FINAL REPORT

Microsoft Partnership Project with WSU

This is the final report of this project

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Final Report

Abstract

The main purpose of this study was to explore how university undergraduate students learn chemistry concepts using the Microsoft Surface Device and digital pen. Data were collected from lesson observations and interviews with tutors and students. The interviews explored the ways in which the participants used the digital pen device and the Surface Device in their teaching and learning of chemistry at the three levels of representation, and lesson observations were carried out to gain an in-depth understanding of the actual use of the Surface device and digital pen. Several key findings of this study are reported. It was found that the use of the device and digital pen was contextualized, dependent on individual differences, and that emerging learning was fostered. Benefits and implications of this study are also discussed in this report.

Introduction

In this study, we explored how university undergraduate students used the Microsoft Surface Device and digital pen to learn key concepts in organic chemistry. In theory, the incorporation of digital pens with mobile learning devices may align more readily with the natural information processing system (cognitive architecture) that underpins how humans think, learn, and solve problems. Support for this theoretical proposition comes from recent integrations of theories of human evolution with theories of human learning (Sweller, 2012). This synergy has generated a raft of new concepts that are likely to be critical to the research and development arm of companies interested in educational technologies.

A key idea that has emerged from evolutionary perspectives on human learning is that we have an in-built information processing system that “is biased towards processing specific kinds of information” (Geary, 2008, p. 180). As an example, we have the ability to recognise faces and to speak our native language without formal, direct instruction. These forms of knowledge have been labelled biological primary knowledge, which refers to knowledge that we have evolved to acquire because of our genetic inheritance. That is, at various critical junctures in our evolutionary
history there have been genetic changes that have flowed on to anatomical alterations (e.g., the voice box, the development of the cerebral cortex) and other changes which, in turn, have led to growth in our unique learning capacities.

Advancements in human learning are not only fueled by biological evolution, but also through the expansion of cultural knowledge. Examples of the development of cultural knowledge over the last few millennia include writing, mathematics, and science (Leahy, Hanham, & Sweller, 2015). Much of our cultural knowledge has not existed long enough to leave a mark on the human genome. As such, we have built educational institutions such as schools and universities which are responsible for the transmission of cultural knowledge, also known as biologically secondary knowledge (Sweller, Ayres, and Kalyuga 2011). A key characteristic of this form of knowledge is that it often requires prolonged periods of instruction (i.e., years) to acquire.

Writing aids such as digital pens may sit at the nexus between biologically primary and biologically secondary knowledge. We use our hands to interact with the world, such as communicating and manipulating objects. The sensorimotor information gained from using our hands may be considered a form of biologically primary knowledge (Ginns, Hu, Byrne, & Bobois, 2015). The use of sticks, pencils, ink pens, and now digital pens, represents an extension of our hands in the acquisition of knowledge. Indeed, writing aids have, and still are, critical in helping us acquire secondary knowledge.

There is evidence (Oviatt, 2013) to suggest that pen technologies are advantageous when learners are carrying out tasks that require the drawing of diagrams and symbols. Examination of human archeological finds shows that the drawing of diagrams and symbols has long been part of how we communicate ideas with each other. Thus, one of the reasons why digital pens are effective is that they align with the natural cognitive processes that humans use to encode non-linguistic information.
Methodology

We adopted a case study approach to explore how students learn chemistry concepts using the Surface device and digital pen. The two research questions that guided our inquiry were:

1. In what ways does the Surface device and digital pen technology contribute to students’ learning of Chemistry?

2. What are students overall experiences of the use of digital pen technology in their learning?

Participants

At the beginning of the 2017 autumn semester, with the support of the Unit Coordinator and tutor, we recruited undergraduate students enrolled in the Organic Chemistry unit in the School of Science and Health at a university based in Greater Western Sydney. In all, 19 students volunteered to take part in our study. Students in this unit were each equipped with a Surface device. For the purpose of this evaluation project, Microsoft provided each participant with a digital pen and keyboard.

