TsoiChem: A Mobile Application To Facilitate Student Learning in Organic Chemistry

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Abstract— Mobile devices, such as the iPhone, are potentially powerful learning tools, with their touch screen capabilities and highly interactive and engaging applications available for download. The dependence of today’s student on mobile devices also contributes to the possibility of increased student engagement and time-on-task – both factors in student success. This paper describes the development of a mobile application (app) created as a learning tool for organic chemistry students. The learning needs of organic chemistry students studying the topic “functional groups” were first identified, appropriate learning theories were chosen, and then a functional prototype of the mobile application “TsoiChem” was designed and then created using Apple’s iOS Software Development Kit. Unlike many existing chemistry applications, this application leverages the multi-touch feature of iPhone to teach fundamentals of functional groups to students and incorporated several learning theories and models in doing so. The ways in which learning theories and models helped inform the design of this mobile app will be discussed.

Keywords— Mobile learning, mobile app, mobile application development, Apple iPhone application, chemistry education, organic chemistry, functional groups, learning theory, learning models

I. INTRODUCTION

The use of mobile devices has grown at an amazing rate over the last eight years. According to [12] and [13], there are currently over 10 billion users of mobile devices. Reference [20] explain that as modes of communication have changed, consumers’ expectations of their mobile information, education and entertainment have also changed. People expect information to be available and accessible anytime, anywhere. This has resulted in the proliferation of mobile devices in the hands of students everywhere, whether it be for gaming, watching videos, listening to music, sending text messages or even to make the basic phone call. These students want their information now – and fast. The fact that most students today own a mobile device has gotten educators considering the use of the mobile device as a learning tool. The idea is that, along with the other streams of information being provided by the mobile device, perhaps course content could also be delivered to students now – and fast.

II. BACKGROUND

A. Mobile Learning

Mobile learning, or m-learning, has received a lot of attention in recent years as the popularity and use of mobile devices has increased. The idea of m-learning basically means facilitating learning by delivering content via a mobile device, according to [11]. However, there has been a wide range of opinions as to how m-learning occurs, what factors affect m-learning, and in what contexts does m-learning occurs [22]. Some research, according to [22], focuses on the device itself and the tools in the device that can be utilized for learning. Others investigate the location of the learner and how that impacts the reception of the content being delivered. And [22] notes that when it comes to the actual mobile applications on the device, a wide range of learning theories are discussed.

In many of these studies, the authors emphasize that mobile learning should be used in addition to an existing learning environment. Learning is not an activity whereby
information is merely absorbed by the user as the device delivers the content. Indeed, as the learner interacts with all modes of information (textbook, lecture, online discussions, etc.), it is thought that the synthesis of the information as the learner evaluates, understands, and applies the new content is what makes up the learning experience. Therefore, mobile devices should be investigated as a promising platform on which students can access information, but also perhaps obtain assistance in synthesizing all the sources of content.

The challenge, then, is “…adapting and appropriating the technology for learning in a way consistent with learning goals and principles” [11]. The device should support the objectives of the course and be user-friendly enough so that the learner engages with the content being supported by the device. As well, the mobile content must be developed in such a way as to appeal to a wide audience, a large range of abilities, and varied levels of technological know-how. So, in the end, when mobile devices are used, they really should be used as enhancements and supplements to the main lesson, and not the only way that the lesson is delivered. Therefore, mobile applications have focused on short, defined goals or tasks so as to be more effective in capturing the interest of users and to simplify the mobile device-user interaction.

The “one-to-one” learning [6, 14] afforded by mobile devices also poses another aspect to be considered in m-learning. The user has a dedicated device that allows him to engage in an “active social interaction activity”. This 1:1 ratio of student to computer allows for a more personalized learning experience tailored to specifically address the needs of the student. Therefore it is imperative that the software involved is capable of dynamically adjusting to the user in difficulty, appearance, feedback, and engagement, among many other factors.

One of the theories that informed a large part of this project is that of “seamless learning spaces”, explained by Looi et al (2010). The use of modern technologies enables today’s students to share and learn in contexts not bound by school walls. Communicating with their peers, friends, and family (and even people they have never met) via avenues such as Internet, blogs, and social networking sites have enabled people to learn and gain information from a multitude of sources. As well, students conduct these interactions wherever they have their mobile device and whenever they have access to a cellular or wi-fi network. Because the learning continues from one context to another, the theory states that the transitions are “seamless” – without sudden starts and ends to the process.

Therefore, in designing this project, it was intended that the mobile application would assist students wherever and whenever they happened to access the mobile application. Location and time would not pose as barriers to the learning experience. Enough structures had to be purposely put into the application so that the user would be able to learn the chemistry concept without the traditional lecturer in the typical classroom.

