Chemistry

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Internal assessment

The May 2020 session was overshadowed by the global crisis precipitated by the COVID-19 pandemic. It was a herculean effort by so many students and teachers to the meet the shifting deadlines and to successfully submit, mark and in nearly all cases fully annotate all pieces of coursework ready for moderation.

All of this endeavor by teachers and subsequently moderators took place not in isolation, when internal assessment in Chemistry could be our sole consideration, but at a time when many feared for the health and wellbeing of loved ones and were also confronting huge challenges professionally as so many colleagues suddenly found their livelihood under threat or were having to develop overnight the skills and resources for online learning. We express our heartfelt gratitude all colleagues in the IB Diploma Chemistry community for their dedication and professionalism. Their efforts protected the well-being and best interests of all candidates during this most challenging of all sessions

Range and suitability of submissions

Most importantly it was seen that the COVID-19 pandemic had not impacted too greatly on the candidates' opportunity to carry out a meaningful internal assessment investigation. A very small minority of candidates reflected on limitations to the amount of data collection possible due to school closure but overall it appeared that nearly all students had safely accomplished the design and data collection phases before the crisis impacted their schools. As commented upon later in this report, school closures and limited contact with teachers may have affected the final stages of the process – such as going back to check and repeat unreliable data or to receive guidance on the final conclusion and evaluation phase – but sufficient work to produce a meaningful and assessable report had been completed by nearly all candidates. And there were cases where the teachers' comments indicated that a student's citation of school closure as an impeding factor actually was covering for very poor time management and the task could have been long since safely completed. An important lesson for the future for all!

Considering all internal assessment reports were submitted it was pleasing that they were still overwhelmingly appropriate for assessment for Chemistry. Every year we see a small number of investigations that lay outside the realms of Chemistry and this year saw no perceptible increase in that proportion.

Although the large majority of investigations were as usual based on traditional hands-on laboratory work there was a small but significant rise in the number of investigations carried out where the data had been collected from secondary or online sources. Of these the greatest proportion used data from online databases such as NIST or Chemspider with a much smaller number acquiring data from modelling software and simulations.

Many of the investigations using data from databases looked at how factors such as boiling temperature changed within an organic homologous series or on the effect of branching which has already been delineated within the TSM. Some novel investigations were seen such as the effect of structural characteristics in related organic compounds on the chemical shift of a specific proton in 1H-NMR. Looking at structural effects on spectral data has not been common in previous sessions but could be a fertile area for future studies.

The use of data from virtual laboratory simulations available online or in some e-textbooks may be a way forward in environments where students are unable to access their school laboratory due to restrictions. However, such data is not truly authentic and will simply reveal the algorithmic relationship the simulation is based on rather than necessarily the underlying chemical principle so a teacher should really vet such a proposal from a student before allowing them to follow such an approach. More guidance will be available on the use of secondary data in the Individual Investigation in the Programme Resource Centre on MyIB.

As usual within the traditional laboratory-based investigations the most common topic areas were food chemistry and kinetics followed by investigations based on calorimetry or electrochemical cells. Within food chemistry investigations into Vitamin C, calcium iron or iron ion contents were as ever the most popular. Where the investigations looked into the effect of a quantitative independent variable the standard of outcome was usually good or very good whereas comparisons of brands or types of foodstuff were less sophisticated and gave less scope for meaningful analysis or conclusion as to an underlying principle or relationship.

With regards to the final outcome report the characteristics of what could be termed a typical Individual Investigation were similar to previous sessions.

The common strengths were:

- Some genuine interest shown in the topic
- A clearly defined research question and a methodology that would yield some data with appropriate consideration of safety and environmental issues.
- Most raw data recorded and presented appropriately, and the main data processing phase carried out satisfactorily.
- An answer to the research question was presented that was consistent with the data and students could identify procedural weaknesses and some relevant improvements or extensions.
- The presentation was good with clear sections, satisfactorily presented tables, graphs and charts and conciseness that kept to the report page limit.

The common limitations to attainment related understandably to the higher order reflective and interpretive thinking skills: Typical weaknesses shown were:

- Not reflecting on their data gathering during the process and failing to correct or extend the methodology.
- Failing to present sufficiently focused and relevant background information that enhanced understanding of the principles lying behind the research question.
- Not coherently processing and interpreting the impact of measurement uncertainties on the analysis and conclusion.
- Not appreciating whether the conclusion was truly consistent with accepted theory within the constraints of measurement uncertainty.
- Not recognizing methodological limitations such as the range of independent variable and the sources of systematic error.