Data Collection

From March to April 2017, we conducted four classroom (2 tutorials and 2 lab sessions) observations, each lasting approximately between 45 minutes to an hour. At least two researchers were present at the research sites for each observation. To capture the students and tutors using the devices in real-time, two video cameras were set up during the observation, and still photographs were also taken. Detailed observation field notes were recorded immediately after the observations for data analysis. An observation checklist that was approved by the Ethics committee was used during the observation. We also documented the learning process in general.

Three focus group interviews with students, one phone interview with a student (who was absent for the focus group interview), and two interviews with tutors (face to face and video conferencing) were carried
All interviews lasted approximately 30 to 45 minutes and were audio-recorded and transcribed for data analysis. An interview protocol that was approved by the Ethics committee was used during the observation.

Method of Analysis

In this study, audio interviews were transcribed into text by professional transcribers and these texts were then imported into Qualrus for data coding. The observation field notes and video files were used as supportive evidence. We used the qualitative analysis software, Qualrus, to analyze the data. In this project, we adopted some grounded theory principles for the analysis. The data analysis followed the guidelines suggested by Strauss and Corbin (1990) for open, axial, and selective coding. Open coding involves the breaking down, comparing and categorizing of data. In such a coding process, specifying the characteristics of categories is crucial. Initially, general terms such as “advantage of pen” and “use of device” were used to describe segments of data. Sub-categories emerged from the general categories. In axial coding, the researchers re-gathered the data and put them back together in new ways by making connections between a category and its subcategories. In selective coding, the aim is to allow a core category to emerge, which captured the essence of the findings. To do so, the researchers re-examined the previously analysed data and the research purpose and questions in order to narrow down the focus and to select a core category.
Findings

Several key findings emerged from our analysis and were presented in the interim report. However, more details are provided in this report.

Use of the Device is Contextualized

There were 16 instances of coding that revealed that students were consistently using the digital pen for specific types of drawing and for precision. An extract from one of the participants illustrates this:

“Each molecule in organic chemistry has a charge. What causes the action is a charge. So that molecule gives away its charge to a molecule depending on certain rules and it follows steps. [It's] well defined, well known or predefined, well known steps are called a mechanism. With the pen, it's much easier to learn the mechanism because there are intermediates - during the emergence of the intermediates, another action is going to happen and that new action is based on a new mechanism...you need to know that potassium permanganate is, what's going to cause the oxidation reaction. You need to know the steps of the mechanism, how it's going to happen, what's going to happen in the end, and how the new molecule is going to appear. So I find the pen and the device are very helpful in learning mechanisms.” Similarly, another student commented that: “I draw the chemical reactions so that it makes more sense and how there was less friction, so I find it easier drawing it, like faster.”

During our observations, we noticed that when drawing molecules using the Chemistry software, ChemSketch, most students preferred to use the digital pen as it was much easier to draw molecules using the Pen than using their fingers.

In chemistry, precision in drawing of molecular structure is critical to learning. The functionality of the Surface device together with the digital pen afforded precise drawing. This is reflected in a comment made during the interview:

“The more important thing about the pen is in organic chemistry. When you twist the mechanism, sometimes the arrowhead, the tip and the head - like the tail and head of the arrow... when you do it by hand, you wouldn't be able to figure out whether it's coming from the carbon and going to the
oxygen...But when you do it with something neat like that (using the Surface and digital pen), it's much neater so you can work it out.”

The unit coordinator shared a similar view when she mentioned that the arrows of the molecular bonds are very important as it shows the movement of the structure.

**Fostering Focused Learning**

As the use of the device (with the digital pen) is contextualized, students were focused in their learning. Our findings suggest that the device and the digital pen reduce students’ cognitive load so that they are able to stay focused, have a clearer understanding of the concepts, interact with their tutor, and engage in **reflective thinking** which leads to better understanding. One student commented:

“So if the teacher was explaining say the stereoisomers...She will actually quickly just scribble on the board just to show us how this reaction takes place...because I'm a very visual person I love to draw the actual structures and how they are going from one form to the other and then becoming a final product. So I find it really easy to draw it in the Surface device.”

