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A cross-cultural comparison study: The effectiveness of Schema Training modules among Hispanic students

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Abstract - **Previous studies indicated that misconceptions related to heat transfer, fluid mechanics, and thermodynamics, persist among engineering juniors and seniors even after they completed college-level courses in these subjects. Researchers have proposed an innovative instructional approach, the ontological schema training method, which helps students develop appropriate schemas or conceptual frameworks for learning difficult science concepts. Three online training modules were designed to help engineering students develop appropriate schemas in heat transfer, diffusion and microfluidics. The effectiveness of these modules was examined with two different student populations from two different universities (US and Hispanic). At each institution, participants were assigned randomly to a control or experimental group. The treatment for each group at both institutions was exactly the same. Preliminary results indicated a mixed effectiveness of the training modules among these populations.**

Index Terms – Cultural Differences, Ontological Schema Training, Quantitative Analysis

INTRODUCTION

Previous studies conducted by Streveler and Miller [1] indicated that misconceptions related to heat transfer, fluid mechanics, and thermodynamics, persist among engineering juniors and seniors even after they completed college-level courses in the subjects. Researchers argued that in order to repair and correct student's misconceptions, it is critical to facilitate conceptual change through training students in the appropriate mental framework or schema for some difficult concepts.[2] Chi and her colleagues proposed an innovative instructional approach, the ontological schema training method to help students develop appropriate schemas or conceptual frameworks for learning difficult science concepts.[3] Chi's studies are grounded in the assumption that students learn new concepts by assimilating or encoding new information into an existing schema or framework. This assimilation allows students to make inferences about and assign attributes to a new concept or phenomenon. Furthermore, an incorrect inference, based on an incomplete or incorrect schema, affects negatively students' understanding of a new and difficult concept by making common errors associated to the targeted concept[2]. In addition, social cultural characteristics factors of learners, such as race and ethnicity, language, social environments are believed to affect students' conceptual change and their approaches to construct meanings[4].

Based on Chi and her colleagues' work, three online training modules were designed to help engineering students develop appropriate schemas, which are needed to understand some key engineering concepts, such as heat transfer, diffusion, and microfluidics. To tests the efficacy of these learning modules, researchers tested and compared performances of two populations at different institutions: a public engineering institution in the Midwest (MPI) and a Hispanic engineering serving institution (HSI). Thus this paper presents results from a study whose objective was to compare the performance of two different populations on the effectiveness of the Schema Training Modules (STM) developed to assess conceptual understanding. The research question that guided this study was: **Are there differences in student conceptual understanding of concepts in thermal and transport sciences based on their cultural backgrounds?**

BACKGROUND

I. *Theoretical Framework – Ontological Schema Training Method*

Previous studies reported students' difficulty understanding concepts related to heat transfer, fluid mechanics, and thermodynamics. Furthermore, the presence of misconceptions has been identified, even after students have completed college-level courses in the domain subjects [1], [5],[6]. These misconceptions have been proven to be robust and resistant to traditional instruction because the correct understanding requires students to not only acknowledge the presence of the misconception, but also to "conceive" them differently [3]. Chi and her colleagues have proposed an innovative instructional approach to repair misconceptions among students. This approach is referred to as the ontological schema training methods (STM). STM focuses on helping students develop appropriate schemas or conceptual frameworks for learning difficult engineering concepts [3],[7]-[9].

Chi has identified Emergent Processes as those "properties of a system that result from its constituent

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elements interacting over time, often in conjunction with equilibration"[1]. Research has shown that Emergent Process misconceptions are particularly resistant to traditional instruction because they are made at the ontological level – where students ascribe a fundamental characteristic to the concept that is at odds with the scientifically normative view[1],[3]. In order to help students learn concepts of the Emerging Process ontology, instruction should first identify the ontology and provide them with some rich examples and properties of that ontology[3],[7],[9]. This would help students develop a "schema" or mental model for that ontology which would make subsequent examples easier to understand. Referred to as "schema training," this instructional methodology has been successful with both middle school students and undergraduate psychology students.[3],[7],[9] Previous work has identified difficult concepts in heat transfer, diffusion and electricity as emergent processes [5],[10].

II. Description of Ontological Schema Training Modules (STM) in Thermal Sciences

A group of researchers developed the STM following the work done by Chi and her colleagues. As shown in Figure 1, the experiment design uses both experimental and control groups of students matched for equivalent levels of engineering education.

