AC 2008-1287: EFFECTIVENESS OF VIRTUAL REALITY APPLICATIONS IN TEACHING ENGINEERING MANAGEMENT CURRICULUM

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Effectiveness of Virtual Reality Applications in Teaching Engineering and Engineering Management Curriculum

Abstract

Virtual reality applications have been becoming more popular over the past several years. Many universities are investigating possibilities of adopting "virtual reality" as a support tool or as an alternate means of teaching students. While there is some potential of using virtual reality, it is not clear how applicable it can be in different programs. The purpose of this paper is to review benefits and challenges related to virtual reality teaching and to discuss potential areas where it can be more applicable. We present the results of a survey analysis that aims to assess the value of virtual reality in engineering and engineering management programs. The survey data is analyzed using design of experiments techniques.

Introduction and Motivation

The purpose of this paper is to overview the potential of virtual reality applications in a university teaching environment, particularly in engineering and engineering management programs. In order to assess the learning value of virtual reality applications for these students, an online survey has been conducted among the entire engineering student population at University of North Carolina at Charlotte, and the results of this survey are analyzed and presented here.

Education is changing rapidly with the latest advances in technology, which were only the creation of a wild imagination a few decades ago. Learning is not about passively listening to the instructor any more but about actively participating in class using the technology available to achieve this goal. Classrooms today are multi-media learning centers where students can understand, learn and apply their skills to deepen their knowledge.

Virtual reality is a computer-simulated environment, which allows real-time interactive online participation in simulated three-dimensional (i.e. virtual) settings with interactive chat possibilities. The particular activities depend on the actual virtual reality environment but in general, many activities in the "real" world can be carried out in the virtual environment. One example of such a place is Second Life, where users are represented in the virtual world using their avatars (customized graphical representations of the users). Possible activities include social interactions, group activities, trade, and even real estate transactions. Second Life is a simulated environment where users from anywhere can control the events in the virtual world. It is not like a game in the sense that it does not require keeping scores or collecting points and it does not even have winners. .

Applications of virtual reality for education are still in their early stages but there are already examples of applications from delivering a lecture, participating in projects or creating simulated business situations in the virtual world, to ER simulations for training nurses in emergency situations or virtual tours of an otherwise non-accessible place like the human heart or the tomb of a pharaoh. Unlike the current methods of online education, which can include online live

lectures every week using headphones and microphones, in Second Life, the lectures can be delivered in the virtual environment where both the students' and the teachers' avatars attend the virtual classes. A possible further application for engineering management students in this virtual world is designing a product, producing a prototype or role-playing, say, as a distributor in a supply chain.

Although some advantages of using virtual reality are very similar to those of online learning (e.g. convenience and improved computer skills), and in some aspects it is even better than online learning (e.g. one of the main drawbacks of online learning, lack of personal interaction is taken onto a different level with virtual reality), it is not without additional challenges such as the cost of creating and maintaining a virtual world, and from the user side, the requirement for increased computer power, special infrastructure, student connectivity, and availability of technical support and help desk. Also, this type of education is not for everybody: students with aversion towards technology will not be eager to participate in this kind of class. On the other hand, there could be students who possibly get addicted to all the activities in a virtual world.

Literature Review

There are a few studies available about using virtual reality in education but as the potential of virtual reality is being recognized in more and more institutions, more research is being done on this subject. A few recent examples of virtual reality applications in education include a wide range of application areas. For example, Ge et al.[5] describe a case study where college students are recreating a role-playing activity of a Maui legend in a virtual reality environment. Cobb[2] presents a brief description of virtual reality environments and the applications from chemistry simulations on the molecular level to applications studying social interactions and interrelations. He also describes in more details four virtual reality research projects to evaluate virtual environment applications for training purposes. Schwienhorst[10] discusses the benefits of virtual reality environments especially in foreign language contexts.

Winn[11], is describing a possible application of virtual reality for hydrology students who can study a complex phenomena such as the relationships among salinity, current, the state of the tide and distance from river mouths and the open ocean. Applications in direct manipulation of source charges in electromagnetic fields, and atoms and bonds in organic molecules are also mentioned. Ong and Mannan[8] present a web-based interactive teaching package with a module on automated machine tools in manufacturing. This is supposed to help to enhance the students' understanding of complex concepts, such as automated machine tools, and the numerical control of the motions of automated machine tools, and also help training students in these operations without actually working on these tools. The interest in virtual reality applications is not limited to the United States as it is shown by Mendez et al.[7]. They describe the Gironacel project, which is a virtual learning environment produced by the University of Girona in Spain for quality management courses within engineering schools to understand, for example, how to implement the ISO 9001:2000 standard in a practical way. They created a virtual company, Gironacel, and explain how this new tool was designed and implemented, and show the successful outcomes. Ramasundaram et al. [9] developed an environmental virtual field laboratory to study environmental properties and processes that stimulate the higher-order cognitive skills of students to enhance existing on-campus courses and/or distance education courses. The work of

Dickey[3] describes virtual worlds as an emerging medium currently being used in both traditional classrooms and for distance education. They also provide an overview and analysis of two specific environments, Active Worlds Educational Universe and Adobe. They also discuss the implications of using each application for educational initiatives by exploring how the various design features of each of these applications may support and enhance the design of interactive learning environments.

