

Motivation of Engineering Students Participating in Multinational Design Projects

Comparison Based on Gender and Class Status

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Abstract—There have been different active-learning initiatives introduced in academia to provide engineering students with the necessary knowledge, skills and attitude to be competitive in the global market. These initiatives have been in response to the need in the corporate world for engineers with exposure to global collaborative environments. Consequently, multinational collaborative design projects have been used by the authors as means of introducing professional global skills to engineering students while exposing them to a project-based learning experience. This educational activity is expected to motivate students so that they can start developing the professional skills that will help them to overcome difficulties and to carry out the project successfully. However, this activity faces many challenges including, among others, cultural and academic background differences, language and time zone barriers, and issues with communication tools. Therefore, this work compares the motivation of students before and after their participation in a multinational design project, using gender and class standing as differentiating parameters. To accomplish this objective, the Intrinsic Motivation Inventory (IMI) was adapted to the implemented multinational collaborative experience and administered to the participating students. Three motivation constructs are taken into consideration: (a) interest/ enjoyment, (b) perception of choice, and (c) perceived competence. Results are discussed based on the research questions posed for this comparative work, and result reflections are presented.

Keywords—student motivation; multinational project; gender differences; international collaboration; class status

1 Introduction

Globalization has changed not only the way companies conduct business, but also how they design, build and sell their products, therefore, companies are utilizing a larger pool of capable and experienced professionals worldwide, partially due to ad-

vancements in ICT (Information and Communication Technologies), and are integrating their skills and knowledge through the conformation of multinational interdisciplinary collaborative teams. Technical and professional skills learning has to evolve to follow current requirements as the industrial world changes and the challenge is always to anticipate the needs and to train students with the required skills to be successful in the global workforce. Engineering students need to be prepared to work in interdisciplinary multinational collaborative environments with all its benefits and challenges. As a result, many universities have been motivated to implement pedagogical activities and programs that help students to learn about those benefits and challenges, as well as how to deal with them and how to work and succeed in those multinational collaborative environments [1]-[3]. Universities around the world are adopting active learning techniques that engage students so their motivation and the depth of their learning is increased while being trained in the required skills [5] and there are educational experiences driven by supranational governments such as Erasmusplus [6] and NSE [7], or by alliances with other institutions like Alliance4Tech [8] and IDEA League [9] that help to develop global competences and foster active learning. One of those experiences is the one presented in this report, with the participation of several institutions from the Americas and Italy, and the aim to promote global collaboration in engineering students, thus developing related professional and interpersonal skills, and increasing motivation towards the subject being studied [10].

The emphasis on motivation of engineering students has come as a strategy to increase the recruitment and retention of college students on majors leading to STEM (Science, Technology, Engineering and Mathematics) professions, where the gap between supply and demand is large in both the U.S. and the rest of the world [11]. It is also interesting to note that STEM programs present a gender disparity which worldwide educators and scholars are concerned about [12]-[14]. While many occupations historically dominated by men have achieved a major gain in gender equality, STEM jobs remain highly unbalanced in this terms, which means that women are more likely to choose degree programs in a variety of fields rather than engineering and computer science despite their talents and abilities [12], [15]. A question continuously investigated by educators and researchers in recent years is why female students are so underrepresented in STEM fields [16]-[21]. Statistics show that in 2009, only 23% of STEM workers were women [11], and those numbers continue being similar across different countries. There is evidence suggesting that women's access to technology is impacted by the general perception that technology is a men dominated area [22]. This means that engineering and technology lack appeal to girls and young women. Therefore, attracting female students into engineering and their retention has proven to be a difficult task due mainly to gender biases and stereotypes formed by media, family and friends, as well as the lack of access to suitable mentors and role models [23], [24]. Due to the continued underrepresentation of women [25] and the need to insure their effective retention in STEM fields, there are different activities and research efforts focused on gender. It is expected that their participation in learning activities such as the multinational design project discussed in this article might help to increase female students' motivation towards engineering.

The authors have introduced multinational collaborative projects in engineering design courses not only to expose students to the needed global competences, but also to offer them an active learning experience that helps to engage them in their learning process and to increase their motivation towards the subject being studied [26]. This paper presents comparative results of an evaluation to determine the level of motivation of students participating in an engineering multinational collaborative design project based on their gender and the class standing.

