SCAFFOLDING CHEMISTRY LEARNING WITHIN THE CONTEXT OF EMERGING SCIENTIFIC RESEARCH THEMES THROUGH LABORATORY INQUIRY

Annette Hilton $^{1, 2}$
Kim Nichols $^{1, 2}$
Christina Gitsaki $^{1, 2}$

1. The University of Queensland
2. CRC Sugar Industry Innovation through Biotechnology

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Abstract

The decline in student numbers in post-compulsory secondary science education is a continuing international trend due in large part to the level of difficulty experienced by students in senior sciences, particularly the physical sciences, and the lack of relevance perceived by students to their personal or future working lives. This paper, which focuses on chemistry education, argues that the use of digital technologies and inquiry-based learning to support students’ understanding of chemistry, particularly in emerging chemical contexts is an area that merits further investigation and it presents the findings of a study that focussed on the teaching of an emerging area of scientific research – the production and properties of biomaterials. The study was conducted with two Year 11 chemistry classes (n = 22, n = 27) that completed an inquiry in which they made two different bioplastics, compared a number of their macroscopic properties, and were asked to explain them in terms of underlying structural characteristics. Students were asked to report their laboratory findings using two different text types: a standard laboratory report and a digital poster. To scaffold this process, students were provided with a range of digital and laboratory resources as well as teacher and peer interaction. A mixed methods design was employed with data collected including semi-structured interviews, surveys, and pretests and posttests that measured students’ conceptual understanding and their use of multiple representations. The data from the study suggest that learning with digital visualisation tools and writing-to-learn strategies improves students’ understanding of chemical concepts and the representations used by chemists to understand them. These results underline the importance of scaffolding students’ learning through the use of emerging digital technologies to help students to make connections between macroscopic phenomena and the underlying molecular entities and processes associated with them. Scaffolding strategies and linking learning experiences to new areas of chemistry research, such as those used in this study, also have the potential to increase both students’ motivation and interest in chemistry.

Background

The theme of this conference, Changing Climates: Education for Sustainable Futures is a pertinent one for chemistry educators. The OECD Global Science Forum (2006) identified a number of trends across a range of countries in science and technology (S&T), including a downward trend in relative numbers of students choosing to study S&T at upper secondary and tertiary levels of education. The forum also noted that this is particularly significant in the physical sciences (e.g., chemistry and physics) with the proportion of students in these disciplines being halved in some countries between 1995 and 2003. One of the causes of this trend, according to the OECD Global Science Forum is that students have negative experiences at school where they are exposed to uninteresting content, or they may have negative perceptions about the level of difficulty of S&T subjects. They added that while the perception of S&T still remains largely positive among young people, there is a sharp difference between this positive opinion and the desire to pursue a career in S&T. Another worrying finding in this report is the disconnect between what is taught in secondary science and cutting-edge science and modern applications of S&T, which leads to dampening of students’ enthusiasm for science as they progress through school. These global trends have also been identified in Australia. For example, Russell Tytler (2007) identified several elements of an Australian “crisis in science education” (p. 7) including increasingly negative attitudes to science throughout secondary schooling and decreasing participation in physical sciences at senior secondary level. Students’ negative views of the relevance of science to their lives were also strongly identified in the report by Goodrum, Hackling, and Rennie (2001) on the status and quality of Australian science teaching and learning.

