldn't understand e.g. greenhouse effect/global warming without it. How do you explain to students why heat gets trapped by the atmosphere on the way out, but not blocked on the way in?*

*I do miss some explicit topics on the connection between the main underlying physics concepts and day to day real life issues. In my experience the dry core physics part is off-putting unless each topic has an element highlighting the crucial relevance to modern technology. These should definitely include: **Sustainable energy** (wind (kinetic to electric Topic EMF5+FM4), **solar** (WMET4+EMF4))*

***Energy storage** (electric to chemical energy, batteries, Pumped storage)
Greenhouse effect (WMET1+WMET4), **Radon gas** in Ireland (MP4)*

*Is the topic of optics so important to leave **levers/moment** out?*

Biology

Suggested **Biology Topics on draft specification to be included/reviewed** are: Plant Science, Biodiversity, climate, Parasites, Ecology, Immunology, , Biotechnology and Molecular genetics, Sustainability and Technology and associated Ethical Concerns, Skeleton, senses and muscles.

One of the submissions received commented on the need to put more emphasis on **plant science** in the specification

The coverage of plants is extremely disappointing. They are presented as add-ons to human/animal biology and Strand 3 does not mention plants specifically at all. There is no explicit discussion of ***understanding biodiversity*** *and the role that plants play in creating, maintaining natural* ***ecosystems*** *and they are presented, at best, as providers of services, rather than interesting organisms in their own right. Nothing on the* ***interactions of plants and climate*** *(other than their possible service as carbon sinks); nothing on the worrying levels of* ***plant extinction****; nothing on the diversity of plant ecology. There also appears to be nothing on algae - immensely important organisms (e.g. where our oxygen largely comes from) and* ***also ecologically really interesting****. The plant content, unless it is delivered exceptionally well, will do nothing to engage and interest students - it looks largely the same as when I did the Leaving over 20 years ago and it was uninspiring and boring then. It was only when I took Biology at university that I started to see how fascinating plants could be because the LC did nothing to highlight that. I am now a lecturer in plant ecology. It is disappointing to see a very uninspired plant biology curricula when this was a good opportunity to improve on what has been done in the past.*

Microbiology

The following comments on microbiology were made by lecturers in Microbiology

Microbiology is disjointed

Microbiome-*Microbiota- the role of the microbiome in human and all life processes has become established over the past 20 years. It could be incorporated into the ecosystems as in the ecosystem of a mammalian body etc.*

Parasites *have been reduced to a small section- Their life cycle for a human and agricultural role is important*

Ecology *should be linked to sustainable WHO SDGs*

The concept of the ***microbiome*** *is missing from the topics in the draft specification. A microbiome is a community of micro-organisms. Microbiomes play a significant role in human health within the GI Tract (digestion/immune signalling/metabolic health) - and also in the soil and other environments where specific microbiomes contribute to nutrient cycling. The 'microbiome' could be introduced as a simple concept (microbial communities) and would link across all of the main strands - Organisation of life (interactive systems); Structure and Processes of Life (digestion as an example of mutualism); Interactions of Life (ecology/ecosystems, nutrient cycling). The topic could potentially form the basis of class work (Biology in Practice Investigation) and would encourage reasoning about biological phenomena, demonstration of investigative skills, integration of learners investigative work* *with that of scientists in society, and development of digital literacy/data handling skills.*

Note that microbiome science has emerged over the past 20 years to ***become a fundamental concept in Biology****. It was not defined in the previous leaving cert Biology syllabus (& is not defined in current leaving cert Biology textbooks) and would therefore represent a significant modernisation of core biological concepts.*

Immunology

Lecturers in Biochemistry & Microbiology pointed out the need for more information on immunity**.**

What is there on immunity is good but:
1. It would be good to cover basis of ***vaccination*** *(nothing on vaccines) given the increasing trend in vaccine-hesitance; they mention adaptive immunity so could fit in quite easily.*
2. No mention of ***when things go wrong e.g. autoimmunity****. Given the prevalence of these diseases in our society, possibly warrants a tiny mention.*
3. Under 'Immunity', it states about how new diseases emerge – this should ***be infectious diseases***