Some further study is already in place to see how students learn in virtual reality environments by contrasting designer's expectations to students' perceptions (Martens et al.[6]). They actually are showing a gap between these as students experience much less authenticity than developers assume, and in general, high expectations are often not fulfilled. The work of Foster[4] is a good example of efforts to develop standards and best practices for this new platform in teaching. He describes a recent project (called Immersive Education) to develop virtual-reality software that can be used for educational purposes, while also trying to develop standards and best practices for this new virtual-reality platform. There are planes for mini-games and interactive lessons within virtual environments such as Second Life, Croquet, and Project Wonderland.

Finally, a more detailed analysis of the possibilities offered by Second Life is given by Childress and Braswell[1]. They address the use of what they call "massively multiplayer online role-playing game (MMORPG)" to foster communication and interaction and to facilitate cooperative learning in an online course. After the definition and history of MMOGs, they also describe current uses of MMORPGs in education, including their own experiences and practical examples while they also explore future uses is education and training.

Even though virtual reality applications in education are still in their infancy, the near future should bring more studies and more applications as the potentials are discovered and expanded.

Survey Analysis

This section describes the survey analysis that was conducted at the College of Engineering at the University of North Carolina at Charlotte during December 2007.

Background

The Engineering Management Program at University X grants M.S. Degree in Engineering Management. The program also offers some course at undergraduate level but does not grant any undergraduate degrees yet. Eighty % of the program's students are working professionals whereas the rest are full-time students. It is a relatively small program with about 30-35 graduate students. While the enrollment has been quite steady in the program, the program has been seeking strategies to boost enrollment. Online and virtual reality learning has been seen as one of the means to increase the enrollment. During the Spring of 2008, the program has started to offer two online courses but none of these courses utilize virtual-reality learning tools. It is hoped that the results of this survey analysis will help shaping some of the program's future online-learning strategy.

Survey Description

The survey (provided in the Appendix) is composed of three parts: 1) general questions about the participants (questions 1-9), 2) online virtual-reality learning perception related questions for all engineering students (questions 10-13), and 3) engineering management-related questions for non-engineering management students (questions 14-17).

Participants begin by answering a series of general questions about their gender, age group, department, level of study, after which they answer several questions about online virtual-reality learning. The main online virtual-reality learning questions are questions 10, 12 and 13. Question 10 aims to understand students' perception towards various types of online virtual-reality learning. Question 12 aims to see the preference of these online virtual-reality courses compared to the traditional approach, given that the online course content and traditional course contents are identical. Question 13 assesses the same question except when the traditional course content is more interesting than the online virtual-reality course. Questions 14-17 they are geared to understand the College of Engineering students' perception towards Engineering Management Program and to assess whether the online virtual-reality learning can increase the student enrollment in Engineering Management Programs.

The survey was conducted primarily online, using SurveyShare.com in an anonymous survey format. The students were also given the option of filling the surveys in hard copy and return it by campus mail.

Survey Demographics

Out of about 2000 students, 109 students replied the survey (5.45 % response rate). Demographic information of this sample (such as age, race, department, full-time/part-time student, graduate/undergraduate and the year of undergraduate) is shown in Figure 1.

