AC 2012-3635: THE DEVELOPMENT OF A SPANISH VERSION OF THE CONCEPT ASSESSMENT TOOLS FOR STATICS

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The Development of a Spanish Version of the Statics Concept Inventory (CATS)

Introduction

Concept inventories (CIs) are criterion-referenced tests designed to evaluate whether a student has an accurate working knowledge of a specific set of concepts.[1] Typically, CIs are organized in a multiple-choice format that addresses a single idea in order to ensure that they are scored in a reproducible manner. The purpose of CIs includes ascertaining (a) the range of what individuals think a particular question is asking and (b) the most common responses and misconceptions to the questions. In its final form, each question includes one correct answer and several distractors.[2]

The impact of CIs in STEM education occurred after the development of the Force Concept Inventory (FCI), a multiple-choice test designed to assess students' Newtonian conceptions of force. Studies with the FCI showed discrepancies between students' performance on physics courses (grades) and their performance on the FCI.[3] Since then, various Engineering Concept Inventories (ECIs) have been developed as a tool to identify common misconceptions on specific engineering domains.[4] For the last 30 years, approximately 21 ECIs have been developed in dynamics, electronics, fluid mechanics, heat transfer, and statics, among others. Unfortunately, ECIs have been developed at institutions were student from underrepresented populations, such as Hispanic, are not considered mainly because there is no access to them. Therefore, there is a need to measure the efficacy of ECIs among underrepresented populations to determine its validity and reliability. Traditionally, underrepresented populations score below nations' average on these instruments.[5, 6]

To address this concern, in 2010 the National Science Foundation (NSF) funded a project whose primary objective is to test the efficacy of the Concept Assessment Tool for Statics (CATS) among bilingual engineering students from the University of Puerto Rico at Mayagüez (UPRM) (EEC-1032563). This study is composed of a 3-phase mixed method design, in which each phase is guided by a specific objective and research question. Also, for this study we have defined a bilingual student as one who is taught both in English and/or Spanish, but Spanish is their primary language. Furthermore, CATS was designed by Dr. Paul Steif to detect errors associated with important and difficult statics concepts. The questions in CATS were developed primarily through the experience of the designer and two Statics professors at different universities and according to 9 difficult concepts.[4] Four distractors were created for each question based on students' written responses to open-ended questions.

This paper discusses activities and findings from the first phase of the study, whose objective was the creation of a Spanish version of CATS, referred to as CATS-S. The research question that guided this phase was as follows: **What is the effectiveness of CATS among bilingual students?** Consequently, the second phase of the study will allow the researchers to determine if Hispanic students exhibit the same misconceptions in Statics, when compared with those identified in CATS. Results of this study will allow CATS-S to be disseminated among Spanish-speaking engineering universities and to students from Hispanic Service Institutions (HSI) in the US. Finally, this paper is intended to inform static professors from HSI about the development of the CATS-S for future use in their courses.

Background Information

The use of English as an international language of science is well documented; depending on one's orientation, English may be seen as a neutral *lingua franca* or it may be seen more insidiously as a dominating and overpowering force.[7] In the last two decades, many ECIs have been developed. Studies have shown a low performance among non-English speakers.[5, 6]

In the literature of CI development, a project was identified to study language implications and students' performance on the FCI.[8] Similar to most ECIs, items of the FCI were originally designed in English by David Hestenes and colleagues[9] to probe students' understanding of Newtonian mechanics, specifically the central concept of force. For the identified study, an Arab version of the FCI was developed and administrated to students at an Arabic petroleum institute (experimental group).[8] Students' responses were compared with those from students at a petroleum-engineering program in a US private institution (control group) to determine if language was a factor that influenced students' performance.[8] Results revealed that some of the factors that can influence students' performance are the cultural biases of the assessment. For instance, many students were familiarized with certain connotations because of the way they were taught and when the interaction with the scientific language was suddenly changed, it was difficult for students to recognize and detect what the question wanted them to reflect on. Also, another difficulty encountered was directly related to the translation of the FCI. Specifically, the words used in the CI are not translated in the best connotation, since Arabic words are compound, i.e. one word can have more than one meaning. These findings were incorporated into our study's research design, which is explained in the following section.

Research Design

Statics is a pivotal course for engineering students especially in the areas of civil and mechanical engineering. Previous work demonstrated the presence of naive conceptions (misconceptions) on statics concepts among mechanical and civil senior engineering students.[10, 11] CATS has been designed to detect errors associated with incorrect concepts necessary for Statics. The development of CATS began with the identification of central Statics concepts based on an analysis of various engineering curriculums, and Statics textbooks, but also from experienced faculty. These concepts were categorized into four main clusters, also referred to as the conceptual framework of Statics: (1) forces are always equal and opposite pairs acting between bodies, which are usually in contact, (2) two combinations of forces and couples are statically equivalent to one another if they have the same net force and moment, (3) the possibilities of forces between bodies that are connected to, or contact, one another can be reduced by virtue of the bodies themselves, the geometry of the connection and/or assumptions on friction, and (4) equilibrium conditions always pertain to the external force acting directly on a chosen body, and a body is in equilibrium if the summation of forces on it is zero and the summation of moments on it is zero.[12]