B. Mobile Applications for Chemistry

Organic chemistry students usually struggle with the content due to its visual nature and its requirement for various learning skills (visual, logical and mechanical). We reviewed existing Chemistry educational applications for iPhone/iTouch devices available in the iTunes store at website [1, 2, 3]. A large majority of these applications provide useful information about various chemistry topics via tools such as color-coded periodic tables, flash cards, quizzes and links to more information on various websites. The reference applications do provide a lot of content-specific information; the periodic tables are color-coded and allow comparison of various elements based on different selectable properties. The app store is also full of chemical problem-solvers, calculators and unit converters. There are only few applications that go beyond mere retrieval of information and use features of the iOS platform to their advantage. None of the applications reviewed, however, addressed our goal of helping learners recognize molecular functional groups represented in a variety of chemical formats.

Functional groups are specific groupings of atoms that react in particular ways. In organic chemistry, it is important for students to be able to recognize these groupings in order to correctly predict how a molecule will react in a certain set of conditions. Molecules can be represented in a variety of formats (condensed, line-bond formula, Kékule, etc.) so the memorization of functional groups has typically been somewhat difficult for organic students. Without a solid mastery of functional groups and the ability to recognize them regardless of the molecular representation, a student would not be able to pass a course in organic chemistry. It is akin to not being able to read without the ability to recognize the alphabet.

The immediate feedback aspect is the reason why representing functional groups in a dynamic, interactive setting is important. With traditional paper flashcards, students are not provided feedback that is tailored to their needs nor address misconceptions. With a mobile application, the code can be designed so that a range of mistakes will elicit a variety of feedback that help guide the learner towards the correct answer and assist him in adjusting his erroneous beliefs about a concept.

C. Student Learning Needs in Organic Chemistry

Traditional organic chemistry courses rely on textbooks and out-of-class problem solving to introduce and convey the content. With the advent of the Internet, there has been an increase in websites that offer other alternatives to mastering the material, with videos, simulations, and alternate models of visualizing the molecules. However, none of these modes of learning incorporate the Theory of Multiple Intelligences [8], which states that there is not one way to measure intelligence and that humans learn through a
variety of methods based on their strongest modes of intelligence. Educators utilize this theory in designing curriculum in schools today, hoping to capture the greatest number of students’ interest and motivation by addressing the wide variety of learning strengths.

Therefore, a mobile application that is able to accommodate the widest variety of learning styles would theoretically be the most useful and transferable of all apps currently available to the student. In addition, the level of mastery by each student must also be addressed in an effective application. Just as students learn via different modes of learning, students also learn at different paces depending on a variety of factors, such as intrinsic/extrinsic motivation, as suggested by [5], and engagement. So the application must also incorporate the learning theory of “scaffolded learning”, a theory introduced in the late 1950’s by Jerome Bruner. This theory states that people learn new material best when sufficient support is provided when first introduced to the material [23]. As familiarity and mastery increases, the support is gradually removed to increase independence and incorporation of the new material into the existing set of and skills possessed by the student.

These two main theories drove the development of TsoiChem because of the longevity and depth of prior evidence supporting these learning theories and the fact that much of science education is based on these two premises.

III. TSOICHEM – THE MOBILE APPLICATION

The goal in creating this mobile application was to transfer the effectiveness of pen and paper practice methods to a portable digital device, while also harnessing the power of the multimedia aspects of the device. Instead of just creating flash cards of functional groups (the traditional and most common method of learning this concept in organic chemistry), in this app students could use the touch-screen feature and highlight the bonds and atoms. Through this kinesthetic action, students would learn what the actual components are that form various functional groups. In addition, since an electronic device could be programmed to deliver a large number of examples and problems (quite a bit more than the number of problems in a traditional textbook), students can better learn how to identify the functional groups when shown in a wide variety of different formats. This is something they could not do with a paper flashcard. Consider the following example.

Fig. 1 shows a general representation of the structural formula of the functional group “ketone”. If a student sees this representation of a ketone, they will be able to identify ketone in other similar examples, such as in Fig. 2, but may not be able to identify the same functional group from when written in the seemingly different format CH₃COCH₂CH₃, which is the same example as Fig. 2, but in a different format.

Figure 1. Structural formula of a ketone, shown in general format that is typical of textbooks.

Figure 2. An example of an actual ketone molecule.

This problem arises due to the fact that looking at the image the user may not necessarily realize or remember that the corner where the double bond begins represents a carbon atom and hence may not recognize the CO in CH₃COCH₂ as a ketone carbon to oxygen double bond. The molecule is a very simple example used here for ease of understanding, but the students may see more complex examples in their exams, many of which are made up by the professors to increase their complexity. Hence, if the student were to practice by identifying and highlighting all three components of the ketone; the corner representing the carbon atom, the double bond and the oxygen atom, that would help emphasize such subtle concepts to the student and thus potentially make recalling the ketone functional group easier. The iPhone/iTouch devices, with their multi-touch capabilities, were hence the best choice to host our application.

