Relationship between Motivation and Effective Communication in Engineering Capstone Projects Design Clinics

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The Causal Relationship between Undergraduate Engineering Students' Motivation and Facultys' Effective Communication in Engineering Clinics

Introduction and background

The importance of capstone design projects in every engineering student's career is very well known [1,2], as it provides them with employment chances and graduate studies scholarships [3,4,5]. In addition to non-technical skills, like project management, communication skills, and decision-making [8]

The industry considers engineers the vehicle for development because they play a crucial role in industrial evolution[9]. The industry requires engineering graduates with skills that meet the current industrial needs. It is essential in engineering schools to focus on industrial needs, as that increases the alignment level between industry and academia. In other words, the more universities know and apply in curriculums the industrial objectives, the more they are helping students to enhance their skills and get trained on what they will face in the industry. Hence, if the lack of capstone design project completion and low student motivation remained the same, it would be challenging for fresh graduate engineers to comply with the current industrial needs as employers struggle to find talented employees that align with their needs.

As all industries are affected by technological and innovational changes, those paradigms are called revolutionary changes as they didn't just affect the industry but the educational system as well [9,10].

Additionally, preparing for joining the workforce has been a cornerstone for educational systems, including non-technical skills such as communication and leadership. These basic skills are an initial step toward joining the real-world industry [9].

Furthermore, a study in 2019 at Rowan University[12] suggested that a lack of faculty communication skills and motivation might limit students' outcomes in capstone design projects. The lack of the supervisors' practical communication skills ultimately affected the students' motivation to develop the projects and apply the required project management techniques. In other words, if students sense that their opinions are respected, they will feel more empowered and motivated. Similar results are observed by the National Institute of Construction Management and Research and Walden University [13,14].

Along with motivation, social-cognitive theory suggests that effective communication affects students' deep thinking and motivation [15]. Hence, learners with strong self-efficacy are more likely to engage in activities that improve their learning, such as setting goals, using effective learning strategies, monitoring and evaluating their goal progress, and creating effective physical and social environments [16,17]. Furthermore, students who feel more empowered and exercise self-determination are more likely to engage in the tasks. In essence, theories support the relationship between empowerment and respecting opinions and the relationship between empowerment and democratic attitude [16,18,19,20].

This problem has been addressed in multiple majors but not validated in capstone design engineering projects. Accordingly, based on theories and past studies [7,8,9,10,11], we knew these variables are connected in theory, but we were interested in validating them in engineering capstone projects. By validating the relationship between faculty's effective communication and

motivation, we might be able to understand their relationship to capstone design projects' outcomes.

As a result of assessing the relationship between Project Management and Team culture and how they were affecting the capstone projects at Rowan University in 2019, we concluded that the capstone projects in completion might be affected by the faculty's effective communication, hence, affecting student's motivation[12]. Consequently, the current study was applied to validate if faculty's effective communication directly affects students' motivation, which in turn is reflected in the student's capstone project completion. Accordingly, we are trying to answer the following: How does the faculty's effective communication affect students' motivation in engineering capstone design projects?

I. FRAMEWORK

The Assessment Scale for Communication Skills measures 6 Communication Skills Dimensions (Respect, Expression, Value, Impediment, Motivation, and Democratic Attitude). However, we were interested in the four dimensions: 1) **Express dimension,** which asks if professors can effectively express themselves through examples, proposing solutions, eye contact, and voice tone. 2) **Value dimension** asks if professors value students' thoughts and opinions. 3) **Democratic Attitude** dimension asks if professors create a friendly atmosphere that allows students to ask questions and freely think. 4) **Respect dimension** asks if professors appreciate and respect students' thoughts and opinions.
The MUSIC Model of Motivation [x] allows for measuring five motivation-related constructs (Empowerment, Usefulness, Success, Interest, and Care). However, we were interested in the following two constructs: 1) **Empowerment** which asks if students feel empowered by having the ability to make decisions about some aspects of the learning. 2) **Care** which asks if students believe that others in the learning environment care about their learning and them as a person.
We chose only the four communication skills dimensions and the two motivation constructs because theory suggests that students who feel respected, valued, and can easily express their opinions feel empowered and cared for [13,14,15,16]. One element that increases the student's empowerment is the perceived control from professors [21] and how students think they have control over learning. Care improves when professors show care toward students' well-being, knowledge, and how friendly they are perceived by students [21]. Hence, we hypothesized that the greater the faculty's democratic attitude and respect perceived by students, the greater the students' empowerment [19], and the more the professors express their positive emotions to students and value students' opinions, the more the students perceive care from their professors [13]. In short, the research **hypothesis** is the following: **If the engineering students perceive influential communication acts from their professors, students' motivation in class will proportionally increase**. [19,20]