These aspects are described in more detail below.

Candidate performance against each criterion

Personal Engagement

Achievement against this criterion was similar to previous sessions with the overwhelming majority of students managing to achieve at least one mark. Some teachers seem to only assess the student's justification of their choice of research question and topic – the personal interest angle – and didn't consider other aspects of the criterion such as evidence of the student reflecting on their methodology through the design and data collection phases to overcome practical challenges or to extend and adapt the data collection to ensure sufficient meaningful data was collected.

Exploration

The achievement in Exploration was similar to previous sessions and there was little evidence that restrictions due to the COVID-19 crisis had affected the fulfilment of this criterion. Most students were able to achieve at least middle band fulfillment of the assessment criterion.

In many cases a suitable topic was identified and a relevant research question was described with the research question often falling into the category of determining how a measurable independent variable effected an identified dependent variable. These research questions achieved well against the assessment descriptor and also frequently facilitated a successful fulfillment of Analysis.

A fairly common weakness was where students posited overly ambitious research questions that could not be answered by their methodology. This was especially prevalent in the food and nutrition based investigations where the Research Question often related to health or environmental effects whereas the methodology simply measured the content of substances such as vitamin C, caffeine or iron in a range of sources or under different cooking conditions. In such cases the Research Question could be more easily rephrased so as to be in harmony with the ensuing practical investigation. Students should be challenged to reflect on what exactly their methodology is testing or measuring and discouraged from stating Research Questions with ambiguous terms such as "efficiency" and "suitable".

The quality of background information was inconsistent. Only a minority of candidates provided a truly relevant theoretical context, including chemical equations, that was directly related to the research question in hand. In most cases the background information was too broad or actually unrelated to the research question under investigation. Again, this was most prevalent in the food chemistry orientated investigations where students described the health effects of vitamin C or iron in the body but didn't discuss the redox processes that they were investigating and the documented likely effect of changing the independent variable in question.

The aspect of the Exploration criterion that is most challenging is to design a methodology that addresses the research question and takes into consideration the significant factors that may influence the relevance, reliability and sufficiency of the collected data. Here students need to consider the range and frequency of the tested independent variable, the number of repeats and the control of other influencing variables. Although only a minority of students achieved this fully most students did describe methodologies that did lead to some relevant data collection.

Some common weaknesses included ignoring the control of variables in the procedure even though they had been earlier identified as relevant or implementing poorly considered methodologies. An example of poorly thought through methodologies were several examples on the effect of geographical region on the caffeine content in tea or coffee. The tea or coffee may have come from a different region but the students were actually comparing very different types of coffee or tea where the change in source region was only one of many factors that were different between the samples.

A number of moderators reported investigations where the stated procedures were simply not credible. On more than one occasion the temperature range of rate experiments with aqueous solutions were supposedly extended way beyond the boiling temperature up to 120, 150 and even 175 °C. In another case a student repeatedly reported making a solid bath salt tablets by mixing lemon juice (not solid citric acid) with sodium hydrogencarbonate. This would of course not have been possible since the ingredients would have immediately reacted. One has to question the authenticity of such reports and teachers need to be vigilant that the students are reporting accurately and honestly what they have done.

The proportion of reports featuring meaningful awareness of safety, ethical or environmental issues relating to the use and disposal of equipment and materials was high. The number of schools that encouraged students to work with green chemistry principles including using much smaller quantities of reagents appeared to be low.

Analysis

The overall achievement for Analysis was slightly lower than previous sessions. Most students secured some credit for recording data however the subsequent processing was understandably varied. The majority of students recorded qualitative observations and sufficient data related to the independent and dependent variables so that they could subsequently carry out sufficiently meaningful processing and interpretation.

Only a minority of students recorded the data regarding the control variables such as reaction temperatures or reactant amounts. It is this wider data that can provide valuable context for the evaluation of the procedure. Other students included the expected qualitative data in the method, but such anticipated results do not always match those obtained during the collection of actual data, therefore this practice shouldn't be encouraged. Recorded quantitative data should include the associated measurement uncertainty. Where students often missed out recording uncertainties was in the molar concentration values of reactant solutions used. As ever a frequent omission was not recording the initial and final volumes in titrations but only the total volume used.

