Multidisciplinary Learning Affordances of a Science-Based Virtual World Environment

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INTRODUCTION

The concept of learning affordances has become increasingly used since Gibson [1] used the term to refer to the functional properties that determine the possible utility of an object or an environment.

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According to Greeno [2] “an affordance relates attributes of something in the environment to an interactive activity by an agent who has some ability”. By definition therefore, affordances are ingrained into authentic learning, which places the student into the role of the doer or actor. Educators claim that authentic learning is the most desirable way to achieve, deeper, more complex, and contextual understanding of particular disciplinary areas [3]. On the other hand, authentic learning also poses significant challenges as it may be too difficult, dangerous or expensive to provide such opportunities in traditional learning spaces [4]. Consequently, an increasing number of educators are turning to Virtual World (VW) environments, where simulations and learning-by-doing can be facilitated within disciplinary and professional contexts [3]. For the purposes of this paper, a virtual world is defined as a computer-, server-, or internet-based virtual environment that allows participants to move around and use various forms of communication (text chat, voice chat, or instant messaging). It allows participants to create a virtual identity which persists beyond the initial session [5]. Second Life (SL) is an example of an immersive and interactive virtual world environment that can be as complex as the real world. Users can create 3D objects, and these can be seen and used also by other individuals in the VW [6]. Interaction in SL takes place through an Avatar and SL includes communication tools such as text and voice chats, instant messaging and sounds can be imported into SL, and audio and videos can be streamed into SL. Rosenbaum, et al. [7] have pointed out, that technology plays an important role in facilitating integration of the skills needed for living in a technology-centric environment and mediating authentic learning experiences by creation of communities of practice around the tools used by disciplinary experts. Consequently, development of future learning spaces calls for leveraging the affordances of advanced digitalized technologies for improved learning outcomes.

1 APPROACH AND METHODS

1.1 Research questions and hypotheses

The overall objective of the studies presented in this paper, is to show how the enablers to learning in 3D virtual worlds could be identified and further used in pedagogically sound ways. The study sets out to answer three research questions:

1. What are the affordances of virtual worlds that facilitate authentic learning in a science-based laboratory simulation and how can these best be leveraged ?
2. What do students perceive to be the barriers and enablers to learning in such a virtual world environment ?
3. What type of support (from the teacher or embedded in the environment) promotes authentic learning in virtual world environments ?

1.2 Study design

Design-based research methodology was used, which is a blend of empirical research with the theory – based design of learning environments. The method focuses on the systematic investigation of innovations designed to improve educational practice through an iterative process of design, development, implementation and analysis in real-world settings [8], and followed the framework outlined in *Fig.1*. A major strength of design-based research lies in its adaptability to adjust the intervention based on ongoing findings from participants.

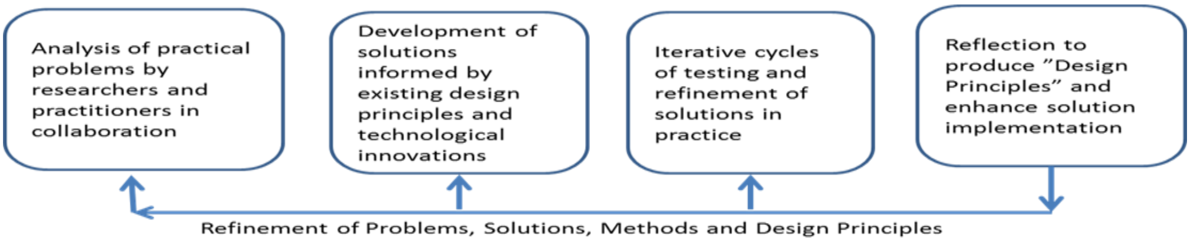

Fig.1. Predictive and design-based research approaches in educational technology research [9].

1.3 Laboratory experiments in Second Life: Lablife3D

To date, we have designed five laboratory experiments into SL https://sites.google.com/site/lablife3d/**,** namely 1) a virus isolation simulation, 2) a molecular biology experimentation, 3) an organic chemistry laboratory safety tutorial, 4) a decarboxylation experiment and 5) a vacuum distillation experiment [10]. For the present study we used the organic chemistry decarboxylation experiments and the molecular biology experiments to study student and teacher responses. The organic chemistry simulation [11] is not a strict laboratory practice exercise (*Fig.2*). Instead, it mimics experimental research at a more general level, with the main focus on teaching scientific reasoning based on empirical results. In the simulation, the task of the student is to compare the reactivity of different carboxylic acids towards decarboxylation and decarbonylation and to deduce the theoretical explanation for the observations. The simulation is controlled by clicking with the computer cursor on the chemical containers and instruments, such as the synthesis station and a balance, in the laboratory 3D space [10]. The primary learning outcome of the molecular biology simulation [12] is to give the student the opportunity to learn the process of identifying a virus from a human cell sample (*Fig. 3*). The virus that is studied is an enterovirus, which students will identify in accordance to standard scientific methodology, based on a specific enterovirus protein known as VP1.