The technology necessarily enables students to learn through visual simulation which is important, especially when laboratory work is required. For instance, one student commented that:

“you can't learn chemistry in the classroom. You have to go to the lab....because if you just try to recall something that doesn't make sense, you'll never remember it. But when you do it, you understand what's going on. So I think the pen and the device are breaking the linkage between what's written on the paper or what's taught in the classroom and what's happening in the lab. You can see the laboratory apparatus on ChemSketch. You can go to the database on the software itself and have a look and sense and feel how the apparatus works in a real lab situation.”

Although students can also use Chemsketch on their computer or laptop, the Surface device with the digital pen enables them to interact better with the technology through effortless manipulation of the variables.
Another student also commented on the flexibility of the technology that enables her to learn more effectively:

“If you have that in your notes, let’s say in your Surface tablet, whenever you come to it, rather than staring at a blank picture or a static picture, you can see the animations and that helps you record information a lot quicker.”

Similarly, another student echoed this view by commenting that as she watched how the tutor sketched the molecular structure, she was able to add to the drawing using her own device. Another student also commented that when he used the digital pen for note taking, he found that he could retain information more easily as compared to typing notes. During one of the observations, we noted that a student used the digital pen for writing down notes and annotating key concepts while the tutor was teaching.

Use of Device Encourages Emerging Learning

Throughout our observations, we noted that students devised new ways of approaching learning with the Device and the pen. In other words, the technology that students were using stimulates learners to construct their own learning content and process (Enonbun, 2010). One student mentioned that she was able to collaborate with three of her peers in Microbiology class on a group task after she learned how to use OneNote. Transferring her skills to another learning context helped her to work effectively on group tasks as she said:

“So four of us sat around a table; it was on everyone’s device, and then everybody could see the one document and then it was shared easily and instantly.”

We observed that impromptu collaborative learning occurred across all lessons when students took the initiative to help each other solve problems on the device. Adaptive learning also emerged from the learning process. It was interesting to note that to overcome some of the challenges of using the device, students devised their own ways of coping. For instance, one student mentioned that: “
I found sometimes the angle at which you have to write with the pen, the surface had to be flat. So when it was upright with the keyboard attached I found it more difficult I think when I had it flat. But then you take the keyboard away but then you don’t have access to the keyboard. So I used to turn my surface around so that the keyboard was facing away from me and then used the pen like that flat, for more detailed work. Because I found that having that at that angle the pen just wouldn't work sometimes. So...I turned it around so obviously the screen turned so that was okay.”

With the flexibility that the device offers, students’ learning is enhanced through multiple representations of the learned concepts. They were able to manipulate the learning space for effective learning. For instance, one student mentioned that:

“It's interesting because you can even have sort of input videos, even GIFs or [JIFs] they’re called, into let's say your notes. That way, you sort of have an animated version of a chemical reaction and it shows how electrons move to which place and what reacts with what. I would say it would provide a good summary as well. This is opposed to a piece of paper when you're just looking at the image. Especially when you're doing revision and you're like what's this image about? Whereas if you see a GIF, you can see everything ...” In this example, the student used a multimodal approach for visualization, leading to effective learning.

Use of Device is Dependent on Individual Differences

Our findings revealed that students’ use of the Surface Device is dependent on individual differences such as prior knowledge of the device and learning preferences. We noted that a number of students in this project were more accustomed to learning through the visual medium. For instance, one student mentioned that:

“I am a visual learner. So sometimes instead of just writing words, I use just pictures to identify what's happening. So instead of saying, for example, this to there, I just do an arrow and maybe whatever - if it’s a molecule, then I would be drawing the two molecules and just an arrow just saying - to pretty much save time.”
There were students who preferred capturing their notes digitally and in this case, the device improves their efficiency in learning as one said:

“I don’t type fast...so, I generally write. I rarely use devices to actually take my notes. But with a device that comes with a digital pen, I can actually write it down digitally and because I do wish to write my notes digitally...I go back home I write my notes digitally by typing it, but it takes more time. To have a device that I could use to write with the pen saves me time when I get back home to write notes.”