The evaluation was done with the results from a survey administered twice to more than 200 students in 6 different countries, the first time before students started to work on the project and the second one after they have finished working on it. Results indicate that before the collaborative project started female engineering students had a greater motivation towards the learning activity than their male counterparts did, with both highly motivated. However, after they finished working in the project, there were not significant differences due to gender in the level of motivation experienced by the students, which in both cases was lower than before.

2 Objectives

There is a direct positive connection between students' motivation and learning mainly because it increases their cognitive, emotional and behavioral involvement [27] and their persistence despite the difficulty of the task [28]. The role of educators is not only to deliver knowledge, but rather to facilitate the students' learning process, something that requires the students' motivation and active involvement [5]. Motivation is expected to help students to work successfully in the project and overcome typical difficulties such as language, time zones and cultural barriers, poor or broken communication, and different level of commitments in the participants. A previous work by the authors showed that students were highly motivated on the prospect of participating in a real-world learning activity that involved collaboration with other students from around the world [29]. Therefore, the objective of this study is to find out if the actual participation in the multinational design project maintained the same level of motivation for the participant students, and how such motivation varies by gender and class status. The following research questions are presented:

1. Are there any significant differences in the motivation reported by students before and after participating in the multinational project based on their gender?

$$H_0: \mu_{Construct (Gender - PRE)} = \mu_{Construct (Gender - POST)}$$

2. Are there any significant differences in the motivation reported by students before and after participating in the multinational project based on their class standing?

$$H_0: \mu_{Construct (Class# - PRE)} = \mu_{Construct (Class# - POST)}$$

3 Methodology

This study utilizes the concepts from the Intrinsic Motivation Inventory (IMI), which is based on the Self-Determination Theory (SDT) and provides a framework for studying motivation based on competence, autonomy, and relatedness [30], [31]. There are six constructs that are measured with the complete multidimensional IMI tool: interest/enjoyment, perceived competence, effort, value/usefulness, pressure/tension, and perceived choice. The survey used in this study consists of only 27 statements and uses a 7-point Likert scale that ranged from 1 (“not at all true”) to 7 (“very true”). Those 27 statements corresponded to five constructs: interest/enjoyment (7 items), perceived competence (5 items), value/usefulness (5 items), pressure/tension (5 items), and perceived choice (5 items). Although the whole instrument is called IMI, only the interest/enjoyment subscale is considered a self-report measure of intrinsic motivation. This subscale is calculated, in this case, by adding the measured values to questions 1, 6, 9, 12, 17R, 21, and 24, where 17R has a reversed value (i.e., it is calculated by subtracting the measured value from 8). Therefore, motivation of students is measured using the scores obtained from the interest/enjoyment subscale of the survey. Additionally, since perceived choice and perceived competences are both theorized as positive predictors of intrinsic motivation (the first as a self-report and the later as a behavioral measure) both scales are also used in the analysis to validate the results. The perceived choice subscale is calculated with questions 4, 8, 15, 20, 26 and perceived competence with questions 3, 13R, 18, 23R and 25R [32].

The multinational design projects considered in this study started in 2005 as a collaborative initiative of two institutions in Latin America and one institution from the U.S. [33]. Since then, the collaborative network has grown and expanded beyond the Americas including an institution from Italy. The multinational design projects follow a parallel design model where teams in different nations work on the same design project and students are required to exchange ideas and information to improve their final designs. Students form teams at each institution, with each team having an average of five students. In order to formalize the collaboration, clusters of teams from different institutions and countries are created so teams from each institution have international partners. The aim is to foster sharing of technical information during the pre-defined exchange sessions, and to learn to deal with the cultural differences, time zone, language and communication barriers typical of this type of endeavors. The projects take up to eight weeks depending on each institution but the mandatory collaborative period last five to six weeks. During this time, teams are required to interact with their international partners in their respective clusters using formal communication tools such as email and Adobe Connect for audio-video conferences, and informal tools such as social media or any other means students consider appropriate to maintain a level of interaction adequate for the project.

The generic hypotheses formulated to test the research questions state that there is no difference between the means of the two samples (null hypothesis) when participants from each survey, and each construct, report their levels. An independent-sample *t*-test was performed for each construct in order to test the hypothesis, as well as a homogeneity of variances test (Levene) for each dataset, specifying a 0.05 signif-

ificance level, due to the fact that the number of valid surveys is different in each category. To assure the reliability of the survey results an internal consistency analysis (Cronbach’s alpha) was performed in each subscale used.