To test this hypothesis, we addressed the following research questions:
RQ1: What is the relationship between students' empowerment and the faculty's democratic attitude?
RQ2: What's the relationship between respecting students' opinions and their empowerment?
RQ3: What is the relationship between valuing students in class and students' perceived care?

II. METHODS

A quantitative research study was conducted in tall o021 at Rowan University. This study aimed to assess how the faculty's effective communication affects students' motivation in engineering capstone design projects. Therefore, we adapted two validated surveys to help us measure the students' perspectives towards the faculty's effective communication and their motivation in class.

A. Instruments

To measure effective communication skills, we used the Assessment Scale for Communication Skills created by Karağöz and Köstereliođlu [19]. This survey efficiently measures the professor's effective communication skills from the student's perspective, in addition to its validity which is proved by Cronbach's alpha reliability coefficient, which was found to be 0.77 [19].

To measure students' motivation, we used Jones's MUSIC Model of Academic Motivation [20,21]. As this survey efficiently measures students' motivation in class. In addition to its validity, it is proved by Cronbach's alpha reliability coefficient, which was found to be between good and excellent. On a sample of 1446 students, Cronbach's alpha reliability coefficient was more than .85 in all motivational constructs, including .86 for empowerment and .86 for caring [21].

Table 1. Motivation and Effective Communication Constructs Instrument Examples

Example Items from the instrument	*Example items*
Music Model Components	
Empowerment	I had the freedom to complete the coursework my own way.
Care	The instructor cared about how well I did in the course.
Faculty's Effective Communication Component	
Express Dimension	Effectively Uses gestures and facial expressions when talking.
Democratic Attitude	Creates an environment in the class where you can easily ask questions
Value Dimension	It makes you feel that s/he gives importance to your opinions.
Respect Dimension	It makes you feel that s/he respects your opinions.

B. Population and sampling

The population of the study consisted of capstone design projects students from 5 departments in Engineering school, including Mechanical Engineering (ME), Electrical and Computer Engineering (ECE), Civil & Environmental Engineering (CEE), Engineering entrepreneurship (E-ship), and Chemical Engineering (ChE). The number of students in every team depends on the project's size and need. The size can vary from a group of two students to a team of 15. Every team is supervised by a faculty member or a graduate student, sometimes both. They ensure students are on track and following the project's objectives, besides allowing the students to work potentially on their clinic.

The population of the engineering department at the College of Engineering of Rowan University in the current research is 109 teams; the recent research sample consisted of 27 capstone design teams of 100 senior and junior students.

C. *Data Collection*

After the study was approved by Rowan University Review Board (IRB), we emailed all department professors, asking their permission to survey their capstone design clinic's students. The research team collected through an online survey. The data collector either sent an email,s including the survey link, or surveyed the students in their labs during their scheduled clinic times via scanning a QR code. The team members identified their team via a unique team identifier. The survey was completed anonymously and privately by each member.

D. *Data Analysis*

We performed descriptive statistics using standard deviation, arithmetic mean, mode, frequency, skewness, and kurtosis, followed by effect size, power, correlation, and Chi-Square analysis. The correlation and Chi-Square test were applied to quantify the degree to which motivation and effective communication constructs are related and to determine if a difference between observed data and expected data is due to chance or if it is due to a relationship between the variables, respectively.

Again, we were interested in four out of six dimensions adapted from the Assessment scale for communication (Express, Value, Democratic Attitude, and Respect) and two out of five constructs adapted from the MUSIC Model inventory (Care and Empowerment). Express and value were the two independent variables testing the dependent variable care. Meanwhile, Respect and Democratic Attitude were the two independent variables testing the dependent variable, empowerment.

E. *Limitations*

A significant limitation of our work is that the research team collected the data only from groups whose supervisors agreed to be visited, which may affect the students' responses. The professors who responded to the email were the ones that were interested in the project and questions since the survey was asking students to rate their supervisors.