During lesson observations, we noticed that students who had been using the device for a while continued to use it for this project and were exhibiting efficiency in manipulating the technology. For instance, several students who were more skillful than the rest in terms of using the device were able to operate the device without any technical issues.

**General Benefits and Limitations of the Device**

There were several benefits reported by students and tutors. In general, it was found that the Surface device together with the digital pen and the keyboard supports learning and teaching. For instance, one student commented that:

“Having all three together, [I] can really understand what it’s like to do it, experience this Microsoft product effectively. It’s like a regular PC how you already have the keyboard and the screen, like the Microsoft Surface if it is together you can have the keyboard, the screen, the major screen and the pen...it is really useful to have all three together.”

The flexibility that the Surface device coupled with the digital pen and the use of OneNote offers is beneficial to student learning. Students mentioned that they were able to flexibly use the digital pen and keyboard for note taking, annotation, and browsing. Some students felt that the device was
cost effective as all they needed, including textbooks, which could be accessed on the device. With the introduction of OneNote, students were able to organize and store their learning materials more efficiently. Such sentiment was reflected in one of the student’s comment:

“So the OneNote application I found absolutely fantastic. So I go to class, I put my lecture notes to OneNote, put it into OneNote and I'm in the class and I actually just scribble on the screen as I'm learning. If I want to delete something it's really easy just to get the eraser and delete. Also the text where it converts your writing into text that's very useful.”

The tutor who previously was not a user of the Surface Device commented that OneNote helps her to teach more efficiently. More specifically, she was projecting her ClassNote page on the screen in class and demonstrating how to draw molecular structures in a precise manner.

Although the Surface device has brought many educational benefits to the students and tutors, some limitations were documented. The most significant limitation was that the learning curve was steep, especially when participants wanted to use the technology for greater functionality such as using OneNote or using other software on it. Some students reported the slow response time of the digital pen and its limitation in terms of scrolling.

**Discussion and Implications**

Using a case study approach, this study set out to explore how students use the Surface device and digital pen to learn chemistry concepts and their overall experience with the technology.

In essence, we found that the Surface technology coupled with the digital pen enabled students to focus on their learning, and they were able to learn through visualisation and manipulation of the technology. This finding is aligned with Oviatt’s (2013) comment on the importance of using interfaces that support expression of non-linguistic representations. This is especially true when learning is contextualised and in the context of learning abstract concepts like chemistry concepts which require multiple representations for better comprehension. Educators may consider tapping into the affordances of the Surface technology for the learning of abstract or difficult concepts,
especially in helping students to manipulate and interact with variables and constructing visual representations of their understanding.

Most recent literature on digital pens (refer to Huang, Su, Yang & Liou, 2017) has suggested that the technology promotes learning attention and motivation and when combined with collaborative problem solving, it might improve learning outcomes. Adding to these known findings, our research highlights the importance of taking into account individual differences given that learning is a complex business.

It is interesting to note that students devised new ways of approaching learning with the Surface device and the pen. This is an important finding as it suggests that learning is a dynamic process and that learners constantly adapt to the process through adjusting their learning behaviors. This might mean that technology must allow for the evolution of emerging learning.

**Future directions**

Given that this is an exploratory case study and was carried out in the context of chemistry learning, it might be beneficial to conduct similar studies in other learning contexts such as mathematics learning, business studies, engineering etc. When we can better understand the dynamic processes of learning that take place in different contexts, we can then modify the technology for meaningful learning to take place.

A quantitative study using robust statistical analysis such as structural equation modeling would also be beneficial for the development and employment of the Surface technology. Such a technique could possibly provide a statistically tested model for explaining the relationships between the Surface technology, students’ experience, and their achievement scores.
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References