Immunity *- perhaps include roles of non T and B cells into innate immunity , antigen presentation by macrophages/dendritic cells*
Bacterial specific immunity and evasion should be highlighted
Bacterial viruses (phage) are endemic and affect many industrial processes and spread antimicrobial resistance

Vaccinations *and the development of novel (RNA vaccines etc- SARS-CoV-2) should be incorporated into the immunity section*
Discussing epidemics, pandemics could be incorporated into the immunity section, we lived through SARS-CoV-2 , responses and mitigation should be addressed along with other major threats such as HIV-1, Influenza, AMR

Sustainability and technology

One lecturer emphasised the need for additional material on sustainability and technology to be included

> *In general, the specification is lucid and comprehensive and I did not observe any major problems. The breadth of material covered and the integration of this material is strong.*
> *Expectations regarding the delivery of scientific content are perhaps more clearly outlined than content relating to sustainability and technology, which are foregrounded as being core aspects of the curriculum but appear peripheral in the learning outcomes.*
> *There are many specific references to particular scientific concepts* ***but relatively few in the area of sustainability and technology****. I would also like a more clear outline of how creativity is facilitated and assessed. I agree that creativity is a key and often under-recognised aspect of science but enabling and assessing creativity in the classroom is another matter. Colleagues in the arts and humanities are probably more experienced in this area than the average scientist.*

Ethical concerns
One lecturer asked for more concrete examples of ethical concerns addressed in the specification.

*I think it is important to find space to make a clear distinction between **science and technology** in order to clearly establish the relationship between them. This is non-trivial and a source of confusion to university students. There is an ambition in the specification to explore ethical concerns but it must be recognised that a great many of these concerns emerge in the technological rather than the scientific domain. While science is not free of ethical concerns many of the case studies of ethics in science are highly particular and rarefied. Most of the ethical issues faced by students will likely emerge in how science is leveraged in their roles in industries that create consumer technology, which is the destination of most STEM graduates. The specification alludes to ethics at several points but I would like to see some concrete examples of how these issues will be explored in a concrete, structured way.*

More information on the senses and skeleton should be included
One lecturer commented as follows:

*The **Senses - Skin, Eye and Ear-**, along with the skeletal system are very relevant topics to students, those who continue to study biology after second level and those who will no longer study biology - knowledge of these topics is helpful for the world we live in today.*

***Skeleton & Muscles** - we are teaching biology.*

The importance of good quality labs in schools and the provision of lab technicians was made by one lecturer.
*I think that it would be important that students get further exposure to **DNA technology and advances in genetics**. But this would, of course, require well stocked labs and technicians in schools, as in other countries.*

Factual correction should be made to Domain of life and photosynthesis:

Under OrgL1 The characteristics of life, the learning about should refer to **"domains of life"** and not three domains of life" as this is still an area where such detail is debated as more phylogenomic data become available.

The description of the **topic of photosynthesis is in places factually incorrect**. Given the importance of photosynthesis for most life on Earth, more attention should be paid to avoiding mistakes and common misconceptions (such as the "dark stage" and mistakes in the description of the biochemical processes).

Appendix 7

Comments from IUA colleagues on the Additional Assessment Component Research Investigation

Concerns around the inappropriate 40% weighting of the coursework component (e.g. such a large weighting on an unseen exam; question around adequate time to teaching content with time allocated):

One lecturer asked for a greater emphasis on continuous assessment: *Over reliance on the final exam, have more CA throughout the two years to determine understanding (proof of understanding) rather than the cumulative regurgitation essay at the end which perpetuates the points race rather than understanding.* However, all other related comments called for a significant reduction in this weighting. The list is detailed below.

We have some concerns about the extent of the project component — giving students a taste for research and enquiry is good, but the depth and large contribution to the final mark seemed misaligned with student's knowledge.

A recommendation would be a smaller contribution for the research project to the assessment total.

Some comments received felt that the curriculum was overloaded with content: *While everything on the specifications has terrific merit in the context of chemistry education, overall, there seems to be too much material for only 160 hours of teaching time, in particular when it counts for only 60% of the total marks.*

There is simply too much content and this needs to be corrected. I think it's hard to pick particular topics to completely remove, rather I think that numerous topics need to be 'trimmed' so that that the specification is less heavy.