III. RESULTS

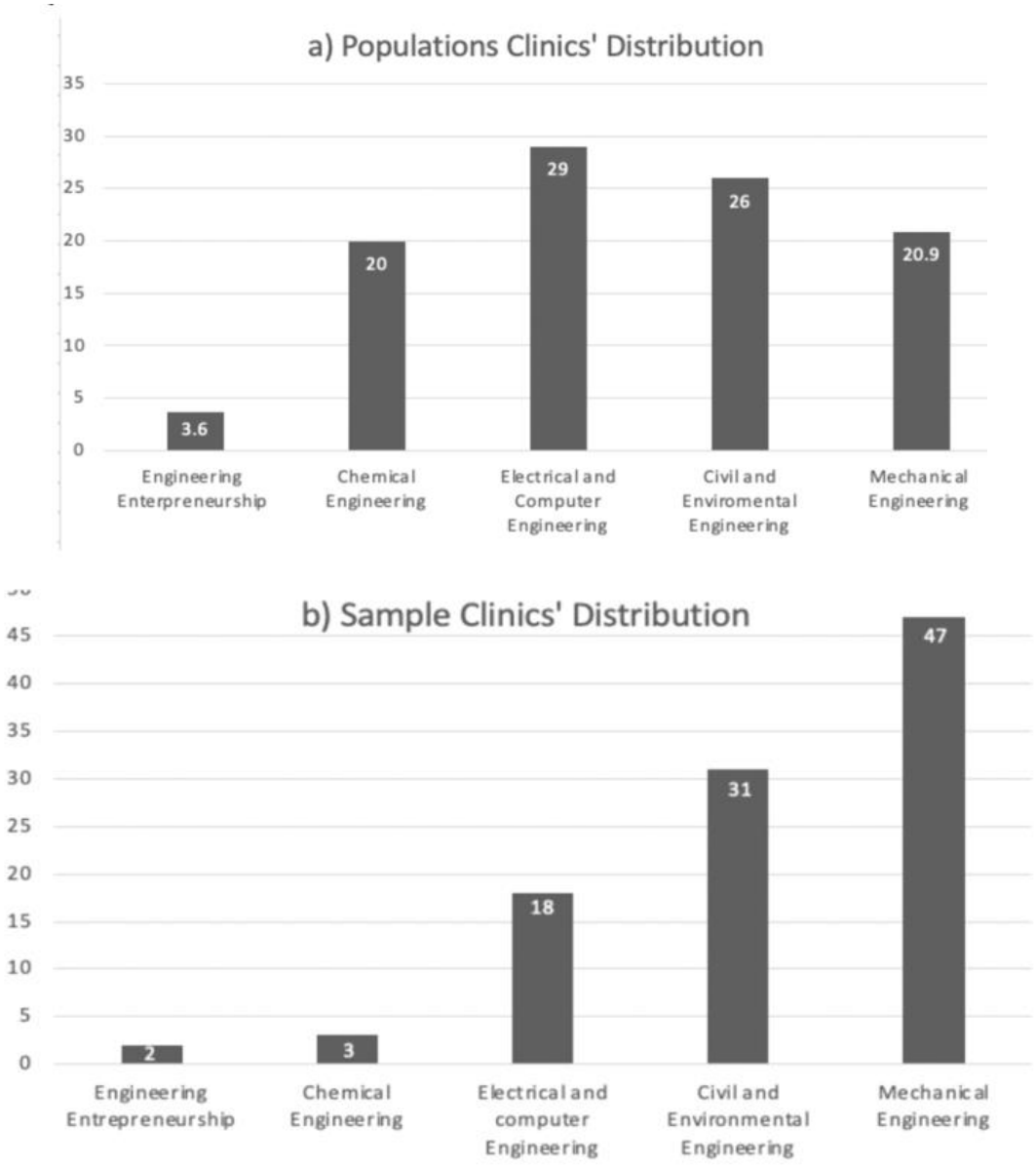
Results from descriptive statistics, correlation, and Chi-Square analysis indicated a causal relationship between the express and value dimension from the professor and the students' perceived care and a moderately causal relationship between the (communicated democratic attitude and respect) from the professor and the perceived empowerment of students, as well as evidence of students' perception of empowerment, care, and teachers' communication skills.