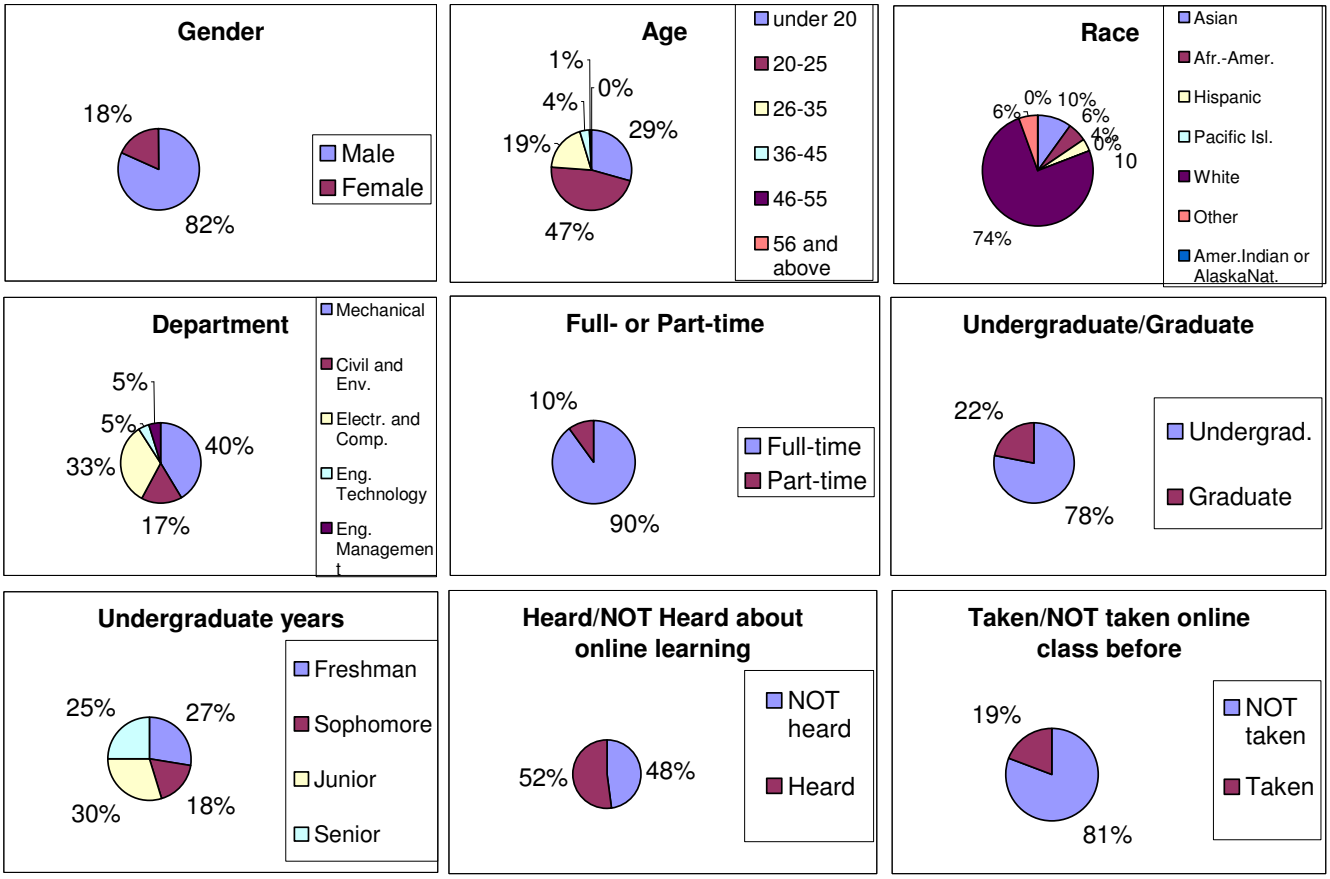

Figure 1. Demographic information for the survey respondents.

Survey Results

Question 10 of the survey is about different ways of delivering the virtual lectures where the respondents give an answer from 1 to 5, 1 being not interested at all and 5 being very interested.

a. attending class sessions (lectures) in the online virtual world
b. attending seminars in the online virtual world
c. working on class projects in the online virtual world
d. role-playing different jobs/positions in the online virtual world
e. attending online virtual factory or facility tours that illustrate best practices running a factory
f. attending business simulations that illustrate processes and best practices of running a supply chain in the online virtual world
g. attending labs (manufacturing, computing, science) in the online virtual world

Table 1. Online virtual-reality learning options compared in Question 10

The essence of these delivery methods is shown in Table 1 and the mean of the answers for all seven sub-questions in question 10 is shown in Table 2. Based on the mean scores, the ranking of these methods from most to least preferred is: e g f d b c a. In other words, the students would be most interested in "attending online virtual factory or facility tours that illustrate best practices running a factory", while options a and b ("attending class sessions or seminars in the virtual world) is the least desirable for them. This result was somewhat expected, just as in real life, the students seem to be more eager to see some practical applications such as tours of facilities than sitting through lectures and seminars even in virtual world.

