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ANALYSIS OF STUDENT ENGAGEMENT WITH ONLINE CHEMISTRY MODULES USING TRACKING DATA

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Abstract

The study in this paper describes how we used a combination of interaction tracking data and stimulated-recall interviews to evaluate student engagement with two online chemistry modules. An engagement index (IE) was developed and tested for accuracy and validity. The students that appeared to engage well were more likely to be mature-age and/or studying in external study mode, extroverts, and verbal learners. Students with prior experience of the graphical depictions of the molecular level were more likely to learn from the animations and interactive exercises.

Keywords

analysis, interaction tracking, chemistry, online, learning styles, engagement

Introduction

When asked to compare learning chemistry on a computer with learning from a textbook, one of our students said the following:

> *"It's the future, isn't it. Like you sit down at the computer and you log on, and as I said, it's fantastic. Even my generation, probably the older generation, would've probably rather sat down and read a book 'cos that was their technology. Whereas people my age or a bit younger or whatever, are coming through with computers. Therefore, they kind of associate "oh computers, cool - learning". They're comfortable with them. So they use them more."*

As part of a long-term project to produce an e-learning alternative to a first-year chemistry textbook we are interested in studying how students engage with online learning modules. We use two research methods - tracking and analysing their screen interactions in an authentic learning context, and without their knowledge; and interviewing students as they recall their experience with the modules. These data are then correlated with information on each student's preferred learning style and academic performance to identify trends.

This paper describes data we have gathered to answer the following questions:

- Can we develop a reliable measure of student 'engagement' with the text, animations, and activities using interaction tracking data?
- What proportion of students engages with the content?
- Is engagement with the module influenced by learning style, gender, teaching style, or study mode?
- Is there a correlation between engagement and performance in conventional assessment of that topic?
- Do students spend more or less time on animation screens than text-only screens?
- Do students read feedback in pop-up text boxes?

Background on the chemistry modules

There is a substantial research literature that shows that high-quality, pre-laboratory exposure to related theoretical concepts and experimental design increases students' deep learning and performance in the laboratory (Johnstone, Sleet & Vianna, and references therein). The modules in *Bridging to the Lab: Media Connecting Chemistry Concepts with Practice* (Jones & Tasker, 2001) can be used either as pre-laboratory preparation, as a laboratory supplement to introduce activities that are not part of the syllabus, or as homework assignments that reinforce lecture topics.

Bridging to the Lab modules are also designed to help students link what they observe in the laboratory to what is happening at the molecular level, and to see how chemical changes are represented symbolically and graphically.

The modules motivate students to learn by proposing real-life problems (for example, designing a new cold pack) in virtual environments. Students make decisions on experimental design, observe reactions, record data, interpret the data, perform calculations, and draw conclusions from their results. Following a summary of the experiment, students test their understanding by applying what they have learned to new situations or by analyzing the effect of experimental errors.

Each module is divided into sections. While working through a section, students can progress only by successfully completing the activities on a screen, or at least seeing the correct answer to a question. Students can always retrace their steps using the *Back* button. Therefore, reaching the last screen in a section ensures that the student has completed the preceding activities correctly. Students can jump to another section, or simply quit at any time.

Two modules in this series - *Reaction Types: Treatment of Copper(II) Waste* (Figure 1) and *Acid-Base Titrations: Finding the pKa of a Food Preservative* (Figure 2) - were selected for this study.

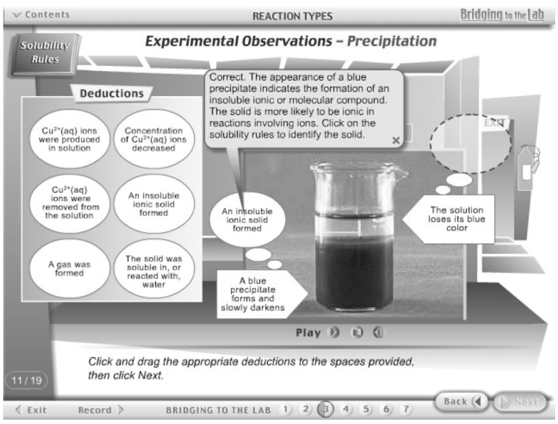

Figure 1: A sample screen from the Reaction Types: Treatment of Copper(II) Waste *module requiring the appropriate deductions to be dragged to the corresponding observations.*

