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Using 3D virtual environments to facilitate students in constructivist learning

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ABSTRACT

Advances in network infrastructure and computing technology have made 3D virtual environment increasingly popular and less costly. Many education institutions have shown interests in its application in teaching and learning activities. In this project, we evaluated how the 3D virtual environment can facilitate students in achieving learning outcomes. To provide students with learning experience in 3D virtual environments, we designed a task which requested students to identify some information security issues in a virtual office set-up in Second Life, the most widely adopted 3D virtual environment. In this paper, we report our experience in having students finish the task within the virtual environment in an introductory management information system course. Evaluation on the students' learning experience showed that 3D virtual environments could indeed facilitate students in achieving learning outcomes through constructivist learning. We suggest some recommendations in using 3D virtual environments as an educational platform.

1. Introduction

Three-dimensional virtual worlds on the Internet have emerged as a popular trend in digital world in the recent decade due to advancement in computing technology and network infrastructure. Virtual worlds such as Second Life, World of Warcraft, Sony Playstation Home and Xbox Live have gained vast popularity and worldwide success. Taking Second Life as an example, according to the statistic provided by Linden Lab — the creator of Second Life, the number of unique users in the Second Life exceeds 750,000 in 2010, and they spent more than 105 million hours in the virtual online world (Linden Lab, 2010).

A virtual world is a computer-generated, boundaryless, immersive "game-like" environment often equipped with three-dimensional graphics that resembles the real world [21]. Users can create in-world characters, known as avatars, to represent themselves in the virtual world and participate in different kinds of activities. User can communicate and interact with other users using body language, voice and text messages. The use of multi-channel expressive communications in the virtual world allows users to communicate and convey their emotions through the Internet in a more real-world-like setting [7].

In light of various special and unique features provided by virtual worlds, there is an opportunity of using virtual worlds for educational purpose. Despite the fact that virtual worlds are mainly for entertainment purpose, it has been suggested that they have great potential to become innovative education platform in the future, providing students with real-world-like experiential learning.

Universities and educational institutions have recently started to study the potential of using virtual worlds for teaching and learning. For example, the Harvard Law School has offered "virtual courses" in Second Life. During the courses, the instructor and students interacted with each other inside the virtual world environment and the overall responses have been very positive [6]. Many other schools have also set up campus or classrooms inside Second Life, including Drexel University, Emory University, New York University, Nottingham University, Ohio University, Princeton University, Stanford University, University of Florida, University of Southern California, University of Notre Dame, and Virginia Tech, among others [26].

Learning in virtual world environment possesses great potential. Although many schools have started using virtual worlds for teaching and learning activities, there is a lack of empirical evaluation of the effectiveness of using virtual worlds as an educational platform. It is desirable to explore the potential of this platform and to study its effectiveness as a learning technology and the impact of virtual world

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on students' learning activities. However, most existing studies only involve the perceived usefulness of 3D virtual world environment. Very few studies investigate why virtual world learning can facilitate learning.

The paper is structured as following: Section 2 reviews related research. Research questions are posed in Section 3. Section 4 discussed the research methodology of our study. The data obtained from our study are presented and discussed in Section 5. We conclude our study in Section 6.

2. Literature review

2.1. Virtual world learning

Virtual world learning or e-learning has been increasingly popular worldwide as information and Internet technologies advance. The topic of e-learning, especially virtual world learning has drawn a lot of research attention. Platforms such as Second Life and Active World are easily available on the Internet for educational purpose. Lots of educational institutions and universities have already set up their own learning platform on the Internet, trying to learn about and utilize this new educational medium [26].

Virtual world learning provides a game-like learning environment for users. Young people nowadays grow up in a digital world surrounded by smart phones, computers, Internet and video games. "Digital Native" is a term describing this group of people who are born within a digital environment; so that they are very familiar with the latest information technologies [25]. They live in a world full of multimedia. The learning space should not be limited to physical space anymore. The unique immersive environment of virtual worlds allows users to have a more personalized learning experience that fits their own need [12] and provides them with higher learning autonomy [17]. It has been reported that virtual environments like computer games can motivate students to engage in learning activities and have achieved promising results [20,31]. Previous research shows that such innovative education media encourage users to have a better collaboration and communication, which form an effective and supportive learning environment for students [5]. [27] also suggests that three-dimensional virtual worlds like Second Life can model the real world much better than text-based or two-dimensional environments, and the increased degree of realism can lead to better student engagement in the learning activities.