The issues of declining numbers and the level of difficulty experienced by students who do choose to study physical sciences need to be addressed. It is essential that numbers in the physical sciences not be sustained but indeed increased if we are to meet the knowledge needs of the field in the twenty-first century. This study is focussed on examining ways of addressing these needs around chemistry education. In order to improve students’ attitudes to, and interest in studying chemistry, researchers have argued that it could be made more meaningful by teaching it through authentic contexts and through “applications-led curricula” (Mbajiorgu & Reid, 2006, p. 9). Over the past twenty years teaching through contexts has become a dominant trend in chemistry education, widely used at the secondary level, locally and internationally (Bennett & Holman, 2002). The concepts studied by students are still largely based on the chemistry of the 19th and early
20th centuries, while chemical research is advancing at a rapid pace (Gilbert, De Jong, Justi, Treagust, & Van Driel, 2002) and there is a need to present chemistry through modern contexts. Context-based curricula aim to increase the relevance of chemistry by developing chemistry concepts within authentic applications of chemistry including social, economic, technological, and industrial applications. This need was identified in the OECD Global Science Forum report, which argued for redesigned curricula that “better reflect the reality of modern science and technology” and emphasise contributions to society (2006, p. 10). Mbajiorugu and Reid argued that a context alone is not enough and that it is important that the topics studied are determined by the applications presented. According to these authors, this approach has been shown to generate positive attitudes in students. Twenty-first century applications of chemistry such as the synthesis and chemistry of biomaterials, chemical aspects of molecular biology, environmental issues, and renewable resource development, need to be effectively and appropriately integrated into the curriculum to introduce chemistry students to the implications of emerging chemical technologies.

The difficulties experienced by students in chemistry have been well documented. Chemistry involves the study of the nature of materials as well as the properties and interactions of the substances from which they are composed, and consequently students encounter complex concepts, entities and phenomena that are abstract and unobservable. This requires students to understand and be able to use a range of representations to comprehend and communicate about chemistry on three levels: macroscopic, microscopic, and symbolic (Gabel, 1999; Johnstone, 1996; Lemke, 2000). As this poses difficulties for students, researchers have focussed on how chemistry students should be taught and the types of resources, including digital resources, that might scaffold students’ development of conceptual understanding and multiliteracies to allow them to interpret and communicate chemistry on multiple levels (e.g., Ben-Zvi, Eylon, & Silberstein, 1986; Kozma & Russell, 1997; Kozma & Russell, 2005; Wu, 2003). Digital technologies have added a new layer of complexity and a new dimension to learning experiences since students must become more proficient in the use and interpretation of visual representations.

Students’ attitudes to the subjects they study are influenced by achievement and cognition (Mbajiorugu & Reid, 2006). Consequently, it is important not only to make the subject more interesting but also to seek ways in which to make the learning of chemistry less problematic for students. If these goals are to be achieved and the decreasing participation in chemistry is to be addressed, pedagogies are needed that expose students to learning experiences that reflect current trends in chemistry research and which incorporate digital technologies including computer-based simulations and visualisation tools. With appropriate scaffolding, these are valuable learning tools that allow students to create and make connections between macroscopic, microscopic, and symbolic representations of chemical phenomena, which in turn will enhance students’ understanding of chemistry (Hilton, Nichols, & Gitsaki, in press). Taken together, future-focussed curriculum and pedagogy should reflect the current trends in chemistry research and related emerging scientific fields. The OECD Global Science Forum (2006) argued that it is difficult to combine participative approaches that would lead to increased interest and general scientific literacy with the teaching methods needed for more conceptual and challenging material. While this may be the case, we argue that with appropriate scaffolding, students can learn challenging concepts through participative inquiry-based approaches.

Advocates of chemistry curriculum and pedagogy reform have also argued that students should learn chemistry through participation in inquiry, however, debate continues regarding the value of learning in laboratory environments (Nakhleh, Polles, & Malina, 2002). It appears likely that the nature of the laboratory experiences themselves rather than laboratory learning in general is at the heart of this debate. For example, an inquiry approach in which open-ended exploratory experiences help students to make connections between macroscopic data, chemical concepts, and authentic applications of chemistry is likely to promote knowledge construction more effectively than ‘cookbook’ experiments with closed outcomes. Developing inquiry experiences can be challenging for teachers since they can sometimes be based on complex problems and consequently may be beyond students’ current levels of understanding, however they are significant for many reasons, including their potential for students to learn about emerging chemistry research topics through investigation and active participation. The study presented in this paper focussed on strategies for scaffolding and promoting students’ learning through laboratory inquiry and the use of digital resources in the process of data analysis and laboratory reporting. The findings presented here relate to students’ conceptual understanding, their use of multiple representations, and their perceptions of their learning experiences, motivation, and interest in the biomaterials topic presented.
Overview of the Study