A. *Descriptive Statistics*

First, we show the students descriptive statistics based on their engineering major, as shown in Figure 1. The results showed that the number of respondents was focused on the ME, CEE, and ECE departments by 46.5%, 30.7%, and 17.8%, respectively. Additionally, the CHE and E-ship departments had a minimal share in the study, with good percentages of 3% and 2%,

respectively, as seen in Figure 1. However, the actual population reflects different numbers, as the ECE, CEE, ME, CE, and ExEEd departments had a 29%, 26%, 20.9%, 20%, and 3.6% share of the actual population, respectively.

Fig. 1 Percentage of respondents for population and sample based on their major.



Then, we analyzed the student's survey responses with descriptive statistics for the two constructs of motivation and the four dimensions of faculty's effective communication: Empowerment, Express, Value, Care, Respect, and Democratic Attitude, as shown in Table 2. The results showed the means for the constructs ranging between 5.3 and 5.6. Hence, Democratic Attitude, Respect Dimension, and Care constructs showed that the data were heavy-tailed on the right side (Kurtosis > 3). Proofing the data are non-normally distributed.

Table 2. Motivation *and Effective Communication Constructs Descriptive Statistics.*

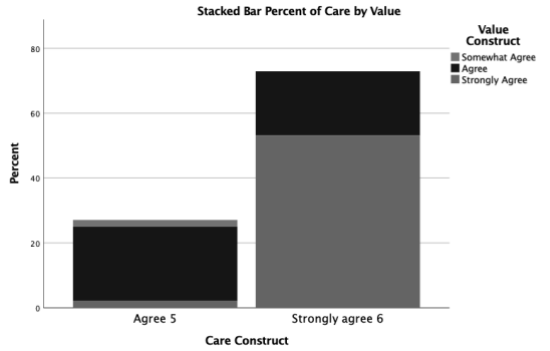
	Mean	*Std. Deviation*	*Skewness*	*Kurtosis*
Faculty's Effective Communication Component				
Express Dimension	5.4257	0.68332	-0.781	-0.535
Democratic Attitude	5.4653	0.72889	-1.774	**4.83**
Value Dimension	5.4554	0.65612	-1.241	2.218
Respect Dimension	5.4554	0.74195	-1.717	**4.35**
Motivation Component				
Empowerment	5.3168	0.87098	-1.595	3.149
Care	5.64	0.62797	-2.047	**4.992**

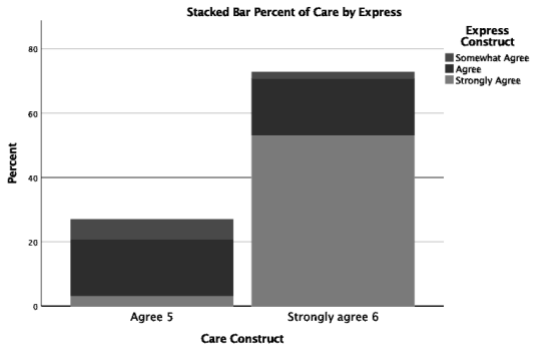
B. Correlation and Chi-Square Analysis

To further understand the relationship between faculty's effective communication and students' motivation [15,16,17,18], we ran a correlation test between the two components constructs, followed by a Chi-square analysis. Results indicate that there is a positive relationship between the constructs. The relationship is significantly genuine with a p-value < 0.001 and a medium effect size (>0.5).

1. *Relationship between Care, Express, and Value. Independent values are Value and Express dimensions, and the dependent variable is the care construct.*

Fig. 2 Cross-tabulation Bar Chart between Motivation constructs and Communication dimensions.





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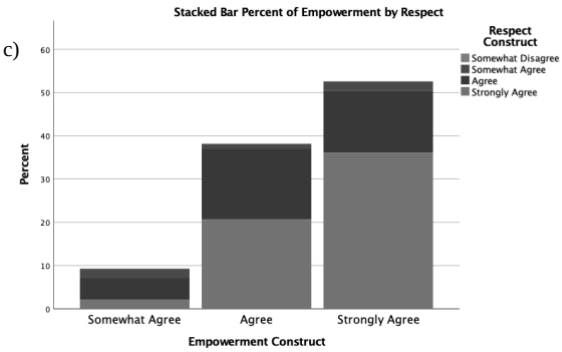