It has been long accepted that immediate feedback helps students self-correct and rectify prior misconceptions [9]. Therefore, the student is forced to find all parts of the functional group before the app moves to the next task. In doing so, the app enforces the concept that there are multiple parts to the functional groups and helps the student understand what those parts are. As well, many students repeatedly make the same error – with TsoiChem, they are prevented from doing so because the app stays on the same screen until the correct parts are identified, thus stopping the misconception from perpetuating in the learner’s mind.

This app has three modes, as shown in Fig. 3. We modeled these modes after the theory of “scaffolded learning”, whereby learners are first exposed to new material, then successively work through levels of practice that gradually remove the “scaffolds” or guides that help reinforce the new content. Many of the available apps do not address the learning process through a methodological approach; they simply provide “easy”, “medium” or “difficult” levels. After launching the application, the user can select from “Practice It”, “Name It” or “Find It” modes.

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\begin{align*}
R' & \quad \text{R} \\
\text{H}_2\text{C} & \quad \text{CH}_2\text{CH}_3
\end{align*}
\]
Figure 3. The title page of TsoiChem app with the three modes shown at the bottom.

The purpose of the “Practice It” mode is to help the user identify all the components of a functional group, identify the functional groups in their various forms, and begin to associate the visual representations with the name. Hence, in the “Practice It” mode, the user is provided with an example, randomly chosen by the application, and then has to touch and highlight the atoms and bonds that form a specific functional group in a molecule. When all the components of a functional group are identified, the name of that functional group is displayed, as well as pronounced verbally. This is to ensure that the app addressed multiple learning styles of users, since some may recall information better visually and some may require an audio component. A single molecule may contain multiple functional groups. In such cases, the user has to identify all the functional groups before proceeding to the next example.

The “Name It” mode is designed to help the user self-assess and review the concepts practiced in the “Practice It” mode. The “scaffold” of providing the name for the user has been removed. Hence, in the “Name It” mode the user is once again provided with a randomly chosen example and once again has to highlight atoms and bonds that form the functional group. When all the components are highlighted, the user is provided with 4 different name options and must select the correct name of the functional group from those options, as shown in Fig. 4. The user gets three chances to correctly specify the name of the identified functional groups. In this mode, the user cannot continue to the next example until all the functional groups in the current molecule have been identified. This mode requires the user to identify each functional group correctly and identify the name of that functional group. Humor is employed as an extrinsic motivator, as three wrong answers result in the friendly avatar being blown up by the exploding beaker. Studies have shown that humor can be effective in easing the tension of learning and to help students retain information.

Figure 4. An example from the “Name It” mode.

The third and final mode, the “Find It” mode is therefore the least scaffolded form of practice and provides multiple examples in various forms to the user, but with no guidance as to the association between functional group and name. The user has to identify the correct examples that include the required functional group, drag those examples one-by-one and drop them in the bin, as shown in Figure 5.

The bin displays a counter that updates as the examples are dropped in it. Once all the examples have been correctly identified the user can move to the next example. As in the other modes, the examples in this mode are also randomly chosen. If incorrect examples are dropped in the bin, they “snap back” to their original position—just enough feedback to show user that the choice was incorrect, but not so negatively as to impact user motivation to try again. Motivation theory states that there is an affective component to motivation; if a learner feels negatively towards an activity, then motivation will decrease and the learner is less apt to continue with the activity. If any of the examples are placed anywhere else on the screen they snap back to their original position. We felt this was an appropriate amount of feedback to alert the user to their error.

Figure 5. An example from the “Find It” mode.
In this mode, the user must be able to accomplish the three goals of functional group recognition: identify all atoms/bonds that must be included in a given functional group, identify the functional group when represented in a variety of formats, and associate the functional group with its correct name—all with no “scaffolding” or guidance.

The application provides audio feedback for all the examples in all the modes, along with visual feedback. Addressing the multiple ways in which learners take in information was important to incorporate into the design of the app. The application also provides tutorials, which also support the theory of scaffolded learning.

CONCLUSIONS

In developing this app for organic chemistry students, we discovered that there were many more aspects to the process of learning functional groups than we originally thought when teaching this concept in the typical lecture-style classroom. There were fundamental issues regarding misconceptions, student interpretations of the figures in the books, and lack of a method of guiding students’ practice in contexts outside the classroom. By harnessing the multimedia, portability, and popularity of mobile devices to aid in teaching functional groups, we believe we were able to enhance the classroom instruction that the students received. Incorporating major learning theories into the design of the app allowed us to create a seamless learning context whereby the classroom experience could continue into the students’ everyday life. TsoiChem takes advantage of the potential multimedia, portability and popularity of mobile devices to support the theory of scaffolded learning.

We hope to expand this project to other topics in organic chemistry, as well as other subjects. We chose functional groups because it seemed a rather straightforward, everyday life. TsoiChem takes advantage of the potential multimedia, portability and popularity of mobile devices to support the theory of scaffolded learning.

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