Fig.2. Screenshot: The organic chemistry simulation on decarboxylation reactions

Fig. 3. Screenshot: The molecular biology experiment.

1.4 Student feedback and development of learning analytics

Two types of forms were used to perfect the collection of student feedback, of which the first was based on a qualitative assessment student perceptions of what they had achieved. However, during the study it became evident that the data was difficult to interpret, and a Likert scale was subsequently used [10]. So far feedback has been collected from 39 students. Piloting different means for collecting feedback was an important part of the study, as it was also used to formulate the teacher interview questions as well as to create an approach for the use of learning analytics to assess student performance in the SL world. Siemens and Long [13] have described big data or learning analytics to be “the most dramatic factor shaping the future of higher education” providing researchers and educators with more quantitative data on what is happening in the learning process. Consequently, one of our current aims is to develop quantitative tools for the assessment of learning in VWs. For this purpose, we have studied the molecular biology exercise in order to elucidate 1) how does the learning process proceed during the VW exercise and what are the critical learning event, enablers and barriers ?, 2) what kind of quantitative data can be collected during this process and what indicators from this data can be used to quantify or describe the learning and 3) how can this data be used to enhance learning in VWs or even other real-world learning events ? The data for this part of the study is still based on a small sample, however, this represents a piloting phase of the project [14].

The quantitative data is based on the automatic monitoring of the time spent and the number of user interactions taken by student whilst performing the tasks in the molecular biology laboratory. By user interactions we refer to the clicks made by student (ie. via computer mouse or other controls) whist carrying out a given exercise in the VW. Nine students took part in the study and three of these were also interviewed as a focus group.

1.5 Teacher interviews

Eighteen individuals participated in the teacher interviews, for which the molecular biology laboratory exercise was used as a demo. Two of these individuals were later considered to represent more administrative staff, and therefore the final data is based on 16 interviews. Prior to the interviews each teacher took part in the molecular biology exercise in Second Life in the University IT class. Teachers were guided through the exercise according to the same script that was used in the student test situation. The interviews were conducted as 45 minute sessions immediately after the demo. Each teacher was interviewed separately and the interview was recorded. The interview consisted of questions under three major themes, namely: 1) previous experience on using SL or similar VWs, 2) assessment of the scientific content of the exercise including the presentation of the assignment to students, the design of the laboratory, the level of difficulty and the technical issues, and 3) the teacher role and advantages or disadvantages for use as part of teaching. Teachers were also asked to provide suggestions for improvement of the exercise itself, the layout of the laboratory or other possible issues.

2 RESULTS AND DISCUSSION

2.1 Student experiences

Both the organic chemistry experiment on decarboxylation and the molecular biology experiment have been assessed as course exercises by groups of first- to third-year students [10]. Organic chemistry exercises were performed in four groups total (two time slots, both with two simultaneous groups) on Mondays and Fridays. The students in Monday groups found the experiment was reasonably interesting and was in line with their previous studies to some extent and felt that they also learned some scientific content. However, it was evident that the students felt that the exercise could be completed by clicking through, without really putting much effort into the scientific contents. In contrast, students in the Friday groups, were more critical. Half of the students did not think that the exercise was very interesting and did not feel that they had learned anything new. They also admitted that they had just used the easiest route to get to the end of the experiment by haphazard clicking. Notes made by two independent observers support these differences. Some explanations for these differences were a) previous experience with virtual worlds and IT skills in general (both better Monday), and b) age (in Friday, freshmen only). We also admit that Fridays may not be the best day to conduct these types of studies. Students in all groups (97%) all emphasized that they felt that face-to-face interaction with the teacher is very important [10].

Based on the experiences gained on the organic chemistry exercise and the student feedback, we designed a new feedback form for use in the molecular biology exercise, based on a Likert scale and paid attention to a more detailed instruction package for the student. Namely, a script was made, in which the students were presented with a fictional case which mimicked a real-life scenario. In this case, the students were part of a team, which was investigating the incidence of a suspected enterovirus infection, which a patient had contracted during a visit to an endemic area. Students had to design and implement the identification of the causative virus by using RNA isolation, purification, detection and sequencing with final comparison to the NIH database BLAST, which is commonly used in real-life comparison of virus sequences. Overall, the student response from the molecular biology experiment was positive [15,16]. Students stated that they had understood the assignment and a clear majority felt that they had learned something new. The difficulty level was considered appropriate. Based on these observations it was evident that the molecular biology simulation was either better pedagogically designed than the organic chemistry experiment, or better connected to the course contents or both.