Participants and Timing

The study was conducted in a large metropolitan public high school, which serves a school community that is both socio-economically and ethnically diverse. Two Year 11 chemistry classes (n = 27, n = 22) with similar distributions of gender, ability, and language backgrounds were chosen for the study. The study was conducted over a 10-week term at the beginning of Year 11, the first year in which students studied chemistry as a separate discipline. Students attended three 70-minute lessons per week for 10 weeks.

Study Design and Scaffolding Approaches

A diagrammatic representation of the study is shown in Figure 1.

During the initial six-week phase of the study, it was important to develop students’ understanding of chemistry concepts relating to bonding and structure and the properties of different kinds of materials. Because the scaffolding resources used in Phase 2, the student-directed laboratory-based inquiry phase, were digital in nature, the materials used in Phase 1 were designed to develop students’ skills in both digital technology use and laboratory settings. Students were taught chemistry concepts using a range of digital technologies, including self-paced simulations adapted from the Molecular Workbench® series, ChemSketch® molecular modelling software, and interactive whiteboard presentations, which utilised video-recordings, animations, and Internet-based resources. These resources were used to help students develop an understanding of the concepts on a molecular level as well as to establish some knowledge about the information inherent in different representations. Lessons involved a combination of student-centred laboratory and computer-based activities with whole class and group discussions. Teacher-led discussions were used to introduce or develop concepts or to demonstrate computer-based activities. Throughout the unit, concepts were linked to the context of the structure and properties of modern materials and applications of these materials. During laboratory inquiries in this initial phase students investigated the properties and uses of a range of materials to develop investigative skills for further laboratory work in the inquiry phase. Students were also involved in discussions about the use of modern scientific applications such as biotechnology for the production of high value biomaterials including biopolymers and biofuels.

During the second phase of the study, students completed two investigative laboratory inquiries: the making and testing of bioplastics, and the fermentation of sugars and starches to produce bioethanol. This phase was conducted over four weeks and required students to design experimental procedures, collect, present, analyse, and explain experimental findings. The first of these, and the focus of the data presented in this paper, was an inquiry in which students made two different bioplastic films and tested their properties. Each laboratory group decided on the composition of their bioplastics, selecting materials from a range of biopolymers and using glycerol solution as a plasticiser. They were then required to present their data and
discuss the differences and similarities between the bioplastics and to link these to the structures and nature of bonding within the plastics. They were also required to propose possible products for their bioplastics based on their properties. Since students were learning new concepts in an area of emerging research and at the same time expected to apply them to their laboratory research, there was a need to scaffold their learning activities. This was done through the use of a range of digital materials, including visual representations, multimodal texts that modelled the ways in which multiple representations could be integrated to explain chemistry concepts, and digital templates. Students were also provided with visualisation tools such as polymerisation simulations and molecular modelling software, genre guides, and heuristics that guided their thinking and the ways in which they collated, presented, analysed, and interpreted data. Students were required to present their findings through either writing laboratory reports or creating a digital poster. The multimodal texts provided to students contained background information to support students’ understanding of the practical applications that they were expected to understand in order to make sense of their laboratory data on molecular and symbolic levels.

