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ABSTRACT

It is criticized that labs generated by computers (simulated labs) or remotely controlled through the Internet (remote labs) deprive students of hands-on experience. In a study of 306 undergraduate students, I found that the importance of physical presence in the labs is positively related with students' perceived effectiveness of the hands-on labs. Similarly, students' psychological presence is positively related with their perceived lab effectiveness in both simulated and remote labs. However, it is surprising that those students who feel physical presence in the labs is important are not less likely to experience psychological presence or think simulated and remote labs are less effective. This result implies that physical presence in the labs might not be the key issue for learning performance in the labs, what the students believe may affect what they think but may not affect what they can achieve.

Keywords

Hands-on labs, simulated labs, remote labs, physical presence, psychological presence, virtual presence, telepresence

INTRODUCTION

The nature and practice of laboratories have been changed by two new technology-intensive automations: simulated labs (laboratories generated by computers) and remote labs (laboratories remotely accessed and controlled through the Internet). These two new forms of labs are seen by some as educational enablers (Ertugrul, 1998; Striegel, 2001) and by others as educational destroyers (Dewhurst, Macleod and Norris, 2000; Dibiase, 2000).

Given the richness of information available to the participants in the traditional hands-on labs, it is often argued that physical presence is preferred by the students (Short, Williams and Christie, 1976; Snow, 1996). Advocates argue that hands-on labs provide the students with real data and "unexpected clashes"—the disparity between theory and practical experiments that are essential for students to understand the role of experiments (Magin and Kanapathipillai, 2000). As a result, simulated labs, and to some extent remote labs, are criticized for their inability to provide authentic settings and interaction with real apparatus (Zeltzer, 1992; Zywno and Kennedy, 2000) which will in turn hinder students' learning performance. However, remote labs and simulations provide alternate forms of presence; telepresence and virtual presence as rivals of physical presence.

Is physical presence necessary in order to perform effectively in laboratories? Or is the belief about that link important? Some researchers argue that the sense of presence can predict the level of performance (Loomis, 1992). By comparing the experimental results fewer than six versions of virtual environments, Bystrom and Barfield (1999) claim that the sense of presence is one of the key factors that contribute to higher task performance. But the relationship between presence and performance is doubted by others (Mania and Chalmers, 2001). A recent review study on presence and performance (Nash, Edwards, Thompson and Barfield, 2000) reports that no consistent correlational relations can be found between presence and performance.

I examine here the possibility that it is not the actual nature of the labs, but the beliefs the students have about the labs that determine the effectiveness of the different types of labs. In the following sections, I will first briefly review the literature from a more philosophical perspective; then I will introduce and build our hypotheses. After that, I will discuss the design of the study on the 306 freshman engineering students. At the end, the results and the implications for the educators will be presented.

THERORETICAL BACKGROUND

Discussion of this issue goes back to more than 50 years. Two different kinds of fidelity, engineering fidelity and psychological fidelity, are clearly distinguished by Miller (1954). He comments that engineering fidelity concentrates on the closeness of simulated environments to the physical surroundings, while psychological fidelity is seen as the factor that determines the effectiveness of a simulation device. The sense of being in a place is described in the literature as *presence.* Analogous to the distinction between hands-on labs, simulated labs and remote labs, Sheridan (1992) identified three types of presence: physical presence, telepresence and virtual presence. Physical presence is "physically being there." Telepresence is "feeling like you are actually there at the remote site of operation" and virtual presence is "feeling like you are present in the environment generated by the computer" (p. 120). His work was echoed in an in-depth discussion about the ontology and epistemology of presence by Ellis (1996) and many other researchers.

Different ontological positions support different understandings for physical presence, telepresence and virtual presence. On the one hand, physical presence is viewed as independent of psychological presence (tele/virtual presence). Noel and Hunter (2000) claim that the critical issue in designing virtual environments is to create a psychologically real setting rather than recreate the entire physical reality. Biocca (2001) also suggests that the root of presence lies in the "perception of reality" rather than physical reality. In other words, presence is more about "the illusion of being here or there and less about being as such" (p. 550), a sentiment also echoed in Bentley, Tollmar, Demirdjian, Oile and Darrell, (2003). On the other hand, Mantovani and Riva (1999) propose an interdependent perspective to look at the objective and subjective features of presence. In their model, the subject-object relationship could be uni-directional, inter-actional or co-constructional, depending on the interdependence of each side. As a result, students may physically be present but psychologically distracted. For example, the students may get unfocused in the hands-on labs. Also, students may physically be absent but still feel "they were there". For instance, a highly interactive 3-D simulation game may make a high-fidelity environment.