2.2 Towards using learning analytics

Preliminary identification of barriers and enablers to learning was performed in line with the framework of Warburton et al.[17]. based on the student interviews as part of piloting the use of learning analytics. Enablers of learning included the contextualization of abstract information, exposure to authentic content and culture, experiencing immersive environments without physical barriers. On the other hand, barriers were also evident, namely technical problems relating to actions in the VW. In addition, it was stated that cultural or professional conduct may become distorted as making a mistake does not lead to a consequence. Moreover, collaboration and interaction may be hindered by pressure caused by the faster advancement of others during a joint demo session and time needed to have the Avatar and the environment functional. As we believe that more quantitative data will be needed in the future, we also explored various routes for the possible application of learning analytics. In order to develop more quantitative tools for assessment of student progress, the total number of user interactions, ie. "clicks" were collected, this also included clicks at an individual working station, clicks made for starting the experiment, mistakenly made clicks and extra or unnecessary clicks. It was evident that students tried 1-3 times to restart the experiment, after which the numbers of clicks varied between 44 and 96 and the time used between 21 and 47 minutes. However, the number of clicks did not correlate with arriving at the correct solution to the exercise. On the other hand, even though the sample size was small, there was a minor tendency for students who tried 2 or 3 times to start the experiment to either not arrive at the right answer or then possibly only come close to the right answer [14]. These data are preliminary testing for the development of methods for the use of learning analytics, which will require large sample sizes.

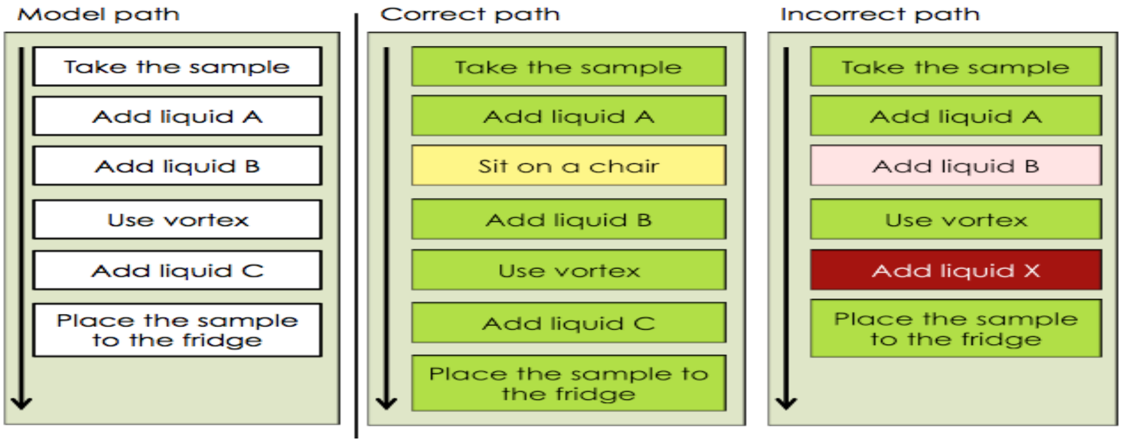

Fig 4. : Model for data analysis: Visualizing different paths the students take during a virtual laboratory exercise [14].

Based on this preliminary data we are currently working on a model for collection and analysis of quantitative data for future experiments (Fig. 4). The data consists of students' actions e.g. clicks and events triggered by the clicks, time tags of all the actions, compositions of the substances used, and needed actions. In the model for data analysis the students' actions will be compared to the "model path" which indicates the correct step-by-step completion of the exercise. Students' actions can be color-coded in order to better understand the difficulties during the exercise. Green boxes represent correct clicks, red boxes stand for incorrect clicks, and yellow boxes are clicks which do not rule out completing the exercise but will not help completing it either. Light red boxes indicate clicks which were supposed to take place, but weren't performed by the student. This approach is most suitable for the measurement of affordances and barriers in learning scientific facts and data, which typically are "right" or "wrong", although this is not exclusive.