Using three-dimensional virtual worlds in teaching and learning has the following advantages [3,27,30]:

- Students can participate in learning activities from anywhere. This can facilitate distance learning of students from their home or anywhere else.
- Students can navigate the virtual learning space easily by "flying" and "teleporting" inside the virtual world without any physical constraints. This allows students to switch between different learning activities more quickly and hence engage in more such activities.
- Instructors and students can meet and interact more easily. It is also possible for different groups of students around the globe to meet inside the virtual world to engage in educational activities (e.g., cultural exchange). Compared with other online media like emails or instant messaging, virtual worlds allow users to have better interaction like movements and gestures.
- The virtual world environment acts as a simulation of the real world and allows students to experiment with different concepts without doing real harm. For example, medical students can experiment with surgery operations; physics students can see a rocket from inside out and even create new designs. The virtual environment also improves students' fantasy and imagination.
- The "game" nature of virtual worlds may have a positive impact on students' motivation and engagement in the learning activities.

The flexibility of virtual world platforms also brings possibility to more interactive distance learning. The virtual platform on the Internet overcame the barriers of distance, time and locations. In the past, there have been many other distance learning platforms, such as videos, textbooks, and audio-recording. However, only e-learning or virtual world learning enables real-time communication and resources for collaboration [16]. It has been suggested that a virtual social space with interaction is essential to improve education [2]. From the previous experience of other researchers, the use of virtual world as a distance learning platform gives satisfying and promising result to the courses [22]. The research by [22] has also shown that most students found that the virtual world learning experience is intriguing enough to trigger further study of the topic involved.

2.2. Constructivist theory and experiential learning

Constructivist learning could be experienced in the virtual worlds. The constructivist learning theory views learning as a process in which learners actively construct or build up new ideas or concepts based upon current and past knowledge [1]. Knowledge building requires the use of real problems, self-organization, monitoring and correction, and the creation of artifacts to advance the collective knowledge, viewing individual learning as a by-product of the process [23]. According to constructivist theory, the learner should interact with meaning activities in order to generate knowledge based on their prior experience [24]. The virtual world simulates the real world environment, in which the learner could learn under an environment that is close to the reality. The virtual world provides learners with opportunities to learn without real-world repercussions and personalize their learning experience [15]. Through interacting with the virtual world, learners could build up new concept and knowledge based on their prior experience. The realism of virtual world could further enhance the learning experience.

Moreover, learners could gain better understanding of conceptual context by performing specific tasks in the virtual world, or by interacting with virtual objects [4] and virtual environment from a first person perspective. In tradition classroom learning, the knowledge is acquired from teachers and the information is represented in the form of text, graphic, video and audio, as described by [28] as "third-person symbolic experiences". Comparatively, virtual world provides learners with more interactive, experiential learning experience. It could provide learners a first-person symbolic experiences, which can further help enrich information representation by experiential learning [28]. By performing specific tasks in the virtual world environment, learners could apply their abstract knowledge on situation in authentic, virtual contexts that are similar to the real world environment [14]. The "learn-by-doing" experience helps learners better understand the context.

Constructivist learning also highlighted the importance of knowledge sharing. According to [18], education has two purposes. Firstly, the individual learner constructs meaning based on personal experience. Secondly the learner confirms the ideas collaboratively within a community of learners. As pointed out by [11], learning experience is further enhanced by collaborative learning and group work activities; the virtual world environment could create an environment for collaborative learning, which learners can interact with each other by performing specific tasks and involving in discussion. Each individual learner builds up their own knowledge. Through sharing of knowledge and activities in the virtual world, learners could build up a network for knowledge sharing or even build up new ideas during the discussion process, which may further enhance their understanding of the context. Furthermore, communal constructivism [19] is similar to the key processes of knowledge building aforementioned and extends it with not only an emphasis on constructing knowledge for current learners but also future learners.