Day	For Control Group	For Experimental Group	Expected Completion Time
Day 1	Nature of Science	Sequential and Emergent Processes: Part I	3 – 4 hours
	Demographic Survey		
	Heat Transfer Concepts Assessment (Pre Test)		
	Scientific World View Instruction	Processes Instruction	
	Diffusion Instruction *Not described as an emergent process*	Diffusion Instruction *Described as an emergent process*	
	Diffusion Concepts Assessment (Post Test only)		
Day 2	Sequential & Emergent Processes: Part II		2 hours
	Heat Transfer Instruction		
	Heat Transfer Concepts Assessment (Post Test)		
	Microfluidics Instruction		
	Microfluidics Concepts Assessment (Post Test only)		

FIGURE 1
SCHEMA TRAINING MODULES

Specifically the modules consist of a pre-test in heat transfer concepts, used as a further measure of the "equivalence" of the two groups' prior knowledge. The experimental group completed a training module describing the characteristics of two kinds of processes (sequential and emergent processes), which was intended to facilitate students' conceptual change. The training modules for the experimental group also describe why diffusion concepts are an emergent process. The control group completed an approximately equivalent module that describes the nature of science. Diffusion is described but no mention is made of emergent processes. Then, both groups completed the same instruction module on heat transfer principles. Later, post-test concept questions were answered by both groups. The post-test was followed by a far transfer experiment in microfluidics instruction and concept assessment. The far transfer experiment was designed in such way because the concept of microfluidics represents an ideal application of emergent process principles, which the participants were unfamiliar prior to the study. This paper discusses quantitative analyses performed on the shaded activities presented in Figure 1.

METHODS

Specifically, we conducted an experimental study with junior or senior engineering students at two universities, a Public Institution located in the Midwest (MPI) and a US Hispanic Serving Institution HIS. A description of the institutions and participants is presented in the following section.

I. Descriptions of participating populations

1. Midwestern Public Institution (MPI)

The selected MPI is a Land Grant institution founded in 1869 and enrolls over 40,000 students across campus. It has been identified as an institution with the largest international student population of any U.S. public university. The undergraduate enrollment for 2011 had a total of 30,776 with 57% male and 43% female. From these students 60% are state residents, 26% other U.S. states, 14% other countries and 13% minority domestic student population. From the total enrollment of undergraduate students approximately 20% are pursuing engineering degrees. Engineering programs at the MPI consist of a four-year curriculum with 12 engineering programs including Aeronautics and Astronautics, Agricultural and Biological, Biomedical, Chemical, Civil, Construction Engineering and Management, Electrical and Computer, Industrial, Materials, Mechanical and Nuclear. The undergraduate engineering program is positioned in ninth place among the national rankings.

In total 60 participants were selected for this study. They were typical college junior and senior students who majored either in mechanical, chemical, or material science engineering. Also, the majority of participants were male and their primary language was English, which is representative of the engineering population at the MPI.

2. Hispanic Serving Institution (HSI)

The College of Engineering (CoE) of the selected HSI is among the largest engineering institutions in the U.S., ranking fifteen in the nation in undergraduate enrollment, about 5000 students (approximately 98% are Hispanic), 67% males and 33% females.[11] Because of this, researchers have an excellent opportunity to impact both Hispanics and women, who are traditionally underrepresented populations in engineering. The HSI's engineering programs were initiated in 1913, two years after the campus was founded as a Land Grant Institution in 1911. As of today, there are six broad ABET-accredited undergraduate programs as well as strong graduate programs in Civil, Chemical, Computer, Electrical, Industrial, and Mechanical Engineering.

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Moreover, this institution has played a critical role in the training of future Hispanic scientists and engineers in the U.S. Some key national rankings as described by the ASEE Profiles of Engineering and Engineering Technology Colleges [12] published in June 2010 include:

- # 1 in Engineering Bachelor's degrees awarded to Hispanics (614)
- # 3 in Percentage of Bachelor's degrees awarded to women (39.6%)
- # 3 in Engineering Bachelor's degrees awarded to women (243)
- # 15 in Engineering Undergraduate Enrollment (4,981)
- # 26 in Engineering Bachelor's degrees awarded (614).

The sample size of this study consisted of forty-five students, from which 65% of them were male. These participants were primarily junior (26%) or senior (70%) students who majored either in chemical (35%) or mechanical engineering (63%). Refer to Figure 2.