Students conducted the inquiries in groups of three or four, of mixed ability and gender. After each laboratory session, students spent several lessons in the school computer laboratory where they produced their laboratory reports or digital posters individually. The teacher’s role in this phase was to be a facilitator and the only teacher intervention in this phase was in response to students’ questions or to direct students to sources of information that might assist them in their task. To assist students in the task of writing their reports or posters, they were provided with the scaffolding materials described earlier on CD-ROM. The CD contained visual representations, ChemSketch molecular modelling software, and a Molecular Workbench simulation that led students through a series of activities in which they learned about polymers, their formation, structural characteristics, and cross-linking. Students were provided with genre guidelines that described the sections they should include and the required information associated with them. The digital poster class was provided with a poster template produced using Microsoft® PowerPoint. The reason for this was to keep the task chemistry-focussed rather than technology-focussed.

**Data Collection**

A pretest was conducted at the beginning of the study and a posttest was conducted at the end of each investigative inquiry. Two types of items were used on these tests: knowledge and conceptual understanding (KCU) items and representational competence (RC) items. KCU items on the two tests were similar, with only minor differences necessitated by modifications made to the inquiries used in the study. RC items were designed to gain a measure of students’ ability to use appropriate representations reflectively to understand or communicate about chemical entities and phenomena, known as representational competence (Kozma and Russell, 2005). The representational competence (RC) items on each test were identical. While the pretest items were repeated on the posttest, the two bioplastics tests were eight weeks apart so memory effects due to repeating items were not considered of concern. Examples of items used on the tests are shown in the appendix. The representational competence scores were assigned using the coding scheme devised by Kozma and Russell (2005), a summary of which is shown in Table 1. Only levels 1 to 4 were assigned as the items used did not allow students to make extended rhetorical use of representations in their responses. A score of zero was allocated to items that were not answered.

<table>
<thead>
<tr>
<th>Level of Representational Competence</th>
<th>Representational Competence Descriptors</th>
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<tbody>
<tr>
<td>1</td>
<td>Representations are limited to physical phenomena using isomorphic or iconic depictions</td>
</tr>
<tr>
<td>2</td>
<td>Representations use a mix of physical, observable characteristics as well as some symbols but no representation on molecular level</td>
</tr>
<tr>
<td>3</td>
<td>Representations use a mix of physical, observable characteristics and underlying entities</td>
</tr>
<tr>
<td>4</td>
<td>Representations, including symbolic representations, are correctly and spontaneously used in explanations and to depict underlying entities or processes</td>
</tr>
<tr>
<td>5</td>
<td>A range of representations are used reflectively and rhetorically to explain relationships between phenomena and underlying processes</td>
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</table>
Following the second phase of the study, 12 students from each class were interviewed using semi-structured interview questions to gauge their levels of interest, motivation, and their perceptions of the learning activities, the test types used, and scaffolding strategies that had been used throughout the study. All students in both classes were also surveyed to gain extra information relating to these areas of interest. The survey, which consisted of 51 items, used a five point Likert-type scale. The survey elicited students’ perceptions with regards to the different text types used to report on inquiries, the use of digital resources for scaffolding, the pedagogical approaches used, and their perceptions regarding motivation, challenge, enjoyment, and interest generated by the different text types. The different data sources were used to gain information that would lead to an understanding of how the approaches and resources used supported the development of students’ knowledge and representational competence.

Results and Discussion

The study examined three areas: the use of scaffolding approaches that utilise digital technologies for assisting students to develop a better understanding of chemistry, the use of laboratory-based inquiry as a means for developing students’ conceptual understanding, and the use of an emerging research area through which to achieve these goals. The scaffolding strategies used involved structured activities that were student-centred and inquiry-based. These activities were situated both in the chemistry laboratory and the computer laboratory. A common feature of the activities used to scaffold learning was the integration of a range of digital technologies. This discussion will present results that relate to three aspects: student achievement on test items conducted before and after the bioplastics laboratory inquiry, students’ perceptions of the scaffolding strategies and resources used, and students’ perceptions of the topic presented and the pedagogies used.

Student Achievement

Students’ pretest and posttest scores on KCU items were compared using paired sample t-tests. The mean and standard deviations for the two tests are shown in Table 2. The high standard deviations in the pretest are due to the fact that many students knew very little or didn’t answer the pretest questions while others were able to answer some items at least partially.