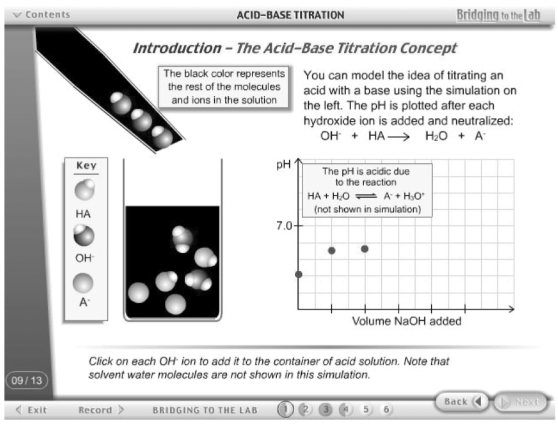

Figure 2: A sample screen from the Acid-Base Titrations: Finding the pK_a of a Food Preservative *module requiring the simulation to be performed before progression is possible.*

Methodology

First-year chemistry students in 2003 at an outer metropolitan university (n = 116 with complete tracking data) and a regional university (n = 54 with complete tracking data) were allocated a small percentage of marks for completing four online chemistry modules. They were told that these modules were designed primarily as learning experiences (i.e., they were encouraged to explore correct and incorrect options in activities and questions), and that their completion of sections in each module was tracked and recorded in a database. Data from only the *Reaction Types* module, collected in 2003, are discussed in this paper.

Data from first-year chemistry students in 2002 at the same outer metropolitan university (n = 78 with complete tracking data) were collected in the same manner for the *Acid-Base Titrations* module. No data on this module were collected from students at the regional university.

In both years the students were *not* told that the timing and nature of every interaction with the modules was also recorded in the database. This deception was considered essential in order to collect interaction data that were not influenced by any perceived notion by students that their selection choices, number of sessions, time on task, or choice of navigation through the modules were being judged by teaching staff. One of the authors (JM), who was *not involved in teaching at either university*, extracted and analysed these data on a confidential basis. This protocol was approved by each University's Ethics Committee on the proviso that each individual's data were not identified, and were unavailable to any teaching staff involved with grading the students.

Volunteers from the two student groups were asked to complete one of two learning style questionnaires - the *Paragon Learning Style Inventory* (Briggs-Myers & McCaulley, 1992; n = 26 students for whom we also had complete tracking data at the metropolitan university; n = 26 students for whom we also had complete tracking data at the regional university) and the *Felder-Soloman Index of Learning Styles* (Felder, 1993; n = 27 students for whom we also had complete tracking data at the metropolitan university, n = 20 students for whom we also had complete tracking data at the regional university). Each student's responses were analysed and an individual summary of the results, with explanation, was given to the student concerned, together with a form asking whether s/he considered the analysis matched their self-perception of their preferred learning styles. The returned forms (n = 16, 30%, outer metropolitan university students only) indicated that students agreed strongly (56%) or mildly (44%), and none disagreed.

One-to-one interviews with student volunteers (n = 8 at the metropolitan university, n = 3 at the regional university), using stimulated-recall techniques, were recorded on video by one of the authors (JM). Transcriptions of these interviews were kept confidential, and students' comments on their interactions were checked against their actual interaction data to check reliability. These different data sets corresponded very well in all cases, confirming the accuracy and validity of the interview data.

Development of an engagement index

A quantitative measure of a student's 'engagement' with a learning program is difficult to define. We defined engagement in terms of measurable tracking variables that we thought might indicate evidence of thoughtful reading of text, deliberation over choice of button options and click-and-drag options, and reflection on the visual messages in animations.