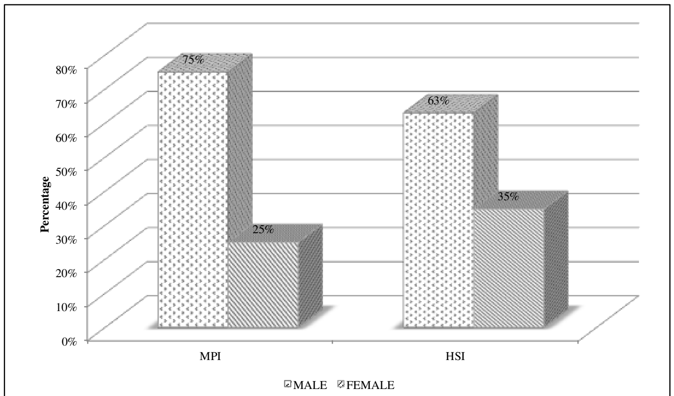

FIGURE 2
GENDER DISTRIBUTION

II. Participant Selection Process

Engineering students were invited to participate in the study via email. Participants had to have completed at least one of the following courses: thermodynamics, fluid dynamics, or heat transfer. At each institution, selected participants were assigned to either a control or experimental group according to their gender, major, grade point average (GPA), and total courses approved. The objective was to have a uniform distribution amongst both groups, control and experimental, within each institution.

Participants were recruited primarily from the chemical and mechanical engineering programs. Students were required to have approved at least one course in thermodynamics, heat transfer and/or fluid dynamics; being 18 years of age or older; being fluent in written English; and haven't previously participated in the study. They were invited by e-mail, which were provided by HSI's Office of Institutional Research and Planning. A description of selected participants is presented in Tables 1 and 2.

TABLE I
DESCRIPTION OF PARTICIPANTS FROM MPI

		MPI			
		Control		Experimental	
Gender	Male	27	82%	21	68%
	Female	6	18%	10	32%
Year	Sophomore	1	3%	1	3%
	Junior	13	39%	18	58%
	Senior	19	58%	12	39%
GPA	4.00 - 3.50	13	39%	7	23%
	3.49 - 3.00	7	21%	14	45%
	2.99 - 2.50	11	33%	9	29%
	Other	2	6%	1	3%
Major	Chemical	4	12%	5	16%
	Mechanical	17	52%	13	42%
	Other	12	36%	13	42%
Courses	Thermodynamics	31	94%	31	100%
	Fluid Dynamics	15	45%	11	35%
	Heat Transfer	6	18%	4	13%

TABLE II
DESCRIPTION OF PARTICIPANTS FROM HSI

		HSI			
		Control		Experimental	
Gender	Male	14	45%	15	65%
	Female	9	29%	7	30%
Year	Sophomore	0	0%	1	4%
	Junior	8	26%	4	17%
	Senior	15	48%	17	74%
GPA	4.00 - 3.50	7	23%	5	22%
	3.49 - 3.00	11	35%	9	39%
	2.99 - 2.50	5	16%	8	35%
	Other	0	0%	0	0%
Major	Chemical	9	29%	7	30%
	Mechanical	14	45%	15	65%
	Other	0	0%	0	0%
Courses	Thermodynamics	31	100%	23	74%
	Fluid Dynamics	11	35%	22	71%
	Heat Transfer	4	13%	17	55%

Specifically, the percentage of women participating in the study was higher for the HSI than for the MPI. This tendency was expected since the number of women enrolled

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in engineering is higher for the HSI. Also, the HSI had more participation from senior students as compared with the MPI that had more junior students. An exception occurred for the experimental group at the MPI that had more senior than juniors. In terms of GPA, the majority of the students had a GPA of 3.0 to 3.49, except for the control group at the MPI that had more students at the highest range (3.5 to 4.0 GPA). At both institutions, the majority of the students belonged to the Mechanical Engineering department. Finally, students from the HSI had more courses approved from the thermal and transport sciences (either thermo, fluids mechanics, or heat transfer). A summary of the course distribution is depicted on Figure 3, which shows a bigger variability for the samples at the MPI within each of the groups (control or experimental).

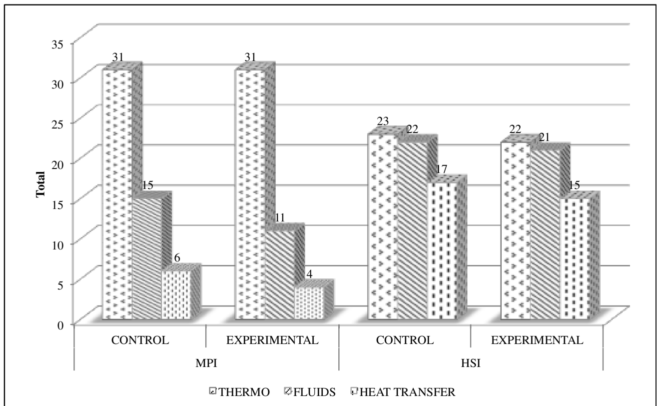

FIGURE 3
COURSES APPROVED

In summary, there are similarities and differences among these populations (HSI vs. MPI). Some of the similarities are as follows. First, participants were primarily from mechanical or chemical engineering. Second, both group were traditional engineering students in terms of age. Finally, participants have taken one, two or three courses in thermal sciences. The main differences include: (1) different ethnicity (Hispanic vs. non-Hispanic participants), (2) primary language differences (Spanish vs. English), (3) type of institution (undergraduate education vs. research intensive institutions), (4) program duration (5-yr vs. 4-yr academic programs).