2.3. Second life and education

Many schools have used Second Life as a virtual world platform for educational purpose. In Second Life, users can register an avatar and download the client software freely. Educational institutions can rent a virtual land in the Second Life and set up their own virtual world educational platform. They could also use the code-free development tools to develop objects for educational purpose. Second Life also provides a lot of online guidance to the educational institutions that want to start using Second Life for educational purpose.

Many universities and educational institutions have noticed the potential of Second Life as a virtual world educational platform. Up till now, there are more than 150 universities or educational institutions in Second Life, and the number is still growing [26]. For example, Yale University used Second Life for industrial ecology, to demonstrate the procedure of paper-making in a virtual company in Second Life [29]. Medical and health schools such as Coventry University, London have used Second Life to provide problem-based learning courses.

Second Life is a flexible, user-friendly platform with high usability for educational purpose. However, a number of these schools have only provided exhibition for their research and virtual classroom in Second Life. Very few of these schools have used Second Life for information system learning in an experiential learning approach. Moreover, few of these studies have evaluated the effectiveness of using Second Life in education. The work of [13] is one of the few examples. They evaluated the presence, awareness, communication, comfort and perceived sociability aspect of the 3D virtual world environment. However, they did not evaluate the learning outcomes of the program. Another example is the work of [22], where users were asked to create an object in Second Life. Both of these tasks involve experiential learning, but the results have not been compared with traditional classroom learning.

3. Research hypotheses

With many studies and research demonstrating the effectiveness of virtual learning environment in the last section, we would like to investigate the potential of using 3D virtual environments to facilitate constructivist learning. Through this research, we would like to study how virtual worlds can allow students to achieve better learning outcomes by a constructivist process in the virtual world. Constructivism focuses on learner-centered learning so that learners can construct knowledge by themselves throughout the learning experience. The study therefore set up two learning conditions to evaluate the difference students' perceived learning outcome and learning outcome achievement. More details will be provided in the next section. The following are the hypotheses to investigate our research question on how 3D virtual environments could facilitate constructivist learning.

H1. Perceived learning outcome of students who explore the 3D virtual world environment is better than those who watch the video showing the exploration in the 3D virtual world environment.

H2. Learning outcome achievement of students who explore the 3D virtual world environment is better than those who watch the video showing the exploration in the 3D virtual world environment.

If these two hypotheses are supported, we argue that 3D virtual environments can facilitate constructivist learning by providing learner-centered conditions and high level of control in exploring details in the learning context. The effectiveness of the 3D virtual learning environment can also be shown.

4. Methodology

In this research, we developed a virtual business office and a computer server room in the virtual world environment Second Life. Second Life was chosen as our platform because it is the largest and the most popular virtual world environment. Many other educational institutions have set up their virtual campuses and learning facilities in Second Life. A piece of virtual land was rented inside Second Life, on which a building and classroom resembling the real buildings in our university and a business office resembling a real office and a computer server room were built. Virtual objects, such as desks, chairs, computers, stationeries, and projectors, among others, were created or acquired and used inside the virtual world environment.

In this study, following the theory of constructivist and experiential learning, we focus on whether performing tasks in a virtual learning environment could help students achieve their learning outcomes better than the traditional classroom environment. Our study was conducted in an introductory management information systems course, which is a core course for all business undergraduates. In the course, there are seven subsections of tutorials. These tutorials were randomly assigned as the experimental group or the control group. Each of this subsection was conducted at different lecture timeslots but with the same teacher and same student mix (i.e., first year business school students).

One of the topics covered in this course is information system security. All students were taught with the information system security concepts and issues in the same lecture by the same teacher to avoid teaching quality bias. After students have taken the corresponding lecture, they were separated into different tutorial classes and asked to identify some security vulnerabilities in a virtual office, which was set up in the Second Life. They were asked to write down their answers on a piece of paper which was later collected by the teacher. The students were randomly assigned to different tutorials to perform the identification task and test. For the experimental group, the students performed the identification task using the 3D virtual world environment. The students registered for an account and got an avatar in Second Life to access the virtual learning space, and explored the virtual office and server room using the avatar to find out the security vulnerabilities inside. Whereas in the control group, a video was taken, showing an avatar going through the virtual office. The student watched the video in the tutorial class and tried to identify some security issues in the virtual office. They could watch the video as many times as they wanted to.