HYPOTHESES

Discovery learning is "an approach to instruction through which students interacts with their environment by exploring and manipulating objects, wrestling with questions and controversies, or performing experiments" (Ormrod, 1995, p. 442). Learning in laboratories is a complex issue; it can take a variety of forms and involve different kinds of activities. A standard form of labwork often involves students working in smalls groups, manipulating experimental apparatus, discussing and writing. Essentially, laboratory learning is a discovering process where students learn by physically manipulating the objects. Two characteristics distinguish hands-on labs from the other two labs: 1) all equipment required to perform the lab is physically set up; 2) the students who perform the lab are physically present in the lab. Therefore, hands-on labs are advocated for providing the students with real data and physical investigation processes that are essential for students' learning (Magin and Kanapathipillai, 2000). There are many ways to learn, and some learn better by doing. Such students prefer hands-on labs because an opportunity to visualize, physically engage with the objects and discover the rationale behind effective learning is provided (Bruner, 1967). As a result, they tend to discredit simulated and remote labs since no physically real investigation is involved. Based on that, I predict:

H1.1 Students' perceived importance of physical presence will positively impact their perceived effectiveness of hands-on labs

H1.2 Students' perceived importance of physical presence will negatively impact their perceived effectiveness of simulated/remote labs

The theory of presence suggests that the role of beliefs may be important in explaining students' behavior in a computer-assisted learning situation (Vuorela and Nummenmaa, 2004). Sheridan (1999) argues that by suspending disbelief, we can experience presence in a virtual environment. Nunez and Blake (2003) asserted that more attention and effort should be given to investigate the suspension of disbelief in virtual environments. By this perspective, physical presence and psychological presence are viewed as two ends of the continuum; the increase in the perceived importance of physical presence will lead to an increase in disbelief in the virtual environment, which will in turn decrease the psychological presence. Thus, I hypothesize:

H2.1. Students' perceived importance of physical presence will negatively impact their virtual presence in simulated labs

H2.2. Students' perceived importance of physical presence will negatively impact their telepresence in remote labs.

It may be that psychological presence, the belief of what is real, is not restricted by physical reality and therefore may play an important role in affecting subjects' behavior in a virtual environment. At the extreme, experimentation can be completely independent of the physical reality. Bradner and Mark (2002) find that people tend to cooperate less with their experiment partners if they believe them to be at a remote location, even if in actuality both of them are at the same location. Loomis (1992) proposes that presence is not a physical state but a phenomenal attribute that can be known only through inference. Slater and Usoh (1993) indicates the extent to which human participants immerse themselves in a virtual environment depends on at what level they are convinced by the computer-synthesized effects. Therefore, I believe that psychological presence does facilitate learning performance in simulated labs and remote labs implicitly or explicitly.

H3.1. Students' perceived virtual presence will positively impact their learning performance in simulated labs

H3.2. Students' perceived telepresence will positively impact their learning performance in remote labs

METHODOLOGY

Sampling and measurement

In order to test the hypotheses, a questionnaire was designed and distributed to collect the information about students' perceptions of lab effectiveness, lab group interactions, learning performance and individual differences. Following the beam labs, students were given the knowledge test immediately. Free coffee was offered as an incentive to complete the questionnaire since completion of that questionnaire could not be considered a normal part of the course requirements.

Participants were undergraduate students at a large school of engineering in the Northeast. 292 out of 306 students answered the questionnaire. This design course had twelve lab sections. Students were divided into lab groups (teams) with 3-4 members each and the team members were the same for all the lab sections. The groups were either self-formed or assigned by the instructors. Each construct was measured using a Likert-type 0 to 9 scale (0 – not at all to 9 – absolutely crucial). Based on the measures developed by Witmer and Singer (1998) and Barfield and Weghorst (1993), a three-item scale was used to measure virtual presence and telepresence. The measures for students' learning outcomes are objective. A four-item multiple-choice test was designed on the two relevant lab topics: beam with a hole and beam without a hole. Two items concerned beams with a hole and another two concerned beams without a hole.

Procedure

The experiment was designed to differentiate three types of labs: remote labs, simulated labs, and hands-on labs, and two lab topics: beam_hole and beam_no hole. In the first set-up, the beam is plain. In the other, the beam has a hole in it. The hole produces stress, and therefore calls for a more sophisticated analysis than the plain beam. Each student experienced two different labs: hands-on remote or hands-on simulation. Also, the orders in assigning different labs were counterbalanced. As a result, four conditions were designed: HandsOn-Remote, Remote-HandsOn, HandsOn-Simulation and Simulation-HandsOn. 14 lab classes ware randomly assigned to one of the four conditions. The detailed design of the experiment is shown in table 1. The first seven sections were referred as the Remote conditions and the last seven sections were referred as Simulation conditions.