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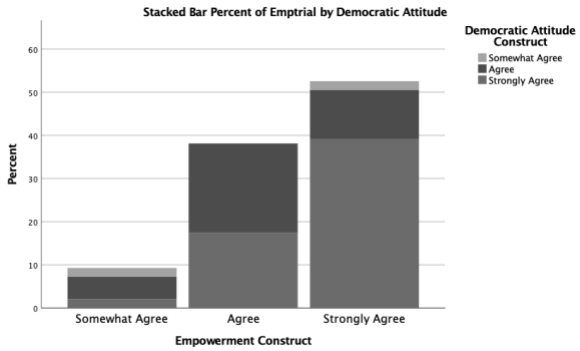

1.1 Correlation and Chi-Square tests between Value dimension and Care construct.

The research team conducted a chi-square analysis to evaluate the relationship between the Care construct and the Value dimension. They concluded that the relationship is statistically significant, $\chi 2(1) = 99.985$, $p < 0.001$. Therefore, **the null hypothesis is rejected**. Cross-tabulated results are in Table 3 and Figure 2. a. The cross-tabulated results indicate that the more students feel their professors value them, the more they feel cared about. The effect size of the correlation was evaluated as Cramer's V = 0.577, 95% bootstrap CI [0.459, 0.840], indicating a medium effect size with a range between medium and large expected in replications.

The variables Care and Value are also strongly correlated ($p = .723$), as the coefficient value lies between ± 0.50 and ± 1.

Based on these results, there appears to be statistical significance and moderate relationship between how students feel their professors value them and how students feel they are cared about by professors. It's also shown that 53% and 42% of the students strongly agree and agree that their professors care about them. Meanwhile, only 3% somewhat agree, and 2% somewhat disagree.

Table 3. Cross-tabulation for Care and Value constructs.

		Value	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	Total
Care	Somewhat disagree	Count	1	1	0	0	2
		Expected	0	0.1	0.8	1.1	2
	Somewhat agree	Count	1	0	1	0	2
		Expected	0	0.1	0.8	1.1	2
	Agree	Count	0	2	22	2	26
		Expected	0.5	0.8	10.9	13.8	26
	Strongly agree	Count	0	0	19	51	70
		Expected	1.4	2.1	29.4	37.1	70

1.2 Cross-tabulation and Chi-Square test between Express dimension and Care construct

The research team conducted a chi-square analysis to evaluate the relationship between the Care construct and the Express dimension. The relationship is statistically significant, $\chi 2(1) = 50.267$, $p < 0.001$. Therefore, **the null hypothesis is rejected**. Cross-tabulated results are in Table 4 and Figure 2. b. The cross-tabulated results indicate that the more students see expressions from their professors, the more they feel cared about. The effect size of the correlation was evaluated as Cramer's V = 0.501, 95% bootstrap CI [0.381, 0.658], indicating a medium effect size with the same expected in replications. The variables Care and Express are also strongly correlated ($p = .621$), as the coefficient value lies between ± 0.50 and ± 1.

Based on these results, there appears to be statistical significance with a moderate relationship between how students perceive their professors' expressions and how students feel they are cared about by professors. It's also shown that 54% and 35% of the students strongly agree and agree, respectively, that their professors efficiently express their care. Meanwhile, only 11% somewhat agree.

Table 4. Cross-tabulation for Care and Express constructs.

		Express	Somewhat Agree	Agree	Strongly Agree	Total
Care	Somewhat disagree	Count	2	0	0	2
		Expected	0.2	0.7	1.1	2
	Somewhat agree	Count	1	1	0	2
		Expected	0.2	0.7	1.1	2
	Agree	Count	6	17	3	26
		Expected	2.9	9.1	14	26
	Strongly agree	Count	2	17	51	70
		Expected	7.7	24.5	37.8	70

2. *Relationship between Care, Express, and Value. Independent values are Value and Express dimensions, and the dependent variable is the care construct.*

2.1.1 Cross-tabulation and Chi-Square test between the Democratic Attitude dimension and Empowerment construct

The research team conducted a chi-square analysis to evaluate the relationship between the Empowerment contrast and the Democratic Attitude dimension. The effect size of the correlation was assessed as Cramer's V = 0.568, 95% bootstrap CI [0.348, 0.751], indicating a medium effect size with the same expected in replications. The relationship is statistically significant, $\chi 2(1) = 130.394$, $p < 0.001$. Therefore, **the null hypothesis is rejected**. Cross-tabulated results are in Table 5 and Figure 2.d. The cross-tabulated results indicate that the more professors provide a democratic attitude in class, the more students feel empowered.