In total, there were 10 security vulnerabilities in the virtual office and server room. Students have to apply their knowledge learnt in the previous lecture to find out the security vulnerabilities, such as a USB flash drive left unattended on the desk and entry of server room kept open by obstruction, as shown in Figs. 1 and 2.

The virtual learning environment was evaluated in the following two aspects: the perceptions of virtual world as an educational platform by students on achieving learning outcomes and the measure on actual achievements of students' learning outcomes. At the end of the session, students were asked to fill in a questionnaire. The above two aspects were assessed in the questionnaire and the students' performance in the given task, and a comparison was made between two groups.

5. Data analysis and discussions

In total 105 students attended the class and completed both the task and the post-task questionnaire. The experimental group (using Second Life) contained 49 students while the control group (using video) contained 56. All of them performed the given task on identifying security vulnerabilities and their answers were scored by a teaching assistant.

The students from both groups were asked to evaluate their learning experience in terms of different aspects of perceived learning outcomes in the questionnaire. The test score of the students act as an indication

Fig. 1. Screenshot of the virtual office.

of learning outcome achievement. There were in total three learning outcomes we were looking for in this course:

- Describe and explain the concepts of information systems/technology and their roles and functions in organization.
- Describe and explain the issues relating to managing information system security and control.
- Apply different models to evaluate the applications of various information systems and propose information system solutions in solving problems.

Our results are summarized in Table 1. Generally, students using Second Life gave higher scores in all perceived learning outcome achievement in all three learning outcomes than those students using video, with p-values less than 0.05 in all cases. The students using Second Life have significantly higher overall perceived learning outcome achievement than those students using video. The students using Second Life also gained significantly higher test scores in the tasks than students using video with a p-value less than 0.0001.

In Learning Outcome 1: Describe and explain the concepts of information systems/technology and their roles and functions in organization, Second Life scores higher (4.61) than the control group (4.09) with a p-value of 0.0240. We suggest that the virtual environment helps students understand abstract concepts about systems/technology better. For Learning Outcome 2: Describe and explain the issues relating to

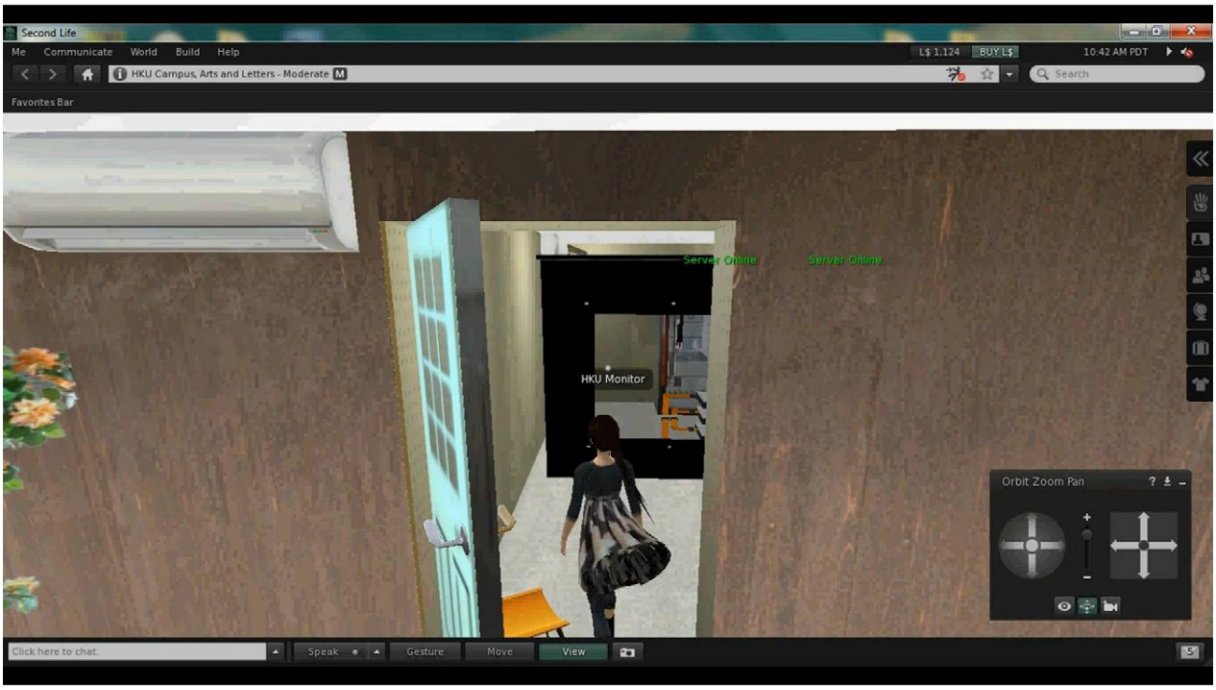

Fig. 2. Screenshot of the virtual server room.