By examining the interaction patterns of the students we had interviewed, and comparing those who had clearly demonstrated a meaningful engagement with the modules with those who had not, we identified distinguishing interaction characteristics. Based on these data we developed an engagement index (EI) for the *Reaction Types* module that was a composite of five parameters:

i. time taken to complete the module
ii. time spent on the two introduction screens
iii. time spent on the experimental set-up screen
iv. the time between opening a screen and choosing one of six options that best described the observation/deduction illustrated by the video image (see Figure 1)

v. accessing the solubility rules (by clicking on the top-left button in Figure 1), to which students were directed in a feedback box and which contained data required for problem solving

Because our intention was to discriminate between students who were “engaged” and those who were not, rather than to construct a scale of engagement, each student was rated as either engaged (= 1) or not engaged (= 0) for each parameter.

Assignment of these cut-off points was necessarily fairly subjective. Initially, parameters i-iv were evaluated from tracking data collected when two academics associated with the course completed the module in the guise of conscientious students. These values were then compared with the 5% trimmed means for each parameter calculated from the complete student sample. The student times were considerably (and unexpectedly) higher than the staff values, so the latter were chosen to represent the cut-off values for each parameter on the premise that the typical capable student would adequately engage with the screen or task in that time. These values were then referred back to the student sample to ensure that they were consistent with a reasonable proportion of students deemed to be “engaged”. A third category (very engaged = 2) was later added to accommodate students who spent excessively long periods on any screen or task. Time periods that were significantly inconsistent with similar screens elsewhere in the module were not included in the calculation. Parameter v was classified as 0 = did not, 1 = did access the solubility rules, and 3 = did so several times. Scores for the five parameters were summed to give the EI. This way of measuring EI was useful and appropriate for a module like *Reaction Types* dealing with qualitative, descriptive content.

The *Acid-Base Titration* module dealt with more conceptual and quantitative content, so we tracked specific interactions on specific screens, such as the time spent reading feedback boxes, the time periods on specific screens, use of the Back button, and times on animation and text-only screens.

Results & Discussion

All statistical analysis was performed with SPSS 10.0 for Macintosh (SPSS Inc., USA). Values quoted below in parentheses are Pearson correlation coefficients at the $p < 0.05$ confidence level.

Reliability of the engagement index

There was a statistically significant correlation between the EI for the *Reaction Types* module and independent interaction data (parameters not used to calculate the EI) that indicated that the students were reading the text rather than just scanning it, exploring all options even after the *Next* button was activated, and revisiting screens where necessary. For example, EI correlated with the students accessing the orientation screens (the *Map* screen, r =0.243; and the *What You Should Know* screen, r = 0.152); examining all the experimental options (r = 0.323); and working through in an investigative, non-linear sequence (r = 0.345).

The reliability of the EI was also validated subjectively by comparing the EI indices of a sub-set of students with their personal recollections of their engagement with the module during stimulated-recall-based interviews.

Proportion of students who did not engage with the modules

Students who clearly progressed through the *Reaction Types* module with little or no meaningful engagement were described as ‘clickers’. These students clicked randomly on button options and graphs without any deliberation until the *Next* button became active. The proportion of students who were clickers was low: 11.7% at the regional university, 6.5% at the outer metropolitan university, and 8.2% overall.

A similar proportion of the 2002 students (6.8%) at the outer metropolitan university progressed with little or no meaningful engagement through the *Acid-Base Chemistry* module.

Effect of age on engagement

The regional university, with its mix of internal and external students, had a broader range of ages. The data in Figure 3 shows the students with the highest EI were mainly older students (r = 0.588). The age distribution for the outer metropolitan university was too narrow for analysis.