Based on these results, there appears to be a statistically significant and moderate relationship between how students perceive their professors' democratic attitude and how they feel empowered. It's also shown that 57% and 37% of the students strongly agree and agree, respectively, that their professors created a democratic environment in class, which increased their empowerment. Meanwhile, 5% somewhat agree, and only 1% somewhat agree and disagree. Additionally, the variables Empowerment and Democratic Attitude is strongly correlated ($p = .6$), as the coefficient value lies between ± 0.50 and ± 1.

Table 5. Cross-tabulation for Empowerment and Democratic Attitude constructs.

		Democratic Attitude	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	Total
Empowerment	Disagree	Count	1	1	0	0	0	2
		Expected	0	0	0.1	0.7	1.1	2
	Somewhat Disagree	Count	0	0	1	1	0	2
		Expected	0	0	0.1	0.7	1.1	2
	Somewhat Agree	Count	0	0	2	5	2	9
		Expected	0.1	0.1	0.4	3.3	5.1	9
	Agree	Count	0	0	0	20	17	37
		Expected	0.4	0.4	1.8	13.6	20.9	37
	Strongly Agree	Count	0	0	2	11	38	51
		Expected	0.5	0.5	2.5	18.7	28.8	51

2.2 Cross-tabulation and Chi-Square test between Respect dimension and Empowerment construct.

The research team conducted a chi-square test to evaluate the relationship between the Empowerment construct and the Respect dimension. The relationship is statistically significant, $\chi 2(1) = 119.957$, $p < 0.001$. Therefore, **the null hypothesis is rejected**. Cross-tabulated results are in Table 6 and Figure 2. c. The cross-tabulated results indicate that the more students feel respected by their professors, the more they feel empowered. The effect size of the correlation was evaluated as Cramer's V = 0.544, 95% bootstrap CI [0.28, 0.714], indicating a medium effect size with a range between small and medium effect size in replications.

Based on these results, there appears to be a statistically significant and moderate relationship between how students feel respected by their professors and how they feel empowered. It's also shown that 57% and 36% of the students strongly agree and agree, respectively, that their professors respect them, which increases their empowerment. Meanwhile, 6% somewhat agree, and only 1% somewhat disagree and disagree. Additionally, the variables Democratic Attitude and Respect are strongly correlated ($p = .548$), as the coefficient value lies between ± 0.50 and ± 1.

Table 6. Cross-tabulation for Empowerment and Respect constructs.

		Respect	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	Total
Empowerment	Disagree	Count	1	1	0	0	0	2
		Expected	0	0	0.1	0.7	1.1	2
	Somewhat Disagree	Count	0	0	1	1	0	2
		Expected	0	0	0.1	0.7	1.1	2
	Somewhat Agree	Count	0	0	2	5	2	9
		Expected	0.1	0.1	0.5	3.2	5.1	9
	Agree	Count	0	0	1	16	20	37
		Expected	0.4	0.4	2.2	13.2	20.9	37
	Strongly Agree	Count	0	0	2	14	35	51
		Expected	0.5	0.5	3	18.2	28.8	51

Hence, based on these results, there appears to be a statistically significant and medium prediction of the faculty's effective communication toward students and students' motivation.

IV. Discussion and Conclusion:

In this work, we questioned if the faculty's effective communication positively affects students' motivation. First, we examined the causal relationship between the faculty's democratic attitude, respecting students' opinions in class, and students' empowerment. In other words, we wanted to understand how showing respect to students and respecting their input and ideas in class affects their empowerment. Second, we questioned how effective and powerful is valuing students' opinions and how that affects their perception of how faculty cares about them. In response, we proposed a study that tests the causal relationship between how faculty's effective communication affects students' motivation in capstone design projects.

Our results showed strong evidence of the faculty's effective communication's impact on student's motivation. Theory [13,14,15,16,17,18] suggests that when students are more motivated, it would likely leads to better outcomes.