<table>
<thead>
<tr>
<th>Class</th>
<th>N</th>
<th>Pretest</th>
<th></th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean (%)</td>
<td>SD</td>
<td>Mean (%)</td>
</tr>
<tr>
<td>Digital Poster Class</td>
<td>27</td>
<td>16.48</td>
<td>16.51</td>
<td>71.85</td>
</tr>
<tr>
<td>Laboratory Report Class</td>
<td>22</td>
<td>17.27</td>
<td>14.53</td>
<td>71.14</td>
</tr>
</tbody>
</table>

The results of the paired sample t-tests for each class showed that following the bioplastics inquiry, there was a significant improvement in students’ knowledge and conceptual understanding (for the digital poster class, $t = 17.86, df = 26, p < .0005$, two-tailed; for the laboratory report class, $t = 10.97, df = 21, p < .0005$, two-tailed). The effect size was large for both classes ($d = 3.54$ for the poster class and $d = 3.79$ for the laboratory report class). These data show that engaging in an appropriately scaffolded laboratory-based investigative inquiry and subsequent writing-to-learn activities led to a significant increase in students’ understanding. This was the case regardless of which genre students were required to use to report on their biopolymer investigation. The efficacy of writing-to-learn activities to enhance students’ understanding indicated here aligns with the results of other studies (e.g., Gunel, Hand, & Gunduz, 2006; Hand, Yang, & Bruxvoort, 2007; Hohenshell & Hand, 2006; Prain, 2006). In this study, scaffolding strategies were necessary to support students’ learning through text production not only because the subject of chemistry was new for students, but also the nature of this emerging area of scientific research meant that most information that students might have accessed alone, for example, on the Internet, would be too advanced for students to understand independently. It was therefore necessary to provide students with a range of appropriate visuals, multimodal texts that modelled the use of representations, and to use resources that demonstrated the appropriate use and description of chemistry representations.
The usefulness of writing-to-learn activities situated in laboratory-based learning has not previously been investigated in relation to its effect on students’ ability to use multiple representations in their explanations (i.e., their representational competence). This study provides evidence that the learning and scaffolding strategies used were effective for developing students’ representational competence. The pretest and posttest representational competence scores were compared using the Wilcoxin Signed Rank Test, which showed that the scores for all items of the post-inquiry test were significantly higher than the pre-inquiry test items ($p<.0005$ for all items). The data illustrated in Figures 2a, 2b, and 2c indicate the representational competence scores obtained by students on each of the three representational competence items on the pretest and posttest.

Figure 2 a. Pre- and post-inquiry representational competence Item 1 scores.

Figure 2 b. Pre- and post-inquiry representational competence Item 2 scores.

Figure 2 c. Pre- and post-inquiry representational competence Item 3 scores.
These data indicate that the number of students who did not attempt the items on the pretest was high and this was greatly reduced from pretest to posttest. The number of students who achieved at higher levels of representational competence increased for each item from pretest to posttest. This suggests that using the approach outlined in the current study to learn chemistry increases students’ confidence to attempt explanations and their ability to use multiple representations to do so. This is most likely due to the scaffolded writing-to-learn activities allowing students to gain experience at selecting and integrating multiple representations, which would be expected to boost their confidence in using them in other settings.

Taking a student-centred approach in which students developed an understanding of chemistry concepts through laboratory-based inquiry was shown to be effective by the results of the pretest and posttest comparisons. When students were engaged in investigative inquiry and then required to present their findings and explanations of their data on the molecular level through texts that integrated multiple representations, students’ understanding of chemical bonding and polymer structure improved significantly. These results extend the findings of other studies in that they are linked directly to laboratory-based activities and they show that students’ representational competence can also be enhanced through such approaches. While students’ performance was markedly improved from pretest to posttest, there were no significant differences between the two classes who produced different genres, which suggests that both report genres (i.e., the laboratory report and the digital poster) were equally effective in improving students’ performance. While both were equally effective, and students’ knowledge and representational competence improved significantly, it is necessary to understand why they were effective in the development of representational competence. Students were interviewed to determine how they felt the digital resources were helpful in scaffolding their learning.