Also, CATS items have the intention of detecting errors reflecting on incorrect concepts (misconceptions), instead of errors in mathematical analysis. Because of this, most questions don't involve mathematical computations. For those questions that require mathematical computations, Dr. Steif argues the computations are very simple, and therefore it is assumed that choosing the wrong answer relates directly to having a misconception of a concept instead of a mathematical computation error. On the latest version of CATS, there are three questions (items) for each of the nine concepts tested on the instrument.[13] These concepts are: (A) drawing forces on separate bodies, (B) Newton's 3rd Law, (C) static equivalence, (D) roller joint, (E) pin-in-slot joint, (F) load at surfaces with negligible friction, (G) representing loads at connections, (H) limits on friction force, and (I) equilibrium. Refer to Steif and Hansen[13] for a complete description of these concepts.

This study consists of a two-phase mixed-method design where each phase is guided by a specific objective. The objective of Phase 1 was to test the effectiveness of the Spanish version of CATS (CATS-S), while for Phase 2 the objective was to identify statics misconceptions among Hispanic engineering students. The first phase is divided into three rounds: (1) translate CATS into Spanish, (2) pilot test the Spanish version with Hispanic students for clarity, and (3) compare Hispanic students' performance on both versions of CATS (English and Spanish). Table 1 presents a detailed description of this phase.

Table 1. Description of Phase 1.

Round	Description	Participants	Outcomes	Status
1	Spanish translation of CATS	4 Hispanic engineering professors	CATS-S v1	Completed
2	Pilot Test	10 graduate students from Civil Engineering	CATS-S v2	Completed
3	Compare students' performance	70-100 undergraduate students from Civil or Mechanical Engineering	CATS-S v3	In progress

Participants. A total of 4 Hispanic engineering professors and 10 graduate students from Civil Engineering were recruited through e-mail invitation and/or written promotions (fliers on bulletin boards). The PI and research assistants followed confidentiality guidelines to conduct research with human subjects as established on the approved IRB protocol. Students' participation was voluntary and they received compensation. Participants' demographics are presented in the table below.

Table 2. Participants' demographics.

Round	Participants	Females	Males	Country of Origin
1	4 Hispanic engineering professors	1 (25%)	3 (75%)	PR and Colombia
2	10 graduate students from Civil Engineering	3 (30%)	7 (70%)	PR, Colombia, Guatemala, and Dominican Republic

Methodology. Specific activities designed for Phase 1 included: (1) identify experts to translate CATS items into Spanish, (2) generate first version of CATS in Spanish, denoted as CATS-S V1, (3) pilot study the first version among graduate civil engineering students who completed their engineering BA degree at a HSI and determine the clarity of the translated items and evaluate/revise research protocols, (4) revise items according to students recommendations and generate a second version (CATS-S V2), (5) conduct a large-scale data collection, and (6) compare students' performance on the English and Spanish versions of CATS. In this phase, experienced faculty at UPRM acted as consultants to translate each question, paying attention to the wording used, not to change the intended objective.

Also, a pilot study was conducted to evaluate if the translation of CATS was appropriate. A group of 10 graduate students from Civil Engineering was identified to take the CATS-S v1. Each participant worked on the instrument independently. A short survey that consisted of a combination of both close-ended and open-ended questions was administered to participants. The survey allowed researchers to determine if participants had difficulties with the instrument (translation) or with the established protocol. Questions that were identified as difficult to understand were evaluated and corrected, which resulted in the creation of CATS-S v2.

Remaining activities of this phase include replicating the protocol of the pilot study with two different groups of participants: a control group and an experimental group. Participants will be recruited from current students enrolled in the Mechanics courses offered at UPRM. Current enrollment is about 200 students, from which we anticipate a participation of at least 70 students that will be randomly assigned to either the control (English version) or the experimental group (Spanish version). Responses will be statistically analyzed to determine if there are significant differences between both groups of participants.

Analysis and Results

Graduate students' responses, from the CATS-S v1, were tabulated for each question and then statistically analyzed, refer to Table 3. Although the main objective was not to demonstrate differences by gender, results were presented by gender mainly because women represent about 30% of the total enrollment of UPRM's Civil Engineering Department. Overall, the percentage of correct answers obtained was about 48%, the lowest score per item was 20% and the highest was 80%. This is consistent with nations' average scores.[14] Finally, the percentage of correct answers obtained by women and men was about 38% and 52% respectively.