This study is a continue study of our group work, the results of which have been discussed by Corter, Nickerson, Esche, Chassapis (2004) and Nickerson, Corter, Esche and Chassapis. (in press). The team will be doing more experiments on related topics and a recent paper that is currently under review (Corter, Nickerson, Esche, Chassapis, Im and Ma, under review) will provide more information about this experiment.

Lab conditions	**Course**	**Section**	**No. of students**	**Beam_no hole**	**Beam_hole**
Remote conditions	E122	E1	24	Hands-on	Remote
	E122	E2	22	Hands-on	Remote
	E122	E5	24	Hands-on	Remote
	E122	D	22	Remote	Hands-on
	E122	K	22	Remote	Hands-on
	E122	E3	22	Remote	Hands-on
	E122	E4	20	Remote	Hands-on
Sum		7	156		
Simulation conditions	E122	A	25	Simulation	Hands-on
	E122	C	23	Simulation	Hands-on
	E122	I	23	Simulation	Hands-on

	E122	B	23	Hands-on	Simulation
	E122	F	19	Hands-on	Simulation
	E122	G	15	Hands-on	Simulation
	E122	H	22	Hands-on	Simulation
Sum		7	150		

Table 1. Design of the Experiment

Analyses and results

Descriptive Statistics

The following table (table 2) shows the descriptive statistics for the variables separated by conditions. Internal consistency reliability (Cronbach's alpha) for VPRESEN is 0.8130, indicating acceptable level of internal consistency Nunnally (1978).

Nash's et al.(2000) comprehensive literature review shows that as an initial step to tackle the relationship between presence and performance, a correlational approach is recommended since "presence is a construct and performance is a measured variable" (P. 34). They argued such data could benefit the researchers as the basis for further investigation and also inform the designers of virtual environments. By this perspective, correlational analysis will be used as the primary method to test our hypotheses.

Lab type	Variable	Beam_no hole			Beam_hole		
		N	Mean	Std. Deviation	N	Mean	Std. Deviation
Simulation	Physical presence in Lab(1)	39	7.49	1.760	15	6.67	1.877
	Impact_Remote (6)	39	5.87	1.704	15	5.60	2.098
	Impact_Traditional (4)	37	6.84	1.323	15	6.33	1.718
	VPRESEN	39	5.8291	1.70974	15	5.5778	1.88337
	Valid N (listwise)	37			15		
Remote	Physical Presence in Lab(1)	61	7.18	2.004	48	6.60	1.943
	Impact_Remote (6)	58	5.00	1.600	47	4.40	1.884
	Impact_Traditional (4)	61	6.28	1.665	47	5.74	1.882
	VPRESEN	61	5.2459	1.77863	47	4.5922	1.75553
	Valid N (listwise)	58			46		
Hands-on	Physical Presence in Lab(1)	116	6.80	1.912	61	7.18	2.004
	Impact_Remote (6)	114	4.64	1.951	58	5.00	1.600
	Impact_Traditional (4)	115	6.08	1.702	61	6.28	1.665
	VPRESEN	115	4.7899	1.78458	61	5.2459	1.77863
	Valid N (listwise)	113			58		

Table 2. Descriptive Statistics

A three-step analysis was conducted to test our hypotheses; the results are listed in the Appendix. The first set of correlation studies indicates that in hands-on labs, the more important students feel about physical presence in the labs, the more likely they will rate hands-on labs as more effective, supporting H1.1. The correlation coefficient in the topic of beam_no hole is 0.357, $P<.001$; Similar to beam_no hole, the correlation coefficient in the topic of beam_hole is 0.399, $P<0.001$. However, no negative relationship has been found between students' perceived importance of physical presence and the perceived effectiveness of the remote/simulated labs (see appendix, table 3.), thus rejecting H1.2. It is interesting to find that students may feel better in the environment they preferred, however, they are not necessarily bad in an environment other than their preference. The preference and performance may not be consistently correlated, which implies that students who think hands-on interactions as indispensable might be able to learn as well in computer automated labs as in traditional labs