Scaffolding with Digital Technologies

When interviewed about the use of digital resources to scaffold their learning and text production, students agreed that the materials were effective in supporting their learning. Many students commented on the usefulness of the visual representations, simulations, and modelling software. For example:

“The molecular structures (from ChemSketch) were really helpful... First of all, I knew I had the right diagram and it put everything visually.”

“Having the structures let me talk about the bonds straight away without having to worry about what the structure was like.”

“Using ChemSketch in the first few weeks was good because it helped you to get used to the different types of diagrams and how to interpret them.”

“I thought the diagrams were helpful. They helped me to understand what happened in terms of the structures of substances.”

Students suggested that not only were the digital resources useful for helping them to understand the task and make sense of the data they collected, but that the resources scaffolded the text production process by modelling relevant information, allowing them to work more efficiently. They felt that they learned more by having access to these materials than they might have if asked to conduct their own research, for example, on the Internet. Many students felt that the resources scaffolded their learning by helping them to understand a topic that is complex and for which independent research might have been overwhelming or beyond their current levels of understanding:

“If you have to research yourself on the Internet, you spend time finding it, then reading it and then trying to understand it, whereas with the resources, you know it (the information) is right and you can read it and use it straight away.”

“If you have to research by yourself, you get bits and pieces ... whereas we got a broader and deeper understanding to begin with.”

“(By researching) on the Internet ... (you) get so much information that it’s hard to interpret and really complicated to read and understand. Even though we still had a lot of information and we still had to
choose what was relevant for ourselves and show that we could look for information, it showed us the kind of information we needed to focus on.”

Several students commented that the digital visualisation tools helped them to visualise chemical entities and processes and understand on a molecular level:

“I liked the simulations – visually I got it because it was molecules moving – I got it first go...”

“I liked drawing molecules and the polymer simulations – the computer showing you how the bonds looked.”

“In the past, it was more words – we didn’t get that many visuals at all. When we write now, when I talk about concepts, I can picture the molecules in my head.”

Student survey responses also indicated that students found the digital resources used to scaffold their learning experiences helped them with a number of different aspects while completing both text types, although some felt that they were more helpful for one text type than the other. These data are summarised in Table 3.

Table 3 Percentage of students who found digital resources useful for particular text types

<table>
<thead>
<tr>
<th>Aspect of resource use</th>
<th>Mostly helpful for laboratory report</th>
<th>Mostly helpful for digital poster</th>
<th>Equally useful for both texts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding the data</td>
<td>6.8</td>
<td>22.7</td>
<td>70.5</td>
</tr>
<tr>
<td>Creating the texts</td>
<td>13.6</td>
<td>25.0</td>
<td>61.4</td>
</tr>
<tr>
<td>Understanding the text production task</td>
<td>11.3</td>
<td>27.3</td>
<td>61.4</td>
</tr>
<tr>
<td>Analysing the data</td>
<td>11.3</td>
<td>15.9</td>
<td>72.8</td>
</tr>
<tr>
<td>Explaining the data</td>
<td>18.2</td>
<td>29.5</td>
<td>52.3</td>
</tr>
<tr>
<td>Understand the chemistry on a molecular level</td>
<td>9.1</td>
<td>29.5</td>
<td>61.4</td>
</tr>
</tbody>
</table>

These data indicate that the majority of students found the resources helpful for both texts. Of the remaining students, more felt the resources assisted when creating the digital poster more than when they were creating the laboratory report. This might perhaps be related to students’ perceptions of a digital poster as a more visual form of text than a laboratory report. The fact that all students agreed that the digital resources were useful provides evidence that the scaffolding approaches described in this paper are a valuable way to enhance students’ learning through text production and laboratory inquiry.

