Construction students' confidence in their abilities to visualize construction methods

Sara Gusmao Brissi
School of Construction Management Technology
Purdue Univesity
West Lafayette, United States
sgusmab@purdue.edu

Luciana Debs
School of Construction Management Technology
Purdue Univesity
West Lafayette, United States
ldecresc@purdue.edu

Mark Zimpfer
School of Construction Management Technology
Purdue Univesity
West Lafayette, United States
mzimpfer@purdue.edu

Abstract— **Students learn and study in different ways, depending on their personality types. As a result, a significant number of learning style models have emerged to enhance the learning process. Previous research on construction management undergraduate students' learning styles in the United States revealed that they are visual, active, sensing, and sequential learners. This information is vital to guide instructors' teaching methods. Expanding on the visual aspect of learning, the goal of this study, presented here as a full paper, is to understand how confident undergraduate construction management students are with regard to their abilities to visualize construction methods necessary to build a structure based on information they read in plans and specifications and which topics they have most difficulties in visualizing. The researchers also analyzed potential differences in gender and school year related to their general confidence level in understanding construction plans using statistical inferential tests. Findings revealed that male students are more confident in their abilities than females and that senior students are the most confident, followed by juniors, and the group of freshmen and sophomores (analyzed together). When gender and school year are analyzed as a set, it is interesting to notice that the group of the female freshman and sophomore students are more confident than juniors and seniors. In relation to topics, mechanical, electrical and plumbing (MEP) plan information was found to be the most challenging for the students. For the researchers, the findings helped to define the most challenging topics and also understand students' differences that can be used to develop further instructional materials. In addition, results will help faculty from undergraduate, construction management programs to identify students' difficulties in visualization, so they can adequately address those during instruction, improving students' motivation and self-confidence. Finally, results suggest that further studies related to students' self-confidence, academic year and gender in construction management education need to be performed.**

Keywords — plan reading, construction, visualization, gender differences, learning styles

I. Introduction

Over the past years, researchers have identified different types of learners in other words, they found out that students learn and study in different ways, depending on their personality types [1], [2]. As a result, a large number of learning style models has emerged as a way to enhance the learning process [3]. Discussions related to learning styles involve Kolb Learning Style Inventory [4] and Felder-Silverman Index of Learning Styles [5]. Kolb and Felder-Silverman studies expanded the theories on how students learn, more specifically how they receive, process, perceive and understand information [1]–[3], [5]–[7].

Kolb [4] learning model proposes a four-stage cycle that encompasses two bipolar modes of receiving information – concrete experience and abstract conceptualization – and two bipolar modes of transforming information – reflective observation and active experimentation [7]. Based on these modes or abilities of receiving and processing information, Kolb [4], [7] presents four basic learning styles:

- Diverging – learners' abilities are concrete experience and reflective observation.
- Assimilating – learners' abilities are abstract conceptualization and reflective observation.
- Converging – learners' abilities are abstract conceptualization and active experimentation.
- Accommodating – learners' abilities are concrete experience and active experimentation.

Felder-Silverman [5] also developed a learning style model for the engineering and science majors. This model combines the Myers-Briggs Type Indicator (MBTI) based on Jung's theory of psychological types and Kolb's learning models, to define how learners receive and process information [1], [2], [5]. Felder-Silverman's model defines five dimensions of learning and teaching styles and ten different learner types, as presented in Table I , adapted from Felder-Silverman [5].

Previous research on learning styles of undergraduate students in construction management programs in the U.S. reveals that they are visual, active, sensing, and sequential learners [2], [6]. With the construction industry becoming more complex and being dynamic in nature, the skill set the construction manager brings to project becomes pivotal for the project's success [8]. As such, it is very important to identify the skills they learn in undergraduate school and how confident students are in what they learn. Construction students' perceptions in their own abilities or capabilities are also termed self-efficacy, that is, a person's belief about their own ability for a particular skill [9].