First, we analyzed the study's descriptive statistics and found that our sample is about 27% of the population. Hence, the sample wasn't fairly representing the population when compared to it. For instance, the sample showed that the highest responses were from the ME department, which covered 46.5% of the sample, although the ME department shared only 20.9% of the population, as shown in Figure 1. Same as the CEE department, which covered 31% of the study's sample, but the actual share of the CEE from the population was 26%, as shown in Figure 1. In contrast, the ECE department covered 18% of the study's sample, but the actual share of the ECE from the population was 29%. Same as the ChE department covered only 3% of the study's sample, but the substantial share of the ChE from the population was 20%, as shown in Figure 1. However, the ExEEd department covered 2% of the study's sample, and the actual

share of the ExEEd from the population was 3.6%, as shown in Figure 1. The results mean that the sample is s overrepresented in the ME and CEE departments compared to the population. In contrast, the ECE and ChE departments were underrepresented compared to the population. In short, the current research data are not equally divided among the engineering departments.

The sample descriptive statistics show that most responses were positive concerning the empowerment and care constructs, and most students agree that they are empowered and cared about in their classes. They were heavy tailed on the Likert scale's positive responses strongly agreed and agreed. Then, other statistics for the data showed that kurtosis for the dependent variables was more than 3, proving that the research data aren't normally distributed.

Results of the correlation between the Care construct and Express and value dimensions suggested that the two independent variables (Express and value) are strongly correlated to care (dependent variable), which **supports our hypothesis**. This strong correlation implies that the more professors express their positive emotions to students and value students' opinions, the more the students perceive the act of care from their professors, which directly reflects on their motivation in class (13,18).

Analyses showed that students' actual count of (strongly agree and agree) responses were double what we expected as an outcome of the study. The conclusion above implies that students feel highly positive toward their professors' effective communication skills, especially with value and Express constructs. These data are shown in Tables 3 and 4, as well as Figures 2. a and 2. b.

Results of the correlation between the Empowerment construct and Democratic Attitude and Respect dimensions suggest that the two independent variables (Democratic Attitude and Respect) strongly correlate to empowerment (dependent variable), **supporting our hypothesis**. This strong correlation implies that the more professors show a democratic attitude in class and respect their students' opinions, the more students will feel empowered. Which directly reflects on their motivation in class (19,20).

Analyses show that the actual count of students strongly agree, agree, and somewhat agree responses was more than what we expected as an outcome of the study. The results imply that students feel favorable toward their professors' effective communication skills, especially with Value and Express constructs. The research data is shown in Tables 5 and 6, as well as Figures 2. c and 2.d.

Additionally, we tested the effect size of 4 correlations between faculty's effective communication and student motivation. Analysis suggested that our sample is considered a medium effect size effect as our Cramer's V value is almost 0.5 in all correlations. The following numbers imply that the result is moderate. In other words, the study indicates a moderate association between the variables.

These findings showed that from the students' standpoint, they think their capstone design professors are excellently respecting and valuing their opinions. Students also claimed that their professors create a democratic attitude in class, allowing them to express their thoughts and ask questions, besides showing their positive emotions with facial expressions. Motivation theory explains that these attitudes increase the perception of caring and empowerment within students, hence, enhancing the students' motivation [21].

Our interpretation of all the above is that the faculty's effective communication positively reinforces their students' motivation. The results align with the motivation-social-cognitive theory [15,16], which suggests a strong causal relationship between how students perceive faculty communication and how that affects their empowerment and care. Besides, effective learning and communication strategies with students help in increasing their motivation [13,14,15]. Hence, learners get more engaged in their projects and feel more empowered to have a positive outcome. Additionally, faculty members who are to be given this acquisition should

have personal skills such as effective communication along with their theoretical knowledge [22] to positively affect their students' motivation. The research team concluded that the better the teaching communication skills, the bigger the students' motivation [22]. Hence, enhance their skill sets and have qualified students who fulfill the basic steps for joining the workforce[10,11].

The purpose of the present study was to test if the faculty's effective communication positively affects students' motivation. In this work, we found evidence of high students' perception of empowerment, care, and teachers' communication skills, a strong causal relationship between the communicated expression and value from the teacher with the students' perceived care, and a moderately causal relationship between the communicated democratic attitude and respect from the professor with the perceived empowerment of students.

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