Students’ Perceptions of the Scaffolding Approaches Used

When students were asked to identify what they enjoyed about the unit, activities, topic, and resources, their answers were focussed on several themes, including visualisation tools and technology, the laboratory inquiries, and the student-centred pedagogies used.

Visualisation tools and technology

Students commented that they enjoyed the activities because of the nature of the technologies and the regularity with which they were used:

“I enjoyed using the computers often rather than just every few weeks.”

“Being able to use the information on the CD and the student drive meant we didn’t get bored writing stuff from the board every lesson.”

“I liked the technology – it’s good that you used the interactive whiteboard – it wasn’t just “copy this down”. We got to see visualisations and interact with them. I went home and downloaded ChemSketch the first day we used it and have used it since at home. I really liked that.”
The nature of the laboratory inquires

Students commented on the value of laboratory inquiries and they appeared to distinguish between the inquiry-based approach and their experience of “cookbook” experiments from earlier years. For example, one student said,

“I enjoyed the pracs…the plastics prac was good. I don’t think we really talked about the chemistry in pracs last year. Last year it was more about ‘please remember to wear your glasses,’ and we concentrated more on procedure than on what was actually happening.”

Other students suggested that the laboratory experiences were valuable for linking concepts to experimental outcomes. For example,

“I enjoyed the research procedure and also to think about the reasons behind the reactions and what we observed in the experiments.”

“I was motivated by the bioplastics experiment because we made them instead of just reading about them – we understood it because we actually did it…”

One of the international students drew a comparison between the use of laboratory experiences in this unit and his past experiences in his home country:

“In China, we do a lot of practice to solve problems and question banks and we seldom do research. I enjoyed this very much. It’s quite different.”

Students also commented that the relevance of the biomaterials topic was a motivating factor:

“I enjoyed learning about the bioplastics because my family is very environmental and I have some knowledge in that already…”

“I was familiar with it because of the news etc, and knew more background information…”

Students reported that being asked to report on their laboratory inquiry and having the opportunity to discuss their findings with peers was an important factor in their understanding and their motivation during the study. For example when describing the conversations that occurred within her group one student said,

“We talked about how different properties were represented in the diagrams and how we’d represent that information in our text. We talked about how different properties related to different structures of the bioplastics.”

Student-centred pedagogies

The student-centred structure of the unit was a factor that students also identified as a reason for their enjoyment of it:

“(The unit) was structured so that we were able to learn by ourselves but with help when we needed it.”

“Last year we had a lot of definitions to memorise. This year we had to find information out for ourselves by looking at diagrams and making links for ourselves.”

“This year it’s more activity-based and we used technology. Last year it was just the teacher telling us stuff.”

“I liked understanding how the chemicals worked – this year it wasn’t just information transfer but the learning came from me as well.”

“I liked having more time in class to understand it and being able to talk with other people.”
“The things we did this year involved the students – the technology and the presentations – you get more involved and pay more attention and learn more.”

“We had the choice to save information from the student drive and then go home and learn more – do our own study – it gave us responsibility.”

One student related the fact that initially this type of approach can be challenging to students who are not used to a student-centred approach but that ultimately it is a worthwhile approach:

“First of all it was hard because it was all new but now it’s heaps better and I know I understand it more because of the way we learned it.”

These comments suggest that students enjoyed being active participants in learning activities and having responsibility for their own learning outcomes. They found the approaches, the topics studied, and the use of digital technologies to be motivating and interesting. The level of interest and motivation can be summarised by students’ concluding interview comments. When asked what they disliked about their experiences, typical answers included:

“Nothing – I looked forward to chemistry lessons – it was my favourite subject.”

“Nothing – I actually enjoyed it.”

“Nothing – I loved coming to chemistry.”

“Missing classes because of music camp.”