TABLE I. LEARNING AND TEACHING STYLES ACCORDING TO LEARNER TYPES [(a)]

Learner Type	Learning Style	Teaching Style
Sensing or intuitive	Perception	Content: concrete or abstract
Visual or auditory	Input	Presentation: visual or verbal
Inductive or deductive	Organization	Organization: inductive or deductive
Active or reflective	Processing	Student participation: active or reflective
Sequential or global	Understanding	Perspective: Sequential or global

a. adapted from Felder-Silverman [5]

Other factors that are important to note when analyzing students' perceptions of learning are gender and academic year. Previous research suggests that faculty-student interactions have differential impact for female and male students, especially in STEM academic fields – including construction related courses – where female students deal with the issue of being underrepresented in a domain with high proportion of male students [10], [11]. Furthermore, encouragement from classmates, faculty, and family has positive impacts on women and may increase their confidence, motivation and aspiration to pursue a career in the STEM field [12]. Research also suggests that upper-division students (juniors and seniors) are more likely than freshman students and sophomores to have confidence in their abilities [10].

However, the current literature research shows that university education alone is inadequate to meet the industry expectation, for preparing professionals to take up their roles in construction field [13]. To bridge this gap, provisions are necessary to improve the curriculum. Some of the key skills the industry is looking in recent graduates and current students in the construction management field are health and safety regulations, leadership qualities, interpretation of contract document and blueprints [14]–[16] Some of the suggested ways to reinforce the curriculum are through integrating hands-on experience to students, scenario-based learning, and auditing [8]. Along with the above mentioned improvements, introducing videos to explain use of techniques based on illustrative scenarios can also have positive impact on learning outcome of undergraduate students [17].

Finally, there is a lack of comprehensive studies on construction students and their perceptions of difficulties per topic, though there are studies related to students' visualization skills. Some of the previous research on visualization in construction education relate to using standardized tests such as the Purdue Rotations of Visualizations (for references see [18]) and other studies investigating the effects of three-dimensional models and Building Information Modeling (BIM) on visualization (for examples see [19] and [20]). These studies are also important to understand some of the important causes and tools to improve visualization skills and can be complemented by a comprehensive survey to understand if there are differences of understanding per topic. Knowing that previous research indicates that the ability to interpret construction documents – though 'construction documents' could encompass more than just plan reading – is seen as the most important skill for construction professionals, understanding students' perceptions is key to providing students with the tools they need for success in their chosen career [21].

Therefore, this study focuses on the construction undergraduate students' self-perceptions with regard to their confidence in their abilities to visualize construction methods necessary to build a structure based on information they read in plans and specifications. The goal of the study is to provide faculty with a list of topics perceived as most difficult, so that faculty can successfully work to encourage students' motivation and self-confidence. The authors have also provided an exploratory analysis of gender and academic year differences in perceptions of self-confidence that can help instructors understand better their students.

II. METHODOLOGY

A. Research Questions

1. Which construction related topics are perceived as most difficult to visualize by undergraduate students?

2. How confident are students in their abilities to visualize construction methods necessary to build a structure based on information they read in plans and specifications?

3. How the levels of confidence perceived by undergraduate construction management students in their abilities to visualize construction methods necessary to build a structure differed by (A) the student's gender; and (B) the student's school year?

B. Instrument

An electronic survey was developed to identify, among other topics, undergraduate construction management students' confidence in their abilities to visualize construction methods necessary to build a structure based on information they read in plans and specifications. The developed instrument contained four parts: (1) introduction - confidence level and learning type; (2) main portion – difficulty of visualization per construction topic; (3) additional information – related to usefulness of a video library and open-ended questions for comments; (4) and demographic information. The first two parts of the instrument contained multiple choice, 5-point Likert-type and ranking questions. The categories and topics in the instrument are included in the appendix at the end of the present paper.

C. Data collection

By the end of year 2018, the researchers reached out to 230 instructors of construction (or construction related) undergraduate programs in the entire United States and asked them to forward the survey to their students. A total of 245 responses were obtained, however, only 138 responses were considered for the study, i.e., only the responses with information sufficient to perform the analysis and whose respondents were from construction related undergraduate students, including: 117 construction management or construction science students, 8 civil engineering students, 7 architecture engineering students, 3 others (management or design related) and 3 not specified.