Where does all the time for the research project come from? Is something else being left out? What is being cut from the curriculum to enable this 40% research project and will the students still have enough rigour in the disciplines to progress. Will they meet the underpinning level needed for Medicine, Dentistry and Pharmacy with only 60% of the current curriculum? We would all support inclusion of a research element but this needs to be done in a measured way.

I think that the introduction of the Chemistry in Practice Investigation has positives, but there are many issues to be addressed, such as, it is worth far too many marks considering the time involved (it should be worthy 10-20% considering the time allocated to it compared to the rest of the specification), and that it will put huge pressure on students/teachers that wasn't there before.

40% is extremely high for research project

40% is a huge amount to be dedicated to the project. The amount of course content for biology seems to be quite high also for 60%.

40% is a huge amount to be dedicated to the project. From teaching the IIS project in Ag Science is worth 25% and the time commitments from teachers exceeds the recommended amount.

While everything on the specifications has terrific merit in the context of chemistry education, overall, there seems to be too much material for only 160 hours of teaching time, in particular when it counts for only 60% of the total marks.

The amount of course content for biology seems to be quite high also for 60%. I think this proposed course will put pressure on teachers and their students and that it will negatively effect the uptake of this subject. It is clear from the Ag Science project that it is not working well

The specification places a significant emphasis on project-based work. On its face, I do not think this is a bad idea. A significant issue in the transition from second to third level is that students are not sufficiently comfortable doing work independently, developing original ideas or being creative. Students from other countries where project-work is more common often engage in class discussions and project work in a more proactive and enthusiastic manner. The weighting of 40% is significant, however, and it might be more prudent to reduce this weighting, especially during initial rollout.

There are major concerns with the new Physics in Practice Investigations. From our own experience with students at 3rd level, we have found that even in first year any type of previously "unseen" study or investigation has to be carefully managed. The key element here is an appropriate level of direction and guidance, in combination with required resources. Teachers and students will need specific examples of possible topics, both in theory and worked examples. There is no doubt that there will be a small subset of teachers and students who would thrive in the context of such self-directed learning, but in reality, the majority of teachers and the vast majority of students will not be able to deal with this aspect of the programme without (i) a dramatically increased degree of specification and clarity and (ii) assurance that the appropriate level of resourcing will be available. The latter is a particularly important point, as this will vary significantly from school to school and region to region. With these very significant reservations in mind, 40% is a highly disproportionate fraction of the overall marks to be allocated to this aspect of the course.

Again in the context of 3rd level: when a student sits a written exam, where we try to probe the understanding of the student (as distinct from what they know by rote) any "unseen" element – e.g. a question generally but not explicitly covered in a lecture – would very seldom indeed be given a weighting of 40% in the exam: more often, half this or less. The same is generally the case for any "unseen" lab exam we might give the student. The only time when a significant assessment of the self-directed element of a students work occurs is in their final year, as part of their final year project. It is our considered opinion that a 40% weighting is pedagogically unsound, and should not be implemented. We would urge that no more than 20% of the overall mark be allocated to this aspect of the course at this time. Perhaps an allocation of 20% to the mandatory laboratory element could also be explicitly included in the scheme: then the overall marks breakdown for the new course would be 60% written (exam based) and 40% (mandatory labs + Physics in Practice

Investigations). The 20% weighting towards the latter could be increased later once this new aspect of the programmes has been properly bedded down.

Concerns around broadening the social division (e.g. unfair advantage of some students regarding resources and social capital heightened with high weighted coursework component):

40% seems extraordinarily high for the physics in practice part…I also believe it will widen disadvantage for already disadvantaged students.

There's nothing to stop abuse of the "Physics In Practice" element. Teachers, especially at "elite" institutions, will be under pressure to ensure results... "match expectations."

It is unclear if students would have equal opportunities at research. If a school has limited resources, will this impact negatively on the student? Not everybody will have a level playing field here. Some students are likely to be able to access third level facilities, others less so – how will this be factored in?

While the practical assessment is a good idea, there is a huge amount of scope for variation and inequality in what students are actually offered depending on both the teacher and the school. I would like clarity on how quality control will be maintained and an equitable learning experience offered to students in different schools.