The second set of hypotheses is focusing on the relationship between physical presence, telepresence and virtual presence. The results of the correlation analysis suggest that H2.1 and H2.2 should be rejected (see appendix, table 4); students' perceived importance of physical presence will not affect telepresence or virtual presence. This result confirms what I found in H.1.2, which indicates that the importance of physical presence will not affect what students think about the effectiveness of virtual environments. Furthermore, I even found that positive relationships exist in simulated labs. Students' perceived importance of physical presence in the labs has significant positive relationships with their perceived effectiveness of the beam with the hole simulated lab (coefficient, .295*, P<.05) as well as the virtual presence they experienced in the simulated labs (coefficient .327**, P<.01). This seems like a paradox; why is it that the more important the students feel the physical presence is, the more likely they will experience a higher virtual presence in simulated labs? This might be related with the quality of the simulation. If the quality of the simulation is very good, it may provide the students with a superior laboratory experience which maybe as good as or even better than traditional hands-on labs. In this situation, even though the student may think physical presence is important, he can still experience virtual presence or think simulated labs are effective. On the other hand, it might also be that the quality of the simulation is very poor. In this situation, the students who think physical presence is very important may compensate the poor experience of the simulation by other resources. For example, they may run the lab many times or may discuss with their team members or TA more often to understand the practicality of the simulation. Such increased interaction between the laboratory apparatus and the students or between the students and other units may actually provide the students with a deeper understanding of the simulation and thus they will learn more through the information from different channels.

The final set of hypotheses was tested by examining the relationship between student's perceived virtual presence and telepresence with their learning performance. Here students' learning performance was measured by both subjective and objective measures: students perceived effectiveness of the labs and the knowledge test students have in the labs. The results were consistent with previous findings and also produced some new interesting ideas. The hypotheses were partially supported (see appendix, table 5). For both simulated and remote labs, the relationship between students' perceived presence and perceived effectiveness of the labs were positively related (.825, P<.01; 616, P<.01; 543, P<.01; 384, P<.05). However, the relationship between students' perceived presence and objective measure of students learning performance were not significantly correlated. It is suggested that the role of psychological presence may affect what students think but may not affect their behavior, which is consistent with the conclusions of Nash's et al. (2000) review study.

DISCUSSIONS

The work above in total suggests that students' learning performance cannot be attributed to the physical presence in the laboratory alone. From these studies, I might expect that students in a simulated or remote lab may experience psychological presence but not physical presence. In a similar way, students in a real hands-on experiment could be exposed to a physically real apparatus, but may not experience psychological presence. For example, the students might get bored or distracted if their role is only to passively watch others interact with the device. Such ideas might be tested by simple framing to further investigate the role of presence in laboratories. By changing students beliefs about a technology (is it real or not?), as well as their ability to immerse themselves (can they interact with it or not?), the potential confounds related to students' learning performance might be separated and evaluated.

We assumed that physical presence and psychological presence are inversely propositional which turned out to be not supported in this study. A focus on how students' mental activities are engaged in coping with the laboratory world may help us to explain this question. From this point of view, other factors that have been discussed in relation to the effectiveness of laboratories, such as motivation (Edward, 2002), peer collaboration (Baxendale and Mellor, 2000), error-corrective feedback (Grant, 1995) and the richness of the media (Chaturvedi, Akan, Bawab, Abdej-Salam and Venkataramana, 2003), should also be studied in order to produce more interactive and immersive settings that ultimately lead to a space perceived as real.

As Nash et al. (2000) stated in their review, correlational design is necessary for research on presence and performance but it is also inherently limited. Although we experimentally controlled the topics, the order, students' spatial ability, SAT, GPA, there are still many factors that might affect the relationship between the presence and performance that cannot be revealed by correlational studies. In addition, it is always impossible to infer the causal directions for any identified relation. Therefore, more qualitative studies are expected to identify more factors that might affect presence and performance in order to support and develop more meaningful regression models.

CONCLUSIONS

I asked, what is the role of presence in laboratories? Specifically, is physical presence necessary in laboratory learning? The relationship between perceived importance of physical presence and perceived lab effectiveness suggests that physical presence is not indispensable for effective laboratory learning. For those who prefer physical presence in the labs may learn better in hands-on labs, but they may also find simulated labs or remote labs are as effective as hands-on labs. This indicates that there might also be other factors that affect effective laboratory learning other than students' preference. For example, the author is currently researching about the pattern of group collaborations in laboratory learning. I believe that students' behavioral activities may be intertwined with students' cognitive activity to impact students' laboratory learning.

I also asked, what is the relationship between physical presence and psychological presence (virtual/telepresence)? Are they interrelated with or independent from each other? Based on previous presence literature, I hypothesized that there is a negative relationship between them. The result is contrary to our expectations. It seems that the psychological attachment for physical presence might just be an inertia which will not hurt or reduce the psychological presence in remote or simulated labs. In addition, an interesting issue is raised about simulated labs of perforated beam. We found that students' perceived importance of physical presence was positively related with virtual presence and perceived lab effectiveness. One of the possible explanations I provided is that there might be an interaction between the quality of the simulation and the perceived importance of the physical presence.