The resulting data set totals 138 responses from 17 American states. Table II presents the breakdown of the numbers of responses by state. A total of 100 out of 138 (n= 72%) of the responses for the surveys came from students attending construction programs in the Midwest of the United States and aapproximately half of the responses came from the state of Indiana (n= 53%). To preserve student anonymity, school name was not asked, so there is no way of knowing if the distribution is also skewed towards one school within the state or not. Indiana has at least four large public universities that offer construction related undergraduate programs.

D. Participants

The participants of this study were undergraduate students from construction related programs. The participants include freshman, sophomore, junior and senior students. Both male and female students were considered, but it is acknowledged that the occurrence of male students in the construction domain is much more significant than the occurrence of female students [22].

TABLE II. RESPONSES PER STATE

State	Responses
Indiana	73
Pennsylvania	14
Ohio	11
Illinois	10
South Carolina	7
Oklahoma	6
Michigan	6
California	2
Others (New Jersey, Montana, Texas, Georgia, Arizona, New York, Colorado, North Carolina and Alabama)	9
TOTAL	138

E. Data analysis

The topic investigated in this study is related to the levels of confidence perceived by undergraduate construction management students in their abilities to visualize construction methods necessary to build a structure based on information they read in plans and specifications.

Data for research question one (1) was obtained using a five level, Likert type scale (from 1 – Extremely easy to 5 – Extremely difficult – students did not see the numbers for this question, only the descriptive label, such as “extremely difficult”) for main topics and subtopics and a ranking scale from 1 (most difficult) to 7 (easiest) for main topics. And data for research questions 1 and 3 was obtained using a five-level Likert type scale (from 1 – Not confident at all to 5 – Extremely confident).

Analysis to answer research questions 1 and 2 was performed using simple data analysis complemented by descriptive statistics. For research question 1, researchers provided descriptive statistics for main topics as well as for the ten subtopics found to be most challenging to students. Seven main topics were tested: site preparation, foundation, framing, envelope, mechanical, electrical and plumbing (MEP), interior finishes and site finishing. Each of these topics had a varying number of sub-topics (for a total of 49 sub-topics) that were also presented to students for rating prior to them rating and ranking the main topics. Therefore, all respondents had the same information about what was considered under each topic at the time when they were asked in the survey to rate and rank the topics. The list of subtopics covered within each topic category can be found in the appendix at the end of this paper. To answer question 1, the researchers also used analysis of variance (ANOVA) to compare the rating scales provided by respondents for the main topics; and Friedman test to evaluate differences in how respondents ranked the seven main topics. The main hypothesis for question 1 is:

- There is no significant difference between construction topics.

Finally, to answer research question 3 the researchers used ANOVA testing, which allowed the researchers to investigate how the levels of confidence perceived by undergraduate construction management students in their abilities to visualize construction methods necessary to build a structure is affected by two factors (independent categorical variables): (A) student’s gender and (B) student’s school year. Therefore, the researchers proposed three hypothesis tests:

- Two main effect tests: one for Factor A, and one for Factor B.
- One interaction test: combination of levels for Factors A and B.

All inferential statistical tests were performed using $\alpha = 0.5$ for statistical significance. And before performing the two-way ANOVA, the data was checked for normality.

III. RESULTS

A. Difficult topics – Descriptive statistics

There were two questions related to difficult topics for students. The rating question was answered by n = 137 students and the raking questions was answered by n = 136 students, though some items were missed by some respondents. Table III summarize the descriptive findings for the rating question. The results show that MEP seems to be the most difficult topic (M = 3.07, SD = 1.204), while interior finishes seem to be perceived as easiest (M = 1.96, SD = 0.957). It is also interesting to note that standard deviation for MEP is highest, indicating more variability in the responses.