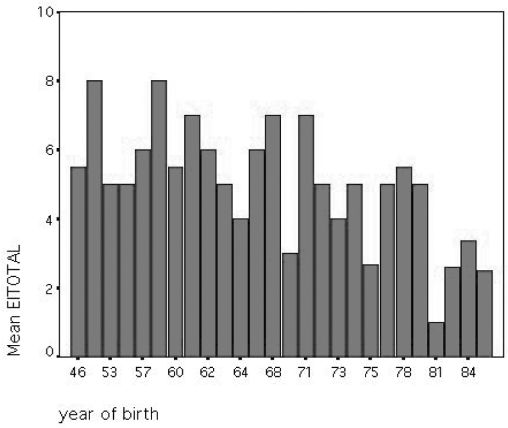

Figure 3: Plot of engagement index for regional university students against year of birth. (Pearson correlation 0.588 at p < 0.05).

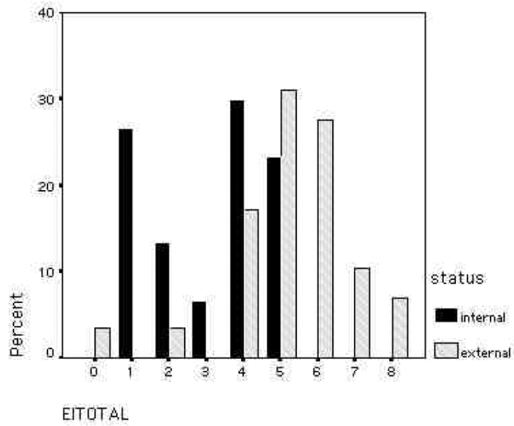

Figure 4: Plot of % students at the regional university enrolled as internal or external students against engagement index. (Pearson correlation 0.560 at p < 0.05).

Engagement by external and internal students

Students at the regional university are enrolled in either internal (n = 27) or external (n = 27) study modes. Figure 4 shows that external students were more engaged with the *Reaction Types* module than the internal students (r = 0.560). Because there is a higher proportion of older students in the external population than among the internal students (Figure 5), it is unclear whether this is primarily an effect of age or can be also attributed to factors exclusive to distance education students.

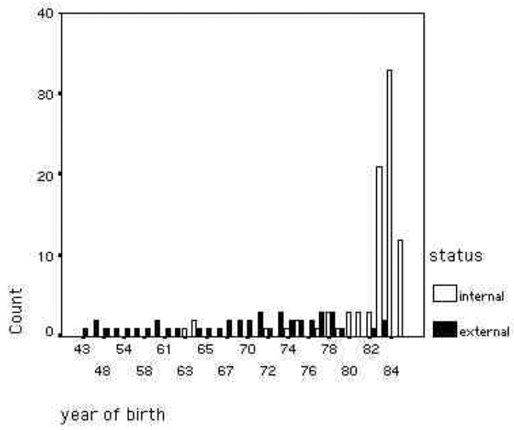

Figure 5: Plot of number of internal and external students against year of birth. (Pearson correlation 0.690 at p < 0.05).

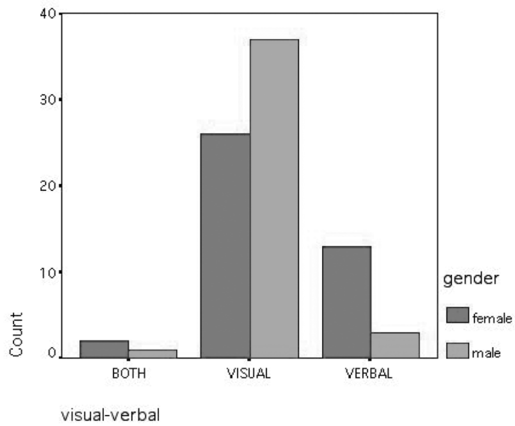

Figure 6: Distribution of verbal and visual learners among male and female students. "Both" refers to students with no preference for a particular style.

The value of this type of module to external students was summarised in a quote from one of the external students:

> *"It's such an intense subject if you haven't done any chemistry before. Things like this on the web really help if you're not in a classroom....You're at home and isolated, so anything that helps is great."*

Effect of visual/verbal learning styles and gender on engagement

One of the dichotomies in the *Fielder-Soloman Learning Style Model* (Felder, 1993) is the classification of students as predominantly visual learners (prefer visual representations of presented material) or verbal learners (prefer written and spoken explanations). This dichotomy correlates significantly with gender for all the students in this study (r = 0.241): females predominate in the verbal group, whereas males predominate in the visual group (Figure 6), although both males and females are predominantly visual.