Q10	*Q10-a*	*Q10-b*	*Q10-c*	*Q10-d*	*Q10-e*	*Q10-f*	*Q10-g*
mean	2.734	2.817	2.798	2.872	3.092	2.917	2.927

Table 2. Mean of responses for Question 10

Source	*SS*	*df*	*MS*	*F*	*p-value*
Treatment	8.78	6	1.46	0.82	0.557
Error	1354.13	756	1.79		
Total	1362.91	762			

Table 3. One-way ANOVA for Question 10

To test weather there is a statistically significant difference among these seven possible virtual reality applications, (i.e. the students would prefer any of the virtual learning environments more than others), a one-way ANOVA was applied to the data. The null hypothesis here is that there is no difference among the seven mean values representing the students' preferences for these different methods. The alternate hypothesis is that at least one of these mean values is different from the others. Table 3 shows the results of a one-way ANOVA test. The results show that with a p-value 0.557, the null hypothesis of equal means cannot be rejected, thus there is no statistically significant difference between the preferences for these different virtual reality methods as it is also visually illustrated on the box-plot of Figure 2. Looking at the figure, it is interesting to note that there seems to be a wider range of values for questions a and b, with very low minimum values for these two questions which correspond to virtual lectures and seminars. It seems that sitting through lectures is not that exciting either way.

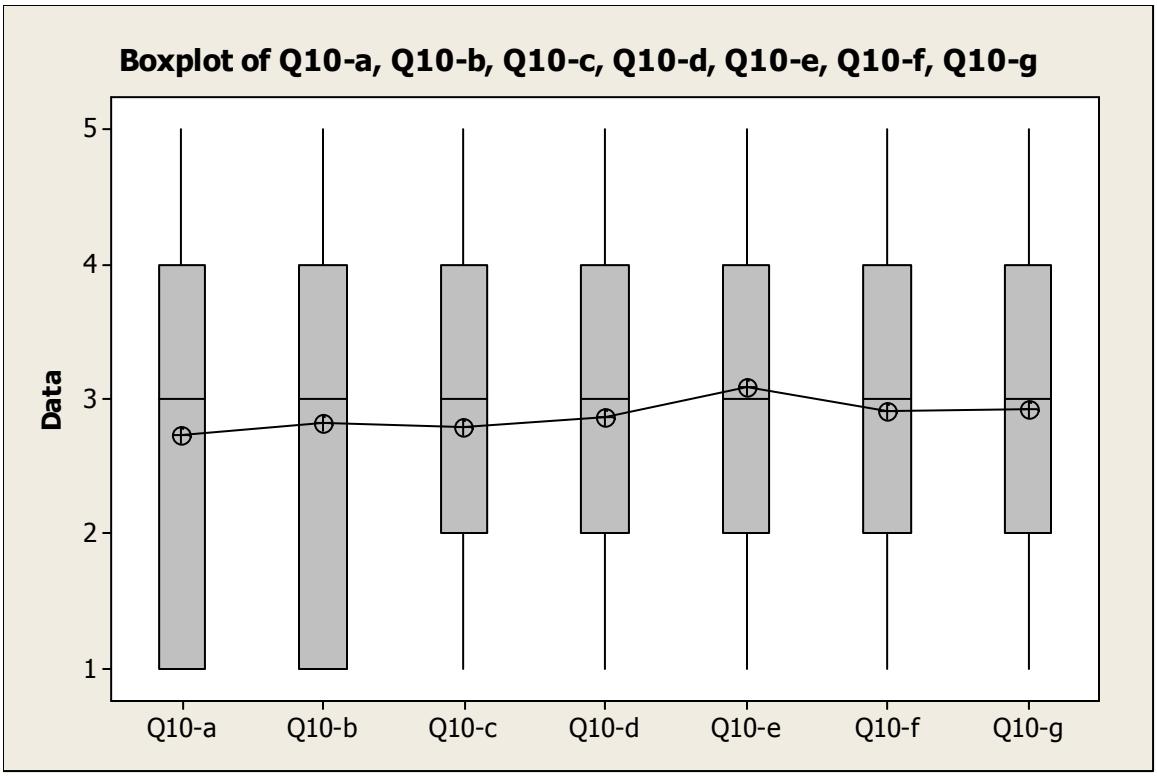

Figure 2. Box Plot for the comparison of responses for Question 10.

Another research question is whether there is a difference between students enrolled in different majors. Figure 3 gives insights about the students' preferences with different majors. There seems to be a well-expressed difference among the majors: for each of the virtual methods, EMGT students are the most interested, ME students are the least interested and ECE students are in the middle. This could be probably explained by the fact the ME students have a lot of hands-on laboratories and projects built into their curriculum, so they have to spend a lot of time on campus. Thus they do not see the benefits of virtual reality applications when they have to and they can work on "real" project, not virtual ones. Among EMGT students, the most preferred virtual methods would be those, which offer virtual tours of factories, simulations of business situations and attending labs in the virtual world. This is probably the element that is not much emphasized in their current curriculum, so virtual applications would actually fill a gap in their education. On the other hand, ME students, who seem to be the least interested in the virtual reality applications, would prefer to see class projects and different job/position role-playing in the virtual world, because perhaps this is currently the missing component from their curriculum.