4 Results

A total of 218 students participated in the multinational collaborative design projects during the Fall 2015 semester, and all of them were asked to go online and do the survey the week before the initial AV session, and the week(s) after they ended their cluster collaboration. There were 164 valid responses to the first request (before starting the project, Pre-) and 84 valid responses to the second request (after ending the project, Post-), which represents a 75% and 39% response rate, respectively. The change in the number of students taking the survey before and after their participation might be due to either the timing of the administration of the survey (i.e., at the end of the respective academic cycle), or a low perception of the value of the survey by a number of students. The instrument was considered reliable, as Cronbach’s α -value of each subscale was superior to the accepted minimum value of 0.6.

4.1 Comparison Based on Gender

The gender distribution of both surveys, as expected in engineering courses, shows that the majority of the students were male (87.2% in Pre, 83.3% in Post) (Figure 1). It is observed that while 66.7% of female students responded the survey after finishing the project, only 48.9% of male students did. This difference could be an indicator that female students give more value to this academic activity than men, or just that they are more responsible.

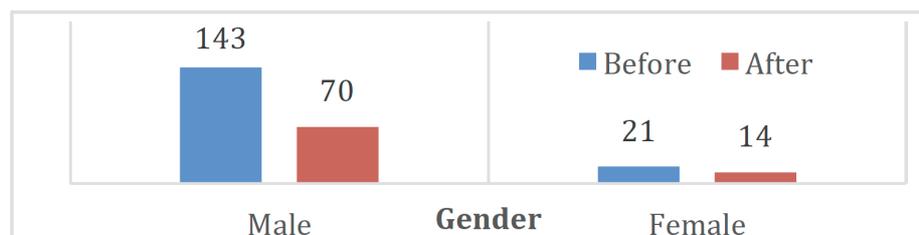


Fig. 1. Distribution of valid Pre and Post survey participants based on Gender

To address the first research question of this study, the perception of students before entering into the multinational collaborative design project is summarized in Table 1. It can be noticed that the level of motivation (i.e., interest/enjoyment subscale) of the students before starting the project is high, with percentage scores of 76% for males and 83% for females (a score of 49 is 100%), with the motivation of female students being higher than the motivation of male students. However, even when it is a statistically significant difference (p -value of 0.048), it is by a small mar-

gin which is confirmed by the fact that the other two constructs, perceived choice (a score of 21 is 100%) and perceived competence (a score of 35 is 100%), show no significant difference in their means. Based on this information it can be stated that all students felt positive regarding their motivation and abilities (i.e., competence) for having a successful participation in the project. Responses by female students showed less variability in their motivation, making it significant different and indicating that the level of motivation towards this type of learning activity is higher and more consistent than the one by male students.

The intrinsic motivation reported by students after (Post-) their participation in the multinational collaborative design project is summarized in Table 2. It can be seen that in both gender cases the motivation is higher than 55% of the highest score possible, so it can be said that students still indicate a positive motivation. However, it is evident that this motivation is lower than it was before they began the project. Additionally, there are not significant differences in the opinions of male and female students regarding their motivation, perceived choice, and perceived competence (all *p*-values > 0.05). It is of interest that the lowest percentage values were related to perceived choice, indicating that several students felt obligated to participate in certain tasks that they perceived as not motivating activities. It is also of interest that although the average level of intrinsic motivation of students is similar despite their gender, in this case female students' responses show more variability, with similar trend for perceived choice and competence constructs, contrary to what happened in the pre-survey.

Comparative results to directly answer the first research question, i.e., differences based on gender are summarized in Table 3. It can be stated that there was a drop in all three constructs (i.e., intrinsic motivation, choice, competence) for male and female students, with all three of the differences being significant (*p* < 0.05 for *t*-test)

TABLE 1. Results from Pre-survey of students - Gender

Gen	Construct	a	n	Mean	SD	%	<i>p</i> -val
M	Intrinsic Motivation	0.92	143	37.09	8.34	76%	0.048
F			21	40.47	6.81	83%	
M	Perceived Choice	0.69	143	12.66	4.39	60%	0.906
F			21	12.80	5.10	61%	
M	Perceived Competence	0.82	143	25.62	4.73	73%	0.154
F			21	27.33	5.02	78%	