managing information system security and control, students also gave higher score for Second Life (4.82) than the control group (4.32) with a *p*-value of 0.0408. The biggest difference is seen in Learning Outcome 3: Apply different models to evaluate the applications of various information systems and propose information system solutions in solving problems. Second Life received a score of 4.73 while the control group received 4.05, with a *p*-value equal to 0.0045. It suggests that students found that they could better apply their knowledge and solve the problem using Second Life instead of using video. The 3D virtual environment brought significant improvement in learning process when students have to apply knowledge of information systems to solve problems. All in all, we suggest that using virtual environment can significantly improve students' learning process of understanding information systems and apply knowledge to solve problems relating to security of information systems. H1, which states that perceived learning outcome by exploring in the 3D virtual world environment is better than that by watching video showing the exploration in the 3D virtual world environment, is therefore accepted.

Students using Second Life also achieved a significantly higher test score (5.97) in the given task than the control group (2.49), with a *p*-value less than 0.0001. The large difference suggests that the learning process is significantly improved using the virtual environment as learning platform instead of traditional learning methods like video. The students using Second Life performed better in achieving the learning outcomes than those students using video. This result corroborates with our questionnaire results. Therefore H2, which proposes that learning outcome achievement by exploring in the 3D virtual world environment is better than that by watching video showing the exploration in the 3D virtual world environment, is also accepted.

The effectiveness of the 3D virtual learning environment is shown in the qualitative analysis. Since both hypotheses in the study are accepted, we think that 3D virtual environments can facilitate constructivist learning by providing learner-centered conditions and high level of control in exploring details in the learning context. First, both the experimental and control groups experienced the 3D virtual environment but only the experimental group students manipulated their avatar to go wherever they wanted to explore. The students interacted more with the learning environment which can facilitate constructivist learning [24]. The learner-centered learning environment encouraged them to build up the knowledge and understanding around the learning environment. The students' exploring experience in the 3D virtual environment was instrumental for them to construct new concepts based on the current knowledge [1]. Gradually the students also constructed the knowledge about the security concepts. Throughout the problem-solving process in the environment, the students noticed more details in the identification task which made them think more deeply. On the other hand, the control group students did not have any interaction with the 3D virtual environment. They just watched the video of exploration in the 3D virtual environment. No matter how many times the students watched the video, they may not be able to construct the knowledge in their mind. The argument can be supported by the large difference of learning outcome achievement between the experimental and control groups. Furthermore, the experimental group had better perceived learning outcome in all 3 aspects than the control group which also entails that the experimental group students had more confidence in the learning process.

The qualitative analysis also provided our insight to further improve the 3D virtual learning environment in the future. In the open-ended section of the post-test questionnaire, a lot of comments were received from the students. Most of the students using Second Life think that learning using virtual environment is “interesting and interactive”. Some students reported that the learning in Second Life is “fun and interesting” and the virtual environment can “attract students”. It is believed that the use of Second Life could enhance the students' interest in learning. The game-like environment of Second Life could provide an interactive environment for the students to learn. Secondly, some of the students think that the use of Second Life is convenient and flexible for learning. Some students think that Second Life can provide “flexible time in studying” and has “less restriction on locations and times”. A student said that the learning is “fun and saves time”, as they “don't have to walk around”. Students also think that the use of Second Life in learning is “efficient usage of resources”. It is believed that the use of virtual environment in education would make learning more flexible.