The third question I asked is about the relationship between psychological presence and laboratory learning. We do find that a higher level of psychological presence will lead to a higher level of perceived effectiveness of the labs. However, I also find that the level of psychological presence will not affect objective measures of laboratory learning. It is suggested that what they believed may affect what they think but may not affect how they behave. The results can be viewed as a reflection of the inconsistent relationship between the sense of presence and performance; it can also provide us a new perspective to map the relationship between beliefs and behaviors.

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APPENDIX

Correlation analysis for first set of hypotheses

Lab type	Variable		Beam_hole			Beam_no hole		
			Impact_Traditional (4)	Physical Presence in Lab(1)	Impact_Re_Sim (6)	Impact_Traditional (4)	Physical Presence in Lab(1)	Impact_Re_Sim (6)
Simulation	Impact_Traditional (4)	Pearson Correlation				1		
		N	68	68	67	37	37	37
	Physical Presence in Lab(1)	Pearson Correlation	.360**	1	.	.555**	1	.
		N	68	68	67	37	39	39
	Impact_Re_Sim (6)	Pearson Correlation	.468**	.295*	1	-.167	.127	1
		N	67	67	67	37	39	39
Remote	Impact_Traditional (4)	Pearson Correlation	1			1		
		N	47	47	46	61	61	58
	Physical Presence in Lab(1)	Pearson Correlation	.336*	1		.324*	1	
		N	47	48	47	61	61	58
	Impact_Re_Sim (6)	Pearson Correlation	.506**	.078	1	.059	.043	1
		N	46	47	47	58	58	58
Hands-on	Impact_Traditional (4)	Pearson Correlation	1			1		
		N	98	98	95	115	115	113
	Physical Presence in Lab(1)	Pearson Correlation	.399**	1	.097	.357**	1	.213
		N	98	100	97	115	116	114
	Impact_Re_Sim (6)	Pearson Correlation	.030	.097	1	.488**	.213	1
		N	95	97	97	113	114	114

Table 3. Correlation Matrix of Hypotheses 1.1 and 1.2

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Physical Presence in Lab: Students' perceived importance of physical presence in the labs

Impact_Traditional: Students' perceived effectiveness of traditional labs

Impact_Re_Sim: Students' perceived effectiveness of remote labs or simulated labs

Correlation analysis for second set of hypotheses

Lab type	Variable		Beam_hole		Beam_no hole	
			Physical Presence in Lab(1)	VPRESEN	Physical Presence in Lab(1)	VPRESEN
Simulation	Physical Presence in Lab(1	Pearson Correlation	1		1	
		N	68	68	39	39
	VPRESEN	Pearson Correlation	.327**	1	--.079	
		N	68	68	39	39
Remote	Physical Presence in Lab(1)	Pearson Correlation	1		1	
		N	48	47	61	61
	VPRESEN	Pearson Correlation	-.171	1	.173	
		N	47	47	61	61

Table 4. Correlation Matrix of Hypotheses 2.1 and 2.2

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

VPRESEN: Students' perceived presence in remote or simulated labs

Correlation analysis for third set of hypotheses

Lab type	Variable		Beam_hole			Beam_no hole		
			VPRESEN	Impact_Remote (6)	Perforated beam score	VPRESEN	Impact_Remote (6)	Not Perforated beam score
Simulation	VPRESEN	Pearson Correlation				1		
		N	68	67	68	39	39	39
	Impact_Re_Sim (6)	Pearson Correlation	.825**	1	.	.543**	1	.
		N	67	67	67	39	39	39
	Perforated beam score	Pearson Correlation	-.117	-.075	1	-.210	-.519**	1
		N	68	67	78	39	39	66
Remote	VPRESEN	Pearson Correlation	1			1		
		N	47	47	47	61	56	61
	Impact_Remote (6	Pearson Correlation	.616**	1		.384*	1	
		N	47	46	47	58	58	58
	Perforated beam score	Pearson Correlation	-.204	.017	1	-.116	-.383**	1
		N	47	47	65	61	58	83

Table 5. Correlation Matrix of Hypotheses 3.1 and 3.2

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

VPRESEN: Students' perceived presence in remote or simulated labs

Perforated beam score: result of knowledge test for beam_ hole

Not Perforated beam score: result of knowledge test for beam_no hole