A common approach to processing was simply to average the dependent variable data and then plot a graph against the independent variable to see the nature of the relationship. Very often this was done well enough to award good credit although there were also many reports where this was too limited an approach and a more detailed treatment should have been made. In particular this related to investigations involving a quantitative determination by titration or colorimetry where the research question had stated the concentration of the compound under investigation but the analysis didn't go beyond plotting simply the average titre or absorbance values rather than actually calculating the concentrations in question.

There were many investigations in the areas of calorimetry, determinations of activation energies or calculations of equilibrium constants where detailed numerical and graphical calculations were undertaken and earned very good credit. As ever it is important to reinforce the message that teachers must check through calculations when assessing Analysis. Again, this session calculations had been awarded the highest level by the teacher but when spot checked by the examiners revealed themselves to contain major errors that significantly affected the conclusions drawn and caused the Analysis mark to be adjusted downwards.

The treatment of uncertainties always proves challenging and this session it was more pronounced with quite a number of candidates failing to consider uncertainties at all in the data processing. This possibly is an area where school closures near to the deadline may have had an effect. Quite often students put off the uncertainty analysis to the end of the task and this is a very common area of weakness in first drafts that students need to improve on before final submission. In many schools this final review and redraft phase was severely disrupted and this may have contributed to the fact that many reports were submitted with little or no regard to uncertainties this session.

Many students were able to interpret their processed data so that subsequently a conclusion to the research question could be deduced although in a significant number of lower attaining reports the interpretations were often merely prose descriptions of the data presented earlier.

Some perennial weaknesses with analysis that arose but were not more common than previous years, hopefully reflecting the feedback given in previous subject reports and 4IAF forms.These weaknesses included

- students using statistical approaches such as Anova tests or standard deviation calculations that were not justified by the low number of collected values. However, this was possibly less common than last year and maybe the Subject Report comment has been heeded.
- Students calculating mean values from very dispersed data or data with clear outliers.
- Students presenting a complicated Excel graph line equation without further interpretation.
- Students incorrectly describing graphical relationships e.g. describing a negative correlation as inverse.

Evaluation

Evaluation always proves the most challenging criterion to be fulfilled since an appreciation of the significance of their findings and the limitations of the methodology requires deep reflective thinking skills. This year the achievement against this criterion was even more limited than usual and, as already described above with regard to the treatment of uncertainties, this shortfall could reflect the disruption faced during the final report writing phase.

The first strand of the criterion usually yielded some credit since most students were able to make a statement that drew a conclusion consistent with their processed data. However, for many this was limited since it was an overstatement of an observed trend but actually not clearly supported beyond the bounds of the measurement uncertainty.

Achievement against the second aspect of Evaluation was poor with many students failing to correctly describe or justify their conclusion through relevant comparison to the accepted scientific context.

Most students did identify weaknesses and limitations although these were mainly procedural (why the planned method was not properly implemented) and few were methodological (why the designed method itself was flawed or limited). Only a small proportion of higher achieving students evaluated errors in the terms of systematic or random. These distinctions are outlined in Topic 11.1 of the Chemistry Guide and their use should be promoted.

With the aspect of the criterion concerning suggestions for improvements the suggestions were often superficial (more repeats or use more precise or digital measurement apparatus) and few addressed meaningfully methodological issues such as calibration, range or adapting the method to reduce systematic error. Extensions were again often omitted although when presented they did seem to be a more relevant next step to the investigation than seen in some previous sessions.

Communication

The Communication criterion was in most cases well fulfilled with many students earning at least three marks.

Many reports were clearly presented with an appropriate structure and many students gained credit for coherently presenting the information on focus and outcomes. Common weaknesses were for insufficient detail to be included in the description of the methodology and for students to not present at least one worked example calculation so the reader could understand how the data was processed. It is not sufficient to simply present a few equations of relevance but not to show how they were actually used with the authentic data.

Reports were mostly concise and most of them did meet the 12-page limit, A significant number of students included lengthy appendices in order to circumvent the page limit ruling or included unnecessary cover sheets or contents pages. Please note that moderators are not compelled to read appendices.

Most of the reports were relevant although the one common area of weakness was the inclusion of too much general background information that wasn't focused on the Research Question as discussed in the section on Exploration earlier. There seemed to be less reports than in other sessions that included excessive numbers of photographs of chemicals, equipment and layouts that take up a lot of space for little positive purpose. Where this was an issue was with the lowest achieving candidates who included multiple photographs to reach the minimum page limit.