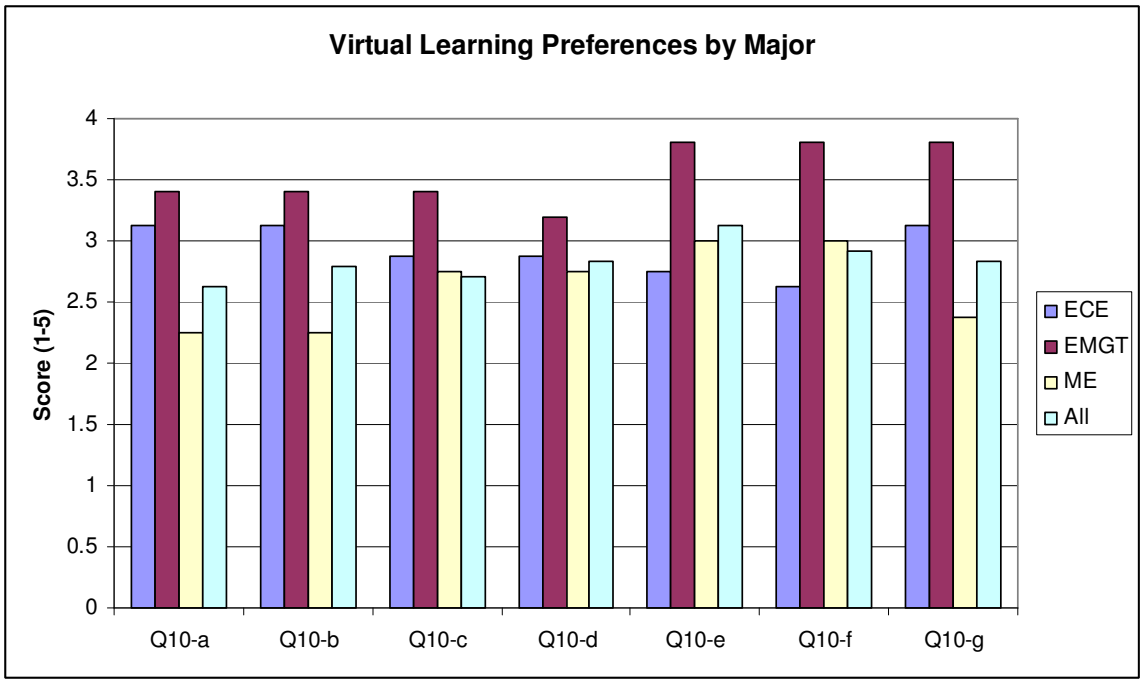

Figure 3. Online virtual method preferences among different majors

Further analysis indicates that there are also differences between the genders. Figure 4 shows the preferences for the different virtual teaching methods according to gender and major. It is interesting to observe that in general, females tend to prefer all the different methods more, than males. The same is true when looking at ECE students' preferences by gender. On the other hand, among EMGT students, this statement is not true any more as the males seem to prefer the last three methods more (virtual factory, virtual business simulations and virtual labs).