Table 2. Results from Post-survey of students - Gender

Gen	Construct	a	n	Mean	SD	%	<i>p</i> -val
M	Intrinsic Motivation	0.94	70	28.98	9.65	59%	0.778
F			14	28.00	12.05	57%	
M	Perceived Choice	0.76	70	11.17	4.77	53%	0.344
F			14	9.78	4.91	47%	
M	Perceived Competence	0.83	70	23.14	5.09	66%	0.674
F			14	24.00	7.16	69%	

Table 3. Comparison of Pre- and Post-survey results - Gender

Survey		Item	n	Mean	p-val
Male Students	Pre	Intrinsic Motivation	143	37.09	0.000
	Post		70	28.98	
	Pre	Perceived Choice	143	12.66	0.029
	Post		70	11.17	
	Pre	Perceived Competence	143	25.62	0.000
	Post		70	23.14	
Female Students	Pre	Intrinsic Motivation	21	40.47	0.003
	Post		14	28.00	
	Pre	Perceived Choice	21	12.80	0.090
	Post		14	9.78	
	Pre	Perceived Competence	21	27.33	0.146
	Post		14	24.00	

for the male students, and only the one for intrinsic motivation for the female students. Table 3 shows that in the case of the perceived choice and perceived competence constructs, comparison based on gender indicate that female students did not have significant differences in the means ($p > 0.05$), and male students did. This means that female students' perception of choice and competence did not diminish significantly, as male perception did. It is also evident the large dispersion in responses, particularly for the interest construct, meaning that the level of agreement among students was low.

4.2 Comparison Based on Class Standing

The survey allowed for five different class standings, from first-year to fifth-year, with the distribution of valid surveys given in Table 4. It can be observed an acceptable level of participants in the Pre-survey, with small number for second and fifth or higher year. The results for each one of the constructs are summarized in Tables 5, 6 and 7.

For the intrinsic motivation (Table 5) there is no significant difference between the level of interest between Pre- and Post- data, with some of what can be considered considerable differences when comparing the mean values, but at the same time the corresponding values of standard deviation are large magnitudes. Therefore, in terms of class standing, the intrinsic motivation declines in magnitude from before to after participation by the students, but it is not a statistically significant reduction.

In terms of perceived choice (Table 6), as well there is no significant difference between the Pre- and Post- data, which is as well reflected in all class standings, except the fourth year which has the largest reduction in score. In general, there is drop in the score (i.e., 12.68 vs 12.07), which occurs for all class standings but first year participants (i.e., 12.74 vs 13.29). Variability of the data is smaller in the Post- survey, with all standard deviations having lower magnitudes, besides the one for fifth year. Therefore, the null hypothesis of equal means is accepted, with exception of the senior class (i.e., fourth year) indicating that they felt constrained in their project activities.

Table 4. Distribution of participants based on Class Standing

Class Standing	Number (PRE)	Number (POST)
First Year	46 (28.0%)	38 (45.2%)
Second Year	44 (26.8%)	8 (9.5%)
Third Year	18 (11.0%)	14 (16.7%)
Fourth Year	35 (21.3%)	22 (26.2%)
Fifth Year or higher	21 (12.8%)	2 (2.4%)
Total	164	84

Table 5. Results of Intrinsic Motivation versus Class Standing

Class	Time	Average Score	Standard Deviation	<i>p</i> (%)	Decision ($\alpha=0.05$)
All	Pre	29.72	4.42	0.329	Accept
	Post	28.80	10.0		
1	Pre	39.04	9.29	0.885	Accept
	Post	31.00	10.49		
2	Pre	38.45	7.30	0.443	Accept
	Post	31.50	7.58		
3	Pre	36.22	7.83	0.900	Accept
	Post	29.36	8.76		
4	Pre	36.74	7.65	0.051	Accept
	Post	24.45	9.84		
5+	Pre	34.67	8.49	0.107	Accept
	Post	21.00	7.07		

Table 6. Results of Perceived Choice versus Class Standing

Class	Time	Average Score	Standard Deviation	<i>p</i> (%)	Decision ($\alpha=0.05$)
All	Pre	12.68	4.48	0.237	Accept
	Post	12.07	3.47		
1	Pre	12.74	5.32	0.580	Accept
	Post	13.29	3.73		
2	Pre	12.41	4.84	0.719	Accept
	Post	12.13	1.13		
3	Pre	13.39	4.39	0.308	Accept
	Post	12.14	2.25		
4	Pre	13.51	3.82	0.001	Reject
	Post	10.00	3.28		
5+	Pre	11.14	3.30	0.978	Accept
	Post	11.00	5.66		