The plot of this parameter against EI (Figure 7) suggests that *verbal students tend to be more engaged* with the module than visual students. Perhaps verbal students need to engage with the module to a greater extent in order to understand what is being communicated in an essentially visual manner. Although this correlation is not statistically significant in our data, we are testing this interesting observation in another study with a larger student population.

Figure 8 shows that visual/verbal learning styles correlate significantly with age (r = 0.397). That is, younger students tend to be more visual in our study.

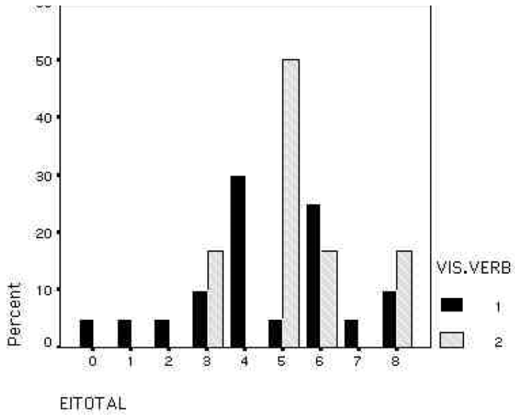

Figure 7: Plot of % visual and verbal students against engagement index.

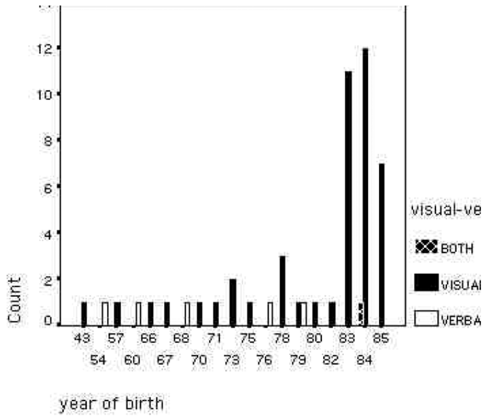

Figure 8: Plot of % visual and verbal studen against year of birth. (Pearson correlation 0.397 at $p < 0.05$).

Linear and non-linear progression

Student learning styles and cognitive preference were also classified using the *Paragon Learning Style Inventory*. The statistically significant data (r = 0.293) summarised in Figure 9 show that extroverts (who learn best from doing) tended to progress in a more non-linear manner than introverts (who like to watch before doing).

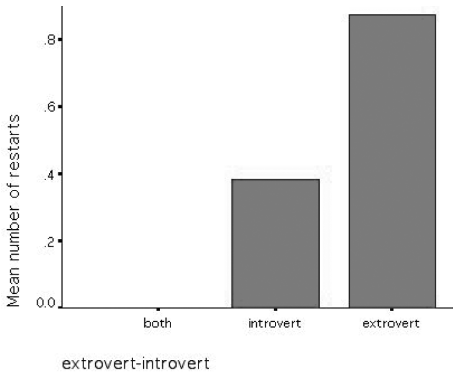

Figure 9: Plot of mean number of non-linea progression interactions against introversion/extroversion. (Pearson correlation 0.293 at $p < 0.05$).

The ratio of extroverts and introverts in the general population is generally about 60:40. In the 2003 outer metropolitan university student group it was 25:75, and in the regional university it was 42:47 (11% could not be classified as one or the other). Clearly, the former student group is abnormally introverted, and this is being followed up in a study with a larger sample at another university.

Influence of teaching style on engagement

The proportions of students who worked through the *Reaction Types* module in a less-engaged linear manner differed in the two institutions: 73% at the regional university and 48% at the outer metropolitan university. This was probably due to the greater emphasis on the three-thinking-level teaching style - a key pedagogical feature of the module (Figure 10) - at the latter institution, and a lack of familiarity with these types of depictions.