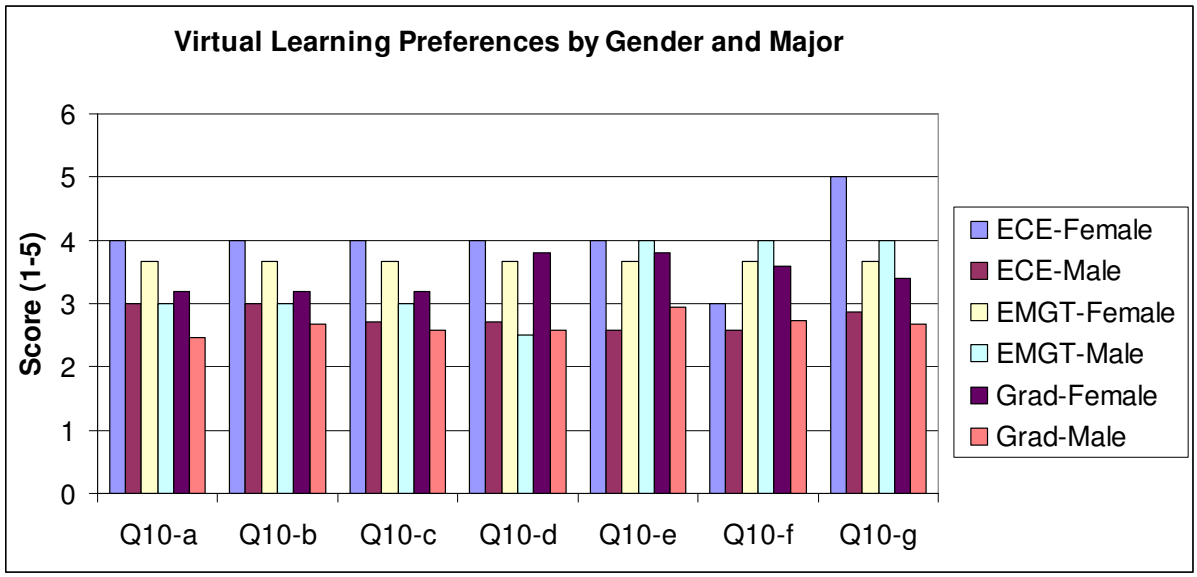

Figure 4. Preferences for the different online virtual methods according to gender and major.

Another interesting research question is whether there is a difference between the part-time and full-time students. Figure 5 gives some insights about preferences of the methods in the virtual applications according to the students' status. It seems that overall the most interested students are part-time graduate students and the least interested are the part-time undergraduate students. In general, part-time students seem to be more interested than full-time students, full-time undergraduates are more interested than full-time graduates and part-time graduate students are much more interested than the undergraduate part-timers. There seems to be no generally preferred method among all of the students, possibly method e (online virtual factory tours) would seem to be the most interesting in general.

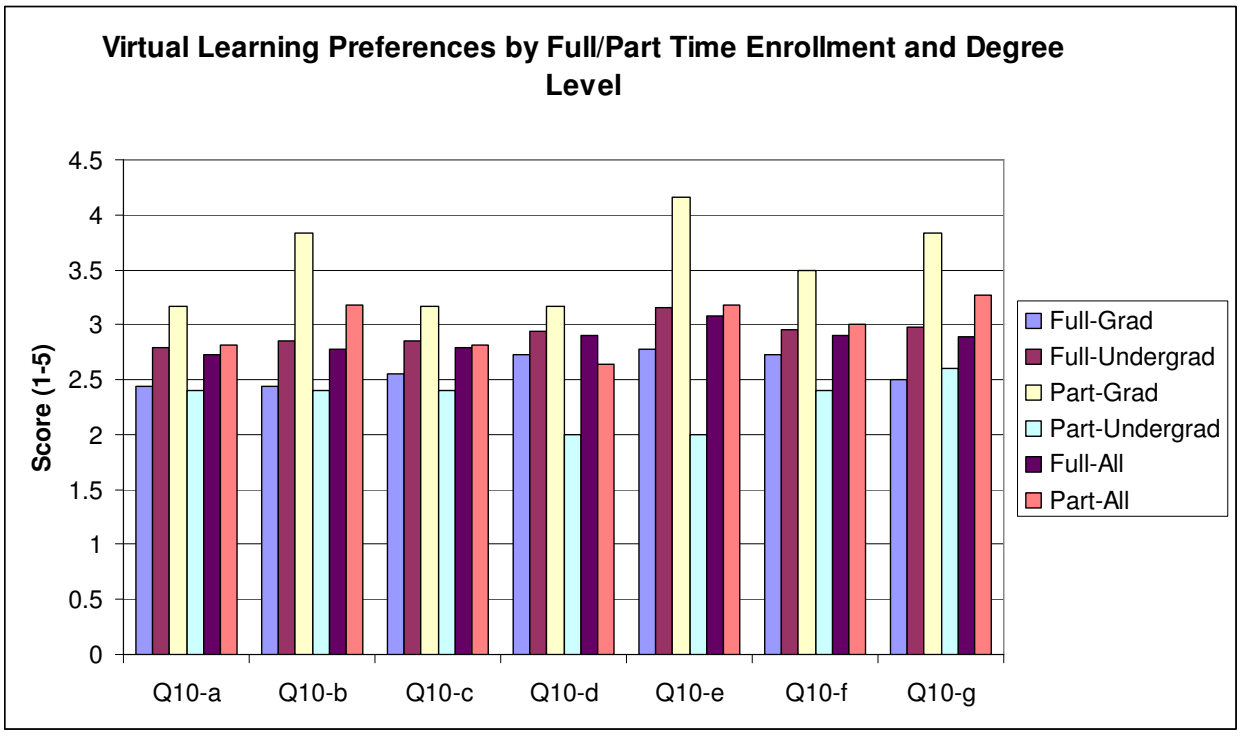

Figure 5. Preferences for the different virtual methods according to full-time/part-time and graduate/undergraduate students

Discussion of Other Survey Questions:

Question 11 is an open-ended question where ideas are solicited for other online virtual learning formats. Interestingly, there were some strong feelings voiced here: "Nothing yet. Now it is just distracting as it is more of a marvel than a tool. Just because a technology exist does not mean that it automatically serves a useful purpose.", along some useful suggestions such as "Finding a job" or "job interviews with potential employers".