Regarding perception of competence (Table 7), it can be said that in general the scores have a decline from before to after participation in the project, with except for the participants in the fifth-year; with the declines in the lower class standings (i.e., first and second years) being statistically significant, as opposed to the upper class standings (i.e., third, fourth and fifth years) which have basically similar levels ($p > 0.05$). There is no trend that can be identified regarding the variability of the data, but it can be stated that it goes up (i.e., 4.79 vs 5.46) when all surveys are taken into account.

Table 7. Results of Perceived Competence versus Class Standing

Class	Time	Average Score	Standard Deviation	p (%)	Decision ($\alpha=0.05$)
All	Pre	25.84	4.79	0.000	Reject
	Post	23.29	5.46		
1	Pre	26.80	4.73	0.036	Reject
	Post	24.34	5.87		
2	Pre	26.64	4.81	0.000	Reject
	Post	19.63	2.77		
3	Pre	25.33	5.18	0.135	Accept
	Post	22.64	4.55		
4	Pre	24.37	4.18	0.321	Accept
	Post	23.05	5.80		
5+	Pre	24.95	5.09	0.976	Accept
	Post	25.00	1.41		

5 Conclusions and Discussion

The level of motivation of engineering students, as indicated by three constructs of an IMI-based questionnaire, participating in a multinational collaborative design project was studied. The constructs are intrinsic motivation (i.e., interest/enjoyment), perceived choice, and perceived competence. The objective was to compare the motivation levels before and after students' participation in the engineering project. Statistical comparison of Pre- and Post- motivational levels was performed, and two demographic factors used were gender and class standing.

Specific conclusions from the data analysis indicate:

- There is a declining trend from before to after students' participation for all three constructs being used, with the differences being significant for the interest and choice constructs, and no significant for class standing.
- When the results are analyzed based on gender, there is statistically significant difference for the male participants in all three constructs. However, for female participants only the intrinsic motivation show situation, the choice and competence constructs show no significant difference.

- Class standing has different effect in each one of the constructs. For intrinsic motivation there is no significant differences according to class standing, with basically significant differences as well for perception of choice (except fourth-year); and split situation for perception of competence, significant difference at lower years and no difference for upper years.

The difference in the reported Pre- and Post- scores, independently of construct or demographic factor, is the most important conclusion from the study. It seems that the challenges that participants are facing while doing the collaborations is overshadowing the benefits of the experience. The fact that students need to get to know participants from other countries, and the requirement to have a new experience outside the classroom in a regularly structured learning process, generate interest and it is exciting to them. However, perhaps logistical issues and challenges might be difficult to overcome once specific deliverables are expected. This situation, even when it is addressed in an introductory session with the students, will be emphasized in future offerings, with the hope that the students keep a high level of motivation.

The results show that participants, independent of their gender, start the project highly motivated and with a high sense of competence to carry out the project at hand. However female students show more consistency when comparing results before and after participation. Indicating that male students are more likely to let the challenges affect their opinion, perhaps an indication of persistence. Since expectations play an important role in motivation, it is probable that the project's high expectations and the challenges typical of this type of multinational collaboration need to be managed in a different fashion. For instance, the difference in the variability of the answers for female students in the Pre- and Post-survey suggests that they had a harder time reconciling their expectations with the experience they had in the collaborative project. Therefore, a qualitative study that captures the students' opinions and perceptions might be useful to find specific areas of improvement.

It is interesting that class standing does not indicate a specific trend in terms of intrinsic motivation, which indicate that the project requires good participation at all levels. At the same time, the perception of competence indicates that there are significant differences at the lower class standings, which is opposite from upper class standing. This might indicate that more some technical requirements that are directed to upper-level students need to be presented and justified to all participants so that better understanding of the design process takes place.

The authors plan to address the aforementioned issues in future offerings, with the main expectation that students maintain their level of interest and excitement. The authors' hypothesis was that if the students experienced a similar, or even higher, level of motivation after finishing the collaborative project it would be confirmation that the activity was not only helping in the learning process, but also helping in the recruitment and retention of students.

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