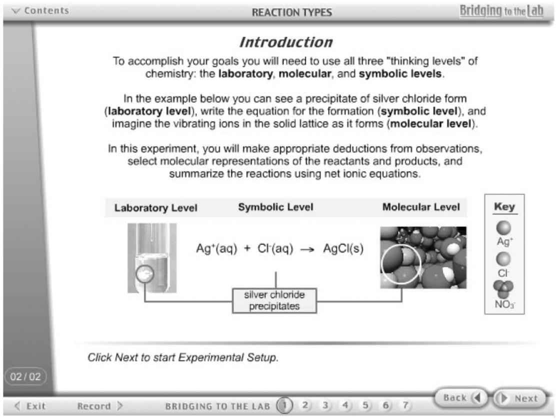

Figure 10: A screen from the Reaction Types: Treatment of Copper(II) Waste *module describing the three thinking levels when learning chemistry.*

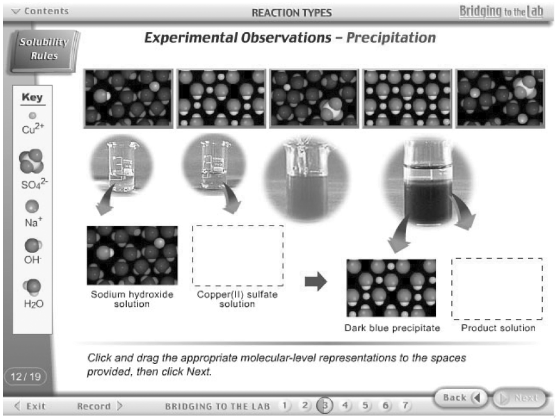

Figure 11: A sample screen from the Reaction Types: Treatment of Copper(II) Waste *module requiring students to drag the graphical representation of the molecular level to its formula representation box.*

For example, representative quotes from students at both institutions reveal different attitudes based on their perceptions of whether their lecturers considered interpretation of graphical depictions of the molecular level were important :

> *Interviewer:*
> *"Were the graphic screens useful?"* (see Figure 11)
>
> *Outer Metropolitan University Student:*
> *Yes because it's one of the things I struggle with so I actually try to work it out myself, thinking logically. It's extremely useful. It was obviously effective because in the exam, I got 10/10 so obviously learnt something. I really tried to think "what does it look like". Without seeing it there, I have trouble thinking about how I'd represent it and what it looks like and how I draw it. I need the example first before I can think it through myself. There's no way I could do it without these things and animations etc.*
> *............... It's absolutely useful to have the three levels of representations together. Because that's how you'd get an exam question. And to learn to write it as Na+ and OH- rather than NaOH in solution - that distinction was good."*

This is in contrast to a selected quote from a regional university student:

> *Interviewer:*
> *"Were the graphic screens useful?"*
>
> *Student:*
> *"Hated these screens. I didn't really understand - Because when I originally did it, I didn't know what these* (graphic depictions of the molecular level) *were, and these confused me. I couldn't work out what I was supposed to be getting out of it. And I couldn't work out how to do it. And I couldn't - there's the key there and everything but they're too confusing to look at. And I kept getting it wrong, even when I was really trying. It seemed to jump from this level of knowledge to that level of knowledge. It was beyond me. I couldn't understand it.*
>
> *Interviewer:*
> *If (the lecturer) had used these sorts of graphics in his lectures, would that have helped?*
>
> *Same Student:*
> *"Yes, probably. And because I'm just struggling learning through the words and symbols, those sorts of graphics would be good as a learning tool anyway."*
>
> *Interviewer:*
> *"Are these useful now you can better handle the concepts?"*
>
> *Same Student:*
> *"I haven't gone back to have another look. They'd probably be more comprehensible now. I haven't because I'm just trying to stick to what* (the lecturer) *does, because I'll just confuse myself trying to do too much else........... The graphics were purely a guess because I had no idea what was in the dark blue precipitate. I learnt nothing from getting the right graphic in the box because I didn't know what it was."*

These and other comments from interviews suggest strongly that the educator's teaching style influences the motivation of students to engage with online modules that embody that philosophy, and are thus more likely to contain examinable material. This observation is relevant to educators when selecting 'off-the-shelf' learning software.