Question 12 asks if the online virtual method would be preferred if the same class was offered using a virtual reality environment (using any combinations of the seven different methods described in Question 10). The mean response value of 2.450 shows a moderate interest in these

methods at all, which could possibly be explained by the fact that students are still not really familiar with these methods, thus cannot see the potential benefits of them. Question 13 is similar to question 12 but with a twist: it asks about the preference of the virtual reality class if the traditional class content seemed actually more interesting. The mean value of these answers is 2.138, which is slightly less than the value for Question 12, as expected.

Starting at Question 14 the focus is on the prospective engineering management students, as it is asking to fill out the rest of the survey only if they are not in currently registered in the engineering management program. Question 14 is about having ever taken engineering management classes before. The answers show that the majority of the non-engineering management students have not taken an engineering management class before. This shows a big potential to offer engineering management classes to non-management engineering students, and possibly using virtual-reality environment methods can be a strong deciding factor for these students.

Question 15 is about possible reasons why the students did not take any engineering management classes before. We have seen that the main reason for the majority of students is that: "I did not know I could take Engineering Management courses", and "I was not informed about the available Engineering Management courses". This shows a big potential to recruit more engineering management students by better marketing.

Question 16 investigates how much a student would be inclined to take an engineering management class if it were offered using a virtual-reality environment. The mean value of 2.391 shows that in average the interest is low in these applications, which could probably be partially explained by the fact that not many students actually understand the exact details of it.

Question 17 investigates the students' aversion towards virtual reality in the engineering management program by asking how strongly feel about not taking an online virtual class in any of the three settings. The mean value of 3.228 shows a big aversion against these methods.

Future research includes further analysis of the survey results by analyzing the possible relationships between the online virtual learning preferences and demographics, majors, years at the university. It is also our intention to repeat a similar survey in the following years to see if there is any change in the attitude towards online virtual learning methods.

Conclusions

Several conclusions can be drawn on the basis of this survey:

- As the best mean scores for the different methods of delivering the virtual reality online classes is only slightly below 3 on a 1-5 scale for almost all of the possible examples given for using virtual reality in the classroom, it seems that none of these applications are particularly preferred. The students seem to feel comfortable in their current settings, and they probably are not aware of the full potentials of virtual reality applications, so they just prefer the familiar traditional classroom settings.

- Among the seven different methods described as possible ways to deliver the class material in an online virtual reality setting, the most preferred methods were e. attending online virtual factory or facility tours that illustrate best practices running a factory, f. attending business simulations that illustrate processes and best practices of running a supply chain in the online virtual world, and g. attending labs (manufacturing, computing, science) in the online virtual world. All of these methods seem to be higher level simulations of activities that the students had very little access to do in the traditional setting. Thus the real applicability of the virtual reality methods for the students seems to be the real-life situation simulations such as role-playing.
- There seems to be a well-expressed difference among the majors: for each of the virtual methods, EMGT students are the most interested, ME students are the least interested and ECE students are in the middle. Among EMGT students, the most preferred virtual methods would be those, which offer virtual tours of factories, simulations of business situations and attending labs in the virtual world.
- It is interesting to observe that in general, female students tend to prefer all the different methods more than the male students.
- It seems that overall the most interested students are part-time graduate students and the least interested are the part-time undergraduate students. In general, part-time students seem to be more interested than full-time students, full-time undergraduates are more interested than full-time graduates and part-time graduate students are much more interested than the undergraduate part-timers.
- It seems that rather than implementing online virtual-reality, there seems to be bigger potential to recruit more students by better marketing of the Engineering Management Courses.

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Appendix: Online Virtual Reality Learning Survey Questions

Please do not respond to this survey twice!!