However, the use of Second Life also received some negative comments from students. One reason is that the server and network were unstable. Some students considered the “jammed server” and “unstable Internet connectivity” as the main weaknesses of the learning experience in Second Life. A student commented that they could “lose control easily when the Internet broke down”. The quality of network and computer hardware diminishes the quality of learning in virtual environment. The poor quality of network and computer hardware may even make the control of characters in Second Life difficult. Secondly, some of the students find the virtual environment to be “difficult to control”. A student suggested that it is “quite difficult to manage the avatar”. Some may even commented that the learning experience is “confusing and hard to control”. The ease of control of characters in the virtual environment is important for learning in virtual environment. Students may need some more time to adapt the control of avatars in Second Life.

6. Conclusions and future work

In general, most students evaluated the Second Life learning experience as rewarding and interesting. The Second Life learning experience provided students with a chance to be situated in an office and server room setting, identifying the security vulnerabilities found in the office. The Second Life learning experience utilized the advantages of 3D Virtual World to give students a unique learning experience. By making use of virtual objects created or easily available in the Second Life, a virtual environment was created in this project. Through virtual objects

Table 1
Analysis results.

	Using Second Life (n = 49)	Using video (n = 56)	*p*-Value of two-tailed *t*-test
Perceived learning outcome (LO) achievement (overall)	4.72	4.15	0.0088
Perceived achievement of LO1: Describe and explain the concepts of information systems/technology and their roles and functions in organization	4.61	4.09	0.0240
Perceived achievement of LO2: Describe and explain the issues relating to managing information system security and control.	4.82	4.32	0.0408
Perceived achievement of LO3: Apply different models to evaluate the applications of various information systems and propose information systems solutions in solving problems	4.73	4.05	0.0045
Learning outcome achievement (mean test scores)	5.97	2.49	<0.0001

and the environment, Second Life has created an immersive and game-like environment that allows users to create their personalized learning experience. Through careful comparison between the result of the experimental group and the control group, we found that the experimental group performed better in the task. We also found that the students in the experimental group have higher perceived learning outcome achievement than those students in the control group. All these evidences show that the virtual environment is able to help students better achieve the learning outcomes. The use of virtual environment as a learning platform has a positive impact on the students' learning outcome achievement. Although many studies investigated the effectiveness and advantages of using 3D virtual environments as learning platform, few investigated why 3D virtual environments can facilitate learning. Based on previous research, the study proposes that 3D virtual environments can facilitate constructivist learning and shows a significant result. Comments received from the students using Second Life also suggested the positive impact of the use of virtual environment in learning. The interesting and interactivity of virtual environment can bring benefit to the learning. There are however some limitations in the study. First, the sample size may not be large enough to significantly generalize our findings to all learning situations. Besides, we only conducted the experiment in one course to evaluate the learning experience of an information system-related topic. The implication may be limited by the research context which may affect the results. Finally, we only focused on learning outcomes in our study. Other potentially influential factors, such as students' enthusiasm, were not evaluated and included in the analysis. These factors may interact with each other to affect the learning outcomes.

Further studies are required with a larger sample size on different age groups in order to have a more comprehensive understanding of the effects of this 3D virtual environment in different educational aspects. In addition to augmenting the sample size, we will continue our research by asking students to perform developmental tasks in the virtual environment. Students can get better hands-on experience in such tasks [8–10]. It will be useful to study the effectiveness of these tasks in 3D virtual environments. Another possible future research direction includes evaluation of others potentially influential factors, such as students' enthusiasm and their influence on learning outcomes. We believed that the creative and engaging aspect of Second Life can increase students' enthusiasm in learning. Since Second Life allows students to perform developmental tasks in the virtual environment, the enthusiasm can be sustained after playing a number of times. In addition to learning outcomes, this kind of individual factors may be instrumental to evaluate learning process. Further investigation of the effectiveness of online 3D virtual environments based on this study can contribute to the knowledge in e-learning. We believe that 3D virtual environments have a great potential to be the educational platform in the future generations. We can see a lot of development possibilities in the 3D virtual environments, which allow educational institutions to create an interactive and immersive learning platform for students and allow student to have better learning autonomy, communication and collaboration. Moreover, the flexibility of virtual environments indicates that learning can now be liberated from the constraints of geographical location. Interactive distance learning is made possible through the use of the Internet and virtual environments. Students can be from different origins but work on projects or coursework together. In the future, educational institutions can use 3D virtual environments to provide students with more complex learning tasks, or even team project, which require team collaboration to facilitate students' learning process.

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