With regard to the use of terminology and conventions many students proved inconsistent in their use of units, decimal places and significant figures. Some students failed to include clear and correct labelling of graph axes which may reflect a weakness in their skills in using the graphing software. A small proportion of schools had not encouraged SI units or IUPAC nomenclature but this is less of an issue now than it was a number of years ago.

The using of citations and references was usually seen although it was common for it not to be clear where and if a cited source had actually been used. Note that proper referencing is necessary to establish the academic honesty of the work. It is not though a part of the Communication criterion so does not impinge on the mark

Recommendations and guidance for the teaching of future candidates

Teachers should reflect on which strategies will be best suited to local conditions and restrictions in order to ensure that all candidates are able to complete an assessable Individual Investigation. Considerations include:

- If the school is able to facilitate practical data gathering consider bringing the school timeline for the Internal Assessment forward so that the data collection phase is not left until late in the programme when any closure would then prove severely damaging to the students opportunity to complete the investigation.
- If practical work is possible encourage students to process and reflect on data while collecting it so they have the chance to immediately adapt or extend their procedural phase if the data are proving insufficient or erroneous. Restrictions could prevent such further data collection if left until a later phase. Also processing data while it is being collected is good practice always.
- If practical data collection is not possible within the school laboratory then students can be directed towards other data gathering activities such as from databases and models and simulations. There are examples of marked investigations of these types in the Teacher Support Material and further guidance is available in the Programme Resource Centre of MyIB
- Database investigations can be particularly successful in terms of assessment especially if the reliability of the data can be evaluated by comparing data sources.
- When using secondary data encourage students to record plentiful data. There is no practical or time limitation that sometimes restrict a student to four or five values of independent variable. Using secondary data a student may be able to delineate a trend or relationship in more detail or across a greater range of values of independent variable.

- The option to carry out practical data collection at home can only be considered for clearly safe and environmentally sound investigations. Most laboratory investigations are not appropriate to be carried out away from a properly supervised school environment.
- If a home-based experiment is deemed safe and of sufficient challenge appropriate to the level of Diploma Chemistry then it is beneficial if some basic school owned measuring equipment and glassware could be loaned to the candidates. Most domestic devices such as kitchen scales, measuring jugs or thermometers are not precise enough to facilitate sufficiently reliable data to draw a robust conclusion.

Whatever type of investigation is carried out the following guidance is appropriate.

- Students should develop investigations that seek to answer research questions related to chemical principles and to avoid research questions whose answer is known beforehand.
- Encourage students to only include background information that is specific to their research question.
- Encourage students to describe briefly in a paragraph the process of developing their methodology. This will help explain the amount of data collected and give insight into the decision making of the student.
- It is good practice for students to give a safety and environmental evaluation in any investigation involving hands on practical work even if it is to show that safety and eco-friendly disposal have been evaluated but no special precaution is then required. Encourage procedures to use lower quantities of chemicals to preserve the environment.
- Ensure students record all relevant associated data and not just the independent and dependent variable data.
- Methodologies should be written in sufficient detail so that the reader could in principle repeat the investigation.
- Where relevant to the analysis students should present at least one worked example calculation so the reader could understand how the data was processed.
- Encourage students to interpret results quantitatively wherever possible. This will also provide a sound foundation for high quality conclusions.
- If practical data collection was possible then encourage students to evaluate errors in terms of being systematic or random. These distinctions are outlined in Topic 11.1 of the Chemistry Guide.
- In order to evaluate and explain their findings in terms of scientific context candidates should either be making the comparison of their experimentally determined quantities with readily available literature values or referring to whether any trends and relationships identified were in line with accepted theory, ideally by referring back to their original background information.
- Students should consider suggestions for improvements that are related to previously identified limitations and that should be realistic and specific to their investigation.
- Students should communicate using the internationally accepted scientific conventions such as SI units and IUPAC nomenclature.
- Title pages, indexes, content pages and appendices are unnecessary and should be discouraged.

When assessing the students work teachers should:

- Carefully check methodology for any missing key variables that would invalidate the conclusions being drawn.
- Carefully check calculations for errors that would affect the conclusions being drawn.
- Apply the model of best fit marking of the criteria evenly and not prioritizing some descriptors over others when awarding marks.

- Include evidence of their assessment decisions for the moderator to understand the thinking behind the marks. Hand written annotations on the report scripts are fine for this purpose.

Further comments