General Questions About You:

1. What is your gender?
   - **a)** Female
   - **b)** Male
2. What is your age?
   - **a)** under 20
   - **b)** 20-25
   - **c)** 26-35
   - **d)** 36-45
   - **e)** 46-55
   - **f)** 56 and above
3. How do you describe yourself? (Select one or more responses.)
   - **a)** American Indian or Alaska Native
   - **b)** Asian
   - **c)** Black or African American
   - **d)** Hispanic or Latino
   - **e)** Native Hawaiian or Other Pacific Islander
   - **f)** White
   - **g)** Other (specify)_____
4. What is your department/program?
   - **a)** Mechanical
   - **b)** Civil and Environmental
   - **c)** Electrical and Computer
   - **d)** Engineering Technology
   - **e)** Engineering Management
   - **f)** Other (specify)_____
5. Are you a full or a part-time student?
   - **a)** Full-Time Student
   - **b)** Part-Time Student
6. Are you an undergraduate or a graduate student?
   - **a)** Undergraduate Student
   - **b)** Graduate Student
7. If you are an undergraduate student, in what year are you enrolled in?
   - **a)** Freshman
   - **b)** Sophomore
   - **c)** Junior
   - **d)** Senior

Questions Related to Virtual Reality:

In a virtual environment, you create characters (called Avatars). With your guidance in the background, these avatars can chat/talk and attend different activities including but not limited to classes, labs, visit virtual factories, or have discussions to conduct projects. One of these virtual worlds is Second Life, which is currently in an experimental phase to include an academic environment component. Note that here we do not refer to online communication such as instant messaging and groups such as "Facebook" as virtual reality.

8. Have you heard about virtual worlds that exist online before this survey?
   a) Yes
   b) No
9. Have you ever participated in such an online virtual world before?
   a) Yes
   b) No
10. Please carefully read the following descriptions and score them according to how much you would be interested in it (5 - very interested, 4 - interested, 3 - somewhat interested, 2 - little interested, 1 - not interested at all):

a. attending class sessions (lectures) in the online virtual world	5	4	3	2	1
b. attending seminars in the online virtual world	5	4	3	2	1
c. working on class projects in the online virtual world	5	4	3	2	1
d. role-playing different jobs/positions in the online virtual world	5	4	3	2	1
e. attending online virtual factory or facility tours that illustrate best practices running a factory	5	4	3	2	1
f. attending business simulations that illustrate processes and best practices of running a supply chain in the online virtual world	5	4	3	2	1
g. attending labs (manufacturing, computing, science) in the online virtual world	5	4	3	2	1

11. What other professional areas (other than the ones specified in question 10 above) do you think the virtual reality would be most suited for?
    h.
    i.
    j.
    …
12. Please read carefully the following description, and score between 1 and 5 depending on how likely it is (5 – very likely, 4 – likely, 3- neutral, 2- unlikely 1 – very unlikely):

Given that you have the option to take **the same course** either **using online virtual reality** (in part or as a whole as described in Question 10, Options a. trough g.) **or** in a **traditional** physical classroom setting, **how likely is it that you would register in the "online virtual reality"-based class?**	5	4	3	2	1

13. Please read carefully the following description, and score between 1 and 5 depending on how likely (5 – very likely, 4 – likely, 3- neutral, 2- unlikely 1 – very unlikely):

Given that you have the option to take only one of the **two different courses** but one is offered using online virtual reality (in part or as a whole as described in Question 10, Options a. trough g.) and the second one is in a traditional physical classroom setting, **how likely is it that you would register in the "Online Virtual Reality"-based course if the Traditional course content is more interesting?**	5	4	3	2	1

Answer the following questions if <u>You are NOT a student of the Engineering Management Program</u>

Engineering Management Program offers curriculum that aims to provide decision making, systems optimization, project management, quality control and management, forecasting, product and process design, simulation, and other planning skills primarily to students with technical/engineering backgrounds.

14. Did you take any Engineering Management courses before?
    a) Yes
    b) No

15. If you did not take any Engineering Management courses before, please tell us the reason? (You can select one or more responses.)
    a) Engineering Management courses do not interest me for my professional development
    b) I did not know I could take Engineering Management courses
    c) I was not informed about the available Engineering Management courses
    d) My study plan does not permit taking additional courses
    e) I rather prefer taking courses offered by the Business College rather than the Engineering Management courses
    f) other:_____

16. Please read carefully the following description, and score between 1 and 5 depending on how likely (5 – very likely, 4 – likely, 3- neutral, 2- unlikely 1 – very unlikely):

How likely is it that you would **register in an Engineering Management course if it was taught using online virtual reality** in any way described above as in question 10 (Options a. through g.)?	5	4	3	2	1

17. Please read carefully the following description, and score between 1 and 5 depending on how likely (5 – very likely, 4 – likely, 3- neutral, 2- unlikely 1 – very unlikely):

How likely is it that you would **NOT register in an Engineering Management course if it was taught using online virtual reality** in any way described above as in question 10 (Options a through g)?	5	4	3	2	1