III. Data Collection Process

Once participants were selected, at each institution, and randomly assigned to either the control or experimental group. They were given a user name and password to access and complete the learning modules available on-line through Blackboard. During the first day, participants completed the activities corresponding to Part 1, which required 3 to 4 hours to complete. The following day, they completed activities corresponding to Part 2. These activities required approximately 2 hours of time to complete. Participants were asked to take their time while completing the modules and researchers were asked to identify those who took less time and expected. Participants' confidentiality was protected according to IRB requirements. Participation was voluntary and they received a compensation of $60 after they completed the modules.

DATA ANALYSIS AND RESULTS

Quantitative comparisons for HSI and MPI participants were conducted on the pre- and post-test of heat transfer and post tests on diffusion and microfluidics. The shaded sections of Figure 1 represent the activities that were analyzed quantitatively, Table 3 depicts the mean gain for the experimental and control groups and Table 4 depicts the summary of the p-values that resulted from comparing significant differences between pre-test and post-test. Firstly, in terms of the mean gain for the experimental and control groups for both student populations (MPI and HSI), results show a significant average gain for the experimental group at the HSI as shown on Table 3.

TABLE III
MEAN GAIN

	Group	Count	Average Gain	Std. Dev.
MPI	Control	33	0.030	0.133
	Experimental	31	0.029	0.132
HSI	Control	20	0.050	0.139
	Experimental	20	0.105	0.101

Secondly, the p-value obtained for MPI 's control group was equal to 0.500 (greater than 0.05), meaning that the difference between the average results of the pre-test and the average results of the post-test is not significant. Similar results were obtained for the MPI's experimental group (p-value = 0.510) and the HSI's control group (The p-value = 0.172). On the contrary, the p-value obtained for the HSI's experimental group was equal to *0.006*, which means that the difference between the average results of the pre-test and the average results of the post-test is significant.

Thirdly, a two-way ANOVA was conducted to examine if either the group differences (control or experimental) or the test differences (pre- and post- Heat Transfer tests) had any significant influence over participants' results. The two-way ANOVA Test for the MPI population produced p-values of 0.128 and 0.467 for the group and test, respectively. This shows that neither the group (control or experimental) nor the test (pre and post) had significant influence on students' performance. For the HSI population results indicated that the group difference did not have an influence on students' results (p-value = 0.068), but on the contrary, the pre- and post-tests indicated an impact on participants' results (p-value = *0.021*). Some students were eliminated from the ANOVA analysis because their post-test was incomplete.

Finally, a two-sample t-test was performed to determine if there is significant difference on students' performance on Diffusion, Microfluidics, and Heat Transfer items. Table 4 shows all the p-values obtained for both group of

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participants (MPI and HSI) for the two-sample t-test. Results indicated a significant difference between average group results (control and experimental) for MPI and HSI for Diffusion items. In Microfluidics items, results from MPI participants showed significant difference between average group results. No significant difference was obtained for Heat Transfer items.

TABLE IV
SUMMARY OF P-VALUE RESULTS FOR T-TESTS

	Two Sample T-test		
	p-value Diffusion	**p-value Microfluidics**	**p-value Heat Transfer**
MPI	*0.044 (Y)*	*0.018 (Y)*	0.976 (N)
HSI	*0.044 (Y)*	0.305 (N)	0.0160 (N)

DISCUSSION AND CONCLUSION

This paper discusses the effectiveness of the STM among populations from two different institutions (MPI and HSI). The outcomes of this study provided some evidence about the variability of performance of the different populations on the STM. Results indicated a greater effectiveness of the STM among the Hispanic population as evidenced from the average gains depicted in Table 3. But as shown in Table 4, in general, participants from the MPI performed better having significant differences in their post-test performance in the Diffusion and Microfluidics concepts. We have previously suggested that one potential explanation of the low effectiveness of the STM on student learning could be that robust misconceptions are resistant to be repaired through traditional teaching methods. For the case of HSI students an additional factor to consider could be the fact that the learning resources were not in their mother tongue—i.e., Spanish.

The main contribution of this study was the comparison of performance on STM with different populations. STM has been designed to help repair robust misconceptions, which are resistant to repair by traditional teaching methods. Further qualitative analyses of students' verbalization of their reasoning are being conducted to determine the role of language in students' conceptual change.

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