2.3 Teacher experiences

The majority of teachers had no previous experience with SL. All except one teacher felt that the exercise left them with a positive feeling on use of SL in teaching. The majority (10/16) were able to start the demo without any problems. Most of the comments concerned technical issues, namely a) moving around with the Avatar, ability to set the view (zooming etc.), moving test tubes or similar objects, for example controlling the Avatar movements. Eleven teachers also felt that this would be an excellent method for familiarizing students with laboratory environments, layouts, instruments and general outlines for experimental work. On the other hand, the teachers felt that the actual classroom implementation must be very carefully planned, and the role of the teacher as an interactive facilitator will be important to define. The teacher should be active at the beginning to assure that students can all get started, and technical issues do not cause hurdles for the students. As the exercise proceeds the teacher should circulate in the classroom (if the exercise is done as a group during a given time and in a set place) and the teacher should give students freedom to proceed and offer assistance only when students really need it and not too soon. If the exercise is completed as an independent on-line exercise, the teacher needs to plan how she/he is available in SL, taking into consideration that the teacher facilitation as an Avatar may be quite different from face-to-face facilitation. However, teachers did add that facilitations via an Avatar opens up possibilities for the teacher to be present in many situations at the same time and students can complete the exercise when it suits them best. SL could also promote more introvert students to ask more questions due to the diminishing hierarchy of the teacher – student interaction in an immersive environment. However, there was also concern about the level of interaction that occurs between students during an SL exercise and it was evident that teachers did not realize that there are many possible communication channels that may be integrated into SL (eg. chats, Facebook, Twitter etc.). However, all the teachers expressed a positive interest towards the use of virtual worlds, such as SL in their teaching. On the other hand, there were certain reservations, which fell into four thematic areas.

First, teachers felt that SL cannot substitute for real life experimentation in the laboratory, but it can be useful in giving more variety to teaching methods. SL can give students also a false sense of working in a laboratory, but then again, it was stated that SL can give a much deeper idea of complex content, than standard textbooks. Some of the hesitation about using SL or virtual worlds in teaching was clearly the rather modest technical abilities of the teachers in comparison to those of the majority of their students. Second, the role of the student and the teacher changes, which influences their mutual interaction. Teachers felt that it is still important to maintain also face-to-face communication, even in the case that they would create an Avatar and become immersed into the SL world. Teachers also felt that it is important to be able to be present and interact whenever a student has a question. Student reflection on his or her performance may also be difficult. There was also concern that students may not form normal day-to-day social networks in SL compared to the real world. The third issue concerned assessment, and teachers emphasized that there is a need to be able to verify the identity of the student as the one who has completed the exercise. The anonymous nature of SL was thought to be a challenge for assessment. Teachers also felt that it is important to be able to design appropriate assessment in order to assess the disciplinary content and skills related to such contents as assessment should not take into account whether or not the student excels in the technical implementation of SL. Fourth, resources were a major issue for concern, ie. questions such as who will do this, who will pay for it, where will teachers find the extra time to learn the technicalities as well as the planning and implementation. Teachers are hard pressed for time and the majority of teachers felt that their technical skills were insufficient for planning and implementing virtual worlds in their teaching. Most teachers viewed SL as a positive addition to teaching, but they did not feel able to start developing their own exercises in SL and the accompanying course materials.

3 CONCLUSIONS

The aim of our work is to generate virtual word learning environments which enhance learning. To do so, we have identified a number of enablers and barriers for learning, which at this point are mainly applicable to Second Life. Students clearly have the ability to complete exercises in a virtual world, regardless of lack of prior experience. Technical issues that appeared to be a hindrance are e.g. moving the Avatar around in a laboratory, obtaining the instructions of how to implement some movement and teleport the Avatar into the laboratory. These issues are very specific to SL, however, they are to be expected to occur also in any other immersive world, where the individual takes on a virtual representation. Such difficulties may be hard to obliterate completely and it is therefore very important that students can familiarize themselves with the control tools of the VW prior to the teaching or learning event. On the other hand, our data shows that students do learn scientific contents and methodology in laboratory experimentations in SL and therefore, as suggested by Strangman [18] content area knowledge and conceptual change could be expected to be an outcome of the virtual world experiments that we have designed. Work on development of quantitative tools in terms of application of learning analytics is progressing and seems promising. However, the world of learning analytics is a complex area, where larger groups of students need to be studied. Currently, we have an excellent setup for data collection, with some preliminary data, which we will expand to a larger group of students. Collecting the information on how long and where students are likely to get “stuck” will allow us to have quantitative proof on how each phase or part of an experiment is approached by the student.

The most evident difference between student and teacher attitudes towards the use of VWs such as Second Life in teaching and learning stems from the teacher perception that they are less qualified to engage in new digital technologies. As the digitalization of learning and teaching is inevitable, this calls for a paradigm shift in teacher education. Moreover, it is important that new digital tools in teaching and learning are aligned with relevant context, the learning goals and desired outcomes are clearly defined, and the use of the digital technologies can be practiced in advance for the users to familiarize themselves with the technical requirements in advance. As use of digital teaching and learning tools require rather similar approaches, build up in confidence will assist the teacher and the students to eventually become comfortable with virtual learning environments. Based on our studies, both teachers and students have a positive attitude towards learning and teaching in VW learning spaces.

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