In summary, the students who participated in the study reported feeling motivated by and interested in the materials used, the topics studied, and the activities they experienced. These outcomes can be attributed to the use of a variety of digital technologies, the active participation required by the learning experiences, the perceived relevance of the topic, and the fact that they were required to complete writing-to-learn activities that allowed them to make sense of their experimental data in terms of the underlying chemistry involved. The value of using digital technologies in this context is that they scaffold students’ learning by providing links between observed laboratory phenomena and molecular-level entities and processes. They can be used to enhance and extend students’ laboratory-based experiences rather than being used in lieu of laboratory work. The results of this study suggest that these goals can be achieved through the use of student-centred activities that incorporate a balance of laboratory-based and digital learning environments alongside explicit teaching and scaffolded learning activities.

Conclusion

The changing climate in chemistry education is one in which student numbers are decreasing because of its difficulty and students’ lack of interest in studying it beyond the compulsory school years. If future chemistry research is to be sustainable, it is essential that this change be reversed to ensure that students not only choose to study chemistry in senior schooling but also in tertiary education. Also of equal, or perhaps even greater concern, is the need to ensure that whether or not chemistry students continue its study in tertiary education, they should leave school with a level of understanding and chemical literacy that will prepare them as informed, participative citizens who are able to make judgments and decisions around chemical applications that may have social, health, or environmental impacts. Several aspects of this study provide an insight into ways of addressing the issues of engaging students, increasing their interest in continuing their study of chemistry, and how to improve their understanding of the complex concepts needed to succeed in the subject and be informed members of the community beyond school. By engaging students in laboratory-based inquiry activities and making learning meaningful and contemporary by situating it in the context of emerging scientific research, chemistry can become more relevant and interesting to students. Another important aspect to addressing the issues facing chemical education is the level of difficulty experienced by students. Learning activities need to be contextualised, should stimulate personal or social construction of meaning, and should involve learning of material beyond declarative information. For such learning activities to be effective, they require appropriate scaffolding because students are operating at a level that is challenging to them. Scaffolding approaches and materials used in this study, such as student-
centred laboratory and digital inquires, heuristics, genre guides and templates, and the utilisation of a range of digital visualisation tools, were shown to be effective in the development of students’ understanding and representational competence. The pedagogical approaches and activities used increased students’ interest and motivation for the topic and more broadly, for the subject of chemistry. This is essential if students are to develop a positive attitude to continuing study in chemistry. The use of an emerging research field, biomaterials, through which concepts were presented, also increased students’ interest and illustrated a cutting-edge field of research. It also illustrated an application that was relevant to their lives and addressed environmental issues of concern to students. This study has implications for the use of activity-based learning in chemistry and for the efficacy of laboratory work linked to writing-to-learn strategies for enhancing students’ learning outcomes and their enjoyment and enthusiasm for the subject. Further research might examine the use of other technologies to collect and analyse data (such as data loggers) or the use of blogs as a means for students to share their understandings with peers. It might also investigate the use of other emerging areas of chemistry research through which students can learn other chemical concepts such as those associated with electrochemistry, equilibrium, and organic chemistry through other emerging areas of chemistry research, for example, nanotechnology, drug design and synthesis, and other biomaterials development.
References


APPENDIX

Sample Representational Competence Test Items

Bioplastics

Item 1: A student added a plasticiser to a biopolymer and noticed that it made biopolymer more flexible. Explain their observations using appropriate representations.

Item 2: This diagram shows a segment of a polymer chain.

Using a diagram, explain how this polymer might form cross-links.

Biofuels

Item 2: These photos were taken by students during an experiment to investigate the fermentation of glucose by yeast over time. Explain using appropriate representations why the balloons inflate over time.

Item 3: During an experiment similar to that in the previous question, a group of students used three different materials: glucose, sucrose, and starch. They obtained the following results. Explain using appropriate representations, the reasons for the shape of the graphs.