Table 3. Percentage of correct answers

Item	% Correct Answers			Item	% Correct Answers			Item	% Correct Answers		
	Total	Fem.	Males		Total	Fem.	Males		Total	Fem.	Males
1	40	33	43	10	80	100	71	19	50	33	57
2	50	67	43	11	80	67	86	20	80	67	86
3	60	67	57	12	60	33	71	21	80	100	71
4	10	0	14	13	40	0	57	22	30	0	43
5	30	0	43	14	70	67	71	23	30	33	29
6	20	0	29	15	50	0	71	24	20	0	29
7	50	67	43	16	20	33	14	25	50	0	71
8	50	67	43	17	30	33	29	26	60	33	71
9	50	67	43	18	40	33	43	27	70	33	86
								Total	**48**	**38**	**52**

In addition, results were presented in terms of concepts. Figure 1 provides a graphical representation of comparison between the scores obtained by males and females. In general, the lowest score was obtained in the items addressing Newton's third law, followed by loads at surfaces with negligible friction and limits on friction force (concepts B, F and H). These results compare with findings from previous studies conducted with English-speaking students.[10, 11, 15]

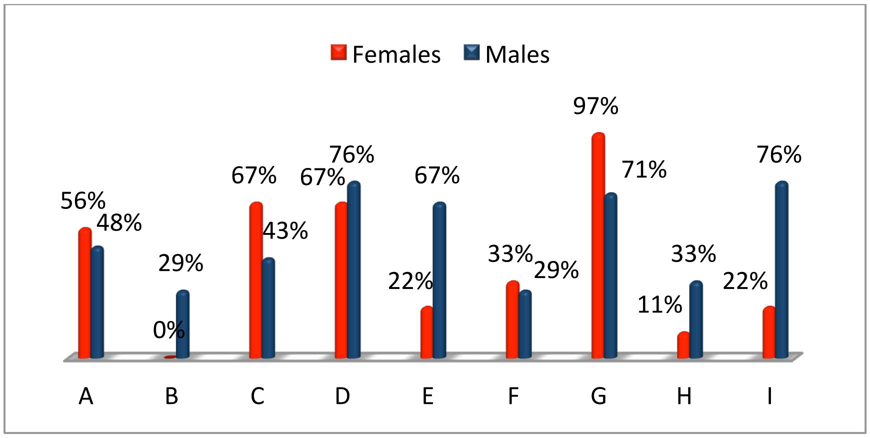

Figure 1. Percentage of Correct Answers per Concept and per gender

Conclusion and Implications

Language is very important in every aspect, without it is impossible to communicate with the people that surround us. But sometimes when an individual faces a different surrounding, out of their comfort zone, it can be difficult to adapt and get the rhythm of both language and culture. This situation can cause a negative effect, especially in the professional and educational formation of individuals. Because of this, one of the purposes of this study was to design CATS-S as a diagnostic tool for students whose maternal language is Spanish.

Future activities of this study will require other HSI in the US to utilize CATS-S for assessment purposes and therefore determine similarities or differences in students' performance. This will allow researchers to test CATS-S for validity and reliability. Also, preliminary results of the activities completed from the second phase indicated the presence of misconceptions that are not considered as distractors in the English version of CATS. Further studies need to be conducted with a diverse population of bilingual students to validate such findings.

Additionally, professors and instructors at HSI could benefit from the use of CATS-S because they will be able to target their instruction. Specifically, they could identify which concepts students have more difficulty with, and therefore they will be able to reinforce them with the appropriate instruction, by allocating more time to those concepts that are expected to be more problematic. This could be achieved mainly because the literature of CIs indicates that these instruments provide evidence on how well students retain and understand the material from previous courses. Specifically CATS has been designed to detect conceptual errors (misconceptions) associated with incorrect statics concepts necessary in the learning process.[4, 14, 16-18] The goal is to identify those misconceptions and correct them for future courses. Finally, another important objective of this study is to recruit more students from HSI and collect more data to validate our findings and test CATS-S for validity and reliability.

Preliminary results of this study were compared with those from the previous identified study were the FCI was translated to Arabic. Mainly the researchers have identified the following. First, the goal of both research studies was to translate a concept inventory into a specific language (in this case Arabic or Spanish), test its efficacy, and finally verify the knowledge of a representative sample of students in fundamental concepts on a specific content area. Both research design studies were similar in terms of comparing a control group (English version) and an experimental group (either Arabic or Spanish). In both cases the instruments did not required complex calculations because the goal was to see how much the student knew about a specific concept. Finally, both instruments are typically used as a diagnostic tool or as a placement test. The primary difference between the studies was that the Arabic study compared students' performance from different institutions, while the Spanish study compared students within the same institution since the population was bilingual. Another difference relates to the participants, in our study students were required to have approved the course of statics, while the Arabic allowed students to take the test even if they were taking the class at the moment of the study.

In summary, the benefits of this study have been the development of a beta version of CATS-S, which is ready to be used. Preliminary analysis of the pilot study revealed a low performance of graduate students on CATS-S. The concepts in which they obtained the lowest scores were: Newton's third law, followed by loads at surfaces with negligible friction, and limits on friction force. This could be as a result of the presence of misconceptions. To validate this, interviews are being analyzed to identify the cause of this behavior. Finally, deliverables of this study are CATS-S is ready for implementation at UPRM in the Spring of 2012.

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