Criticisms on the basis that students may not have access to computers or means to conduct projects should be taken seriously; however, teachers should be encouraged to explore these questions early with the class in order to identify any issues faced by students so that they can be addressed early in the process (laptop loans, school computers, group-based work, analog approaches). It should also be recognised that students will be expected to do such projects in university and/or the workplace, so preventing such projects entering the curriculum for accessibility reasons simply delays giving students the opportunity to develop skills that will be expected of them eventually.

I have concerns about the level of marks assigned. I have concerns, also, about equity amongst students. I worry about the integrity of the system and ultimately for the uptake of the Science subjects at LC.

40% is a huge amount to be dedicated to the project. The amount of course content for biology seems to be quite high also for 60%. I think this proposed course will put pressure on teachers and their students and that it will negatively affect the uptake of this subject.

When a high stakes exam is worth 40% pupils will use artificial intelligence to write up their project or pay a tutor or a student from this institution to give them significant help with a project. This will exacerbate the inequality that already exists in second-level pupils. The Leaving Cert. can be bought!

Concern regarding the resourcing of the coursework component (e.g. technician support, health and safety support, costing of investigation materials (equipment/chemicals))***:***

> *It is great to see the introduction of a continuous assessment component to take exam pressure off the students but considering it all seems to be based on a research project, 40% seems to be a lot and we have concerns as to how this would work in practice. Introduction of a research project is a welcome development, but it raises a number of issues:*
>
> - *Are the schools and teachers going to be provided with the resources to enable this work and the training to lead out on research? There would be a considerable increase in workload for the Chemistry teachers to deliver on projects. Will technician resources be provided?*
> - *How will Health and Safety be managed?*
> - *Will resources be provided to cover the cost of the research projects which is not trivial.*
> - *Who will examine the projects?*
> - *Will there be scope for the research investigation to be a group project or is just individual?*
>
> *Some schools will not have the laboratory equipment required.*
>
> *…assurance that the appropriate level of resourcing will be available. The latter is a particularly important point, as this will vary significantly from school to school and region to region.*
>
> *The amount of equipment/resources is not always available. We have issues with space for the IIS projects (Agricultural Science Projects) also.*

Concern regarding stress on teachers (e.g. pressure of large assessment weighting, time to complete core course content, students opting out of science, volume of content to be taught in 160 hours)***:***

> *Far too many marks allocated which will put severe pressure on teachers to deliver results.*
>
> *That the Chemistry in Practice Investigation is to be carried out during the second term of 6th Year seems very unfortunate. With teachers very pushed to get the course finished and reviewed, and with students' efforts concentrated for a substantial period on the "mocks", the new proposal will inevitably prove to be very problematic. This would still be the case even if only, say, 10% was on offer. Also, given the open-ended nature of the process – in particular with reference to the "appropriate primary data" – it will add considerably to teachers' time and work stress. In the same context, if one of the stated objectives of this change is to reduce the stress placed on students, then it will produce the diametrically opposite result. With both the biology and physics equivalents slotted in for the first term of 6th Year, I can envisage many students opting to do either or both of these rather than to choose chemistry.*
>
> *The amount of course content for biology seems to be quite high also for 60%. I think this proposed course will put pressure on teachers and their students and that it will negatively effect the uptake of this subject. It is clear from the Ag Science project that it is not working well*
>
> *There is not enough time allocated for this additional assessment component. Teachers and students will be under tremendous pressure to complete this research investigation in just 20 hours.*

Concerns regarding integrity with recent access to AI (e.g. integrity issues that arise with ubiquitous access to AI)***:***
When a high stakes exam is worth 40% pupils will use artificial intelligence to write up their project or pay a tutor or a student from this institution to give them significant help with a project. This will exacerbate the inequality that already exists in second-level pupils. The Leaving Cert. can be bought!

Another issue to be addressed is the issue of AI; how will it be ensured that students produce their own work for the investigation?

Concern regarding clarity of what the coursework entails:
The lack of direction concerning the new Physics in Practice Investigations will pose a major challenge to some teachers and the majority of students, to the extent that it may be unimplementable in the current circumstances. It is very clear that a 40% weighting is much too high in these circumstances, and is in danger of undermining the effectiveness of entire course and seriously impacting on student numbers at a time when we can ill afford this to happen.

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