Students completed the *Acid-Base Chemistry* module on one (79.5% students), two (17.9% students), or three (2.6% students) occasions. Working through the module ranged from non-linear progression (29.5%), to linear progression with use of the *Back* button (29.5% students), to completely linear progression without resort to the *Back* button (38.5% students).

Use of the *Back* button was a strong indicator of engagement in this module. Nearly half the students (46.2%, 32 students) used the *Back* button, with 28.2% (22 students) using it more than once.

Correlation between reading feedback text boxes and performance in assessment

Another strong indicator of engagement in the Acid-Base Chemistry module was the mean time spent reading feedback boxes. There was a statistically significant correlation ($r = 0.245$) between this time and the mark obtained in the two questions that examined the concepts covered by this module in the mid-semester test.

Strong correlations were found between the mean time spent reading feedback boxes and the mean time spent on reading screens ($r = 0.582$), and the mean time spent on animation screens ($r = 0.592$).

Engagement with non-interactive text-only and animation screens

Students working through the *Acid-Base Chemistry* module spent more time on animation screens (mean time 58 s) than on text-only screens (mean time 25 s), even though the former involved only playback interactivity. Student quotes indicate why they consider molecular-level animations useful:

> *Student:*
> *"(They were) very good. Very very good. You know, they actually tell you what's going on. And even when you have experience with these things* (points to the animation)*, when you are faced with problems or questions in the exams you are able to picture these. That helps you to answer questions."*
>
> *Another student:*
> *"I like these modules because they actually show you what's going on at a molecular level as well as a physical level. Because a lot of people, kind of when they go from one to another, they kind of freak out."*
>
> *Another student:*
> *"They're very helpful. They're the first thing - I mean,* (the lecturer) *uses a lot of them and I find them very good. Because we never did anything like this in high school. We just sort of - you know, I suppose we did it with the models but this is really good. Actually understanding what's happening between each molecule. Because you don't often think about it and I'm more of a mathematician than a chemist, so I often just look at them mathematically, as opposed to actually thinking about what's happening. So I quite like them."*

Student quotes also indicate why they consider text-only screens less useful:

> *"You better put some question on the reading screens or, you know, sometimes it's too lazy to not half read it. And I've found when there is a "next" I want to skip that page......You'd better use a question to make sure the student will read it."*
>
> *...you don't want it to be like a textbook so much. .... And yeah, I'm probably not so interested in reading all the writing. If I knew absolutely nothing about any of this, then I probably would. But because it's just something to sort of revise, then I don't really read all the text.*

Conclusion

This study revealed that few students acted as just 'clickers' in the two multimedia learning tools investigated. Externally enrolled students were demonstrated to engage more effectively than internally enrolled students. It is tempting to hope that these computer-based modules are particularly useful to students who necessarily lack some on-campus resources. However, older students engaged more effectively than younger students. Because external students also tend to be older, it is as yet unclear how these two effects influence one another. Our interview data suggest that older students are less confident with computers and software learning tools than younger students. It is also well recognized that both external and older students are highly motivated. From the complex interplay of these factors, we hope to dissect out, with future research, the usefulness of these online chemistry modules in various contexts and to different sorts of students.

Gender had no effect on the parameters evaluated in this work, apart from in the distribution of visual and verbal learning styles. Our data suggest that verbal students engaged with the modules better than visual students, although this observation was not statistically significant. Data with a greater number of students are being collected to test this proposition.

Extroverts tended to progress in a non-linear way to a greater extent than introverts, however they were not necessarily more engaged.

As expected, students engaged with the modules more fully if the content was presented in a similar style to that used by the educator. For example, students were more willing to work with molecular-level graphics in these modules if their educator had already used them in his teaching. Educators need to be aware of this point when selecting 'off-the-shelf' learning software.

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