TABLE III. DIFFICULT TOPICS – RATING (N=137)

Main Topic	Number of responses	Mean	Standard Deviation (SD)
MEP	137	3.07	1.204
Envelope	137	2.60	1.067
Site Preparation	137	2.35	1.004
Site Finishing	134	2.29	1.017
Foundation	137	2.15	0.974
Framing	135	2.05	1.017
Interior Finishes	136	1.96	0.957

For the ranking, table IV summarizes the results. The top three most difficult topics stay the same – MEP (M = 2.76, SD = 2.133), envelope (M = 3.43, SD = 1.724) and site preparation (M = 3.43, SD = 1.961), though envelop and site preparation show the same mean value. However, foundation (M = 4.01, SD = 1.766) is ranked as fourth most difficult, which is different than what was found in the rating question. Again, MEP presents the higher variability in the answers. Tests for normality indicate that data is non-normal (kurtosis ranges from -0.780 for interior finishes and 0.870 for MEP) rather skewed (ranging from -1.070 for site preparation to -0.666 for interior finishes).

TABLE IV. DIFFICULT TOPICS – RANKING (N=136)

Main Topic	Number of responses	Mean	Standard Deviation (SD)
MEP	136	2.76	2.133
Envelope	136	3.43	1.724
Site Preparation	136	3.43	1.961
Foundation	136	4.01	1.766
Framing	136	4.47	1.817
Site Finishing	136	4.66	1.709
Interior Finishes	136	5.24	1.753

Finally, table V presents the descriptive statistics for the ten most challenging subtopics. The information on table V seems to corroborate with the findings for the main topics, with MEP related subtopics being perceived by students as the ones most difficult to visualize. Of the ten most difficult to visualize subtopics, seven are within the MEP topic category and all of them seem to be related to mechanical, electrical and plumbing, either at the building or at the site level. Findings could have been influenced by the sample size composition, which is largely skewed towards one state (Indiana). On the other hand, the easiest topics mentioned by students were mainly related to finishes and wall framing. The five easiest topics rated by students were, in descending order: wall and ceiling paint (M = 1.65, SD = 0.848), wall framing (M = 1.69, SD = 0.842), carpet floor finishes (M = 1.72, SD = 0.834) and tile finishes (M = 1.76, SD = 0.873).

TABLE V. TEN MOST DIFFICULT SUB-TOPICS (N=138)

Rank	Sub-topic	Topic	# Responses	Mean (M)	Stand. Dev. (SD)
1	Smart Home Building Systems	MEP	138	3.16	1.122
2	Electrical Wiring and Panels	MEP	138	3.12	1.252
3	Septic Systems	MEP	138	3.09	1.029
4	Energy Efficient Systems	MEP	138	3.08	1.074
5	Water Wells	Site Prep.	137	3.08	0.946
6	Connection to Main Utilities	Site Prep.	137	3.01	1.025
7	HVAC Equipment	MEP	138	2.96	1.205
8	Vent Systems	MEP	138	2.91	1.146
9	Drainage System	MEP	138	2.89	1.131
10	Site Drainage	Site Fin.	138	2.82	1.115

B. *Difficult topics – Inferential statistics*

A repeated measures, one way ANOVA and the Friedman test will identify if there are any statistically significant differences between each main topic ($\alpha = 0.5$). In both cases the dependent variables are the main topics. Finally, the one-way ANOVA can tolerate violations to data normality and Friedman test is also robust against non-normal data distribution.

1) *Analysis of variance (ANOVA)*

A repeated measures, one-way analysis of variance (Table VI) was used to test the hypothesis for :

- Main topic: H_0: $\mu_{T1} = \mu_{T2} = \mu_{T3} = \mu_{T4} = \mu_{T5} = \mu_{T6} = \mu_{T7}$ | H_a: at least one μ_T is different than the others (levels: MEP, Envelope, Site Preparation, Foundation, Framing, Site Finishing, Interior Finishes).

TABLE VI. REPEATED MEASURES ANOVA – MAIN TOPICS

Dependent Variable: Main Topic						
Source	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*	*Partial Eta Squared*
Greenhouse-Geisser	116.349	5.141	22.630	32.522	0.000	0.200
Error	465.080	668.374	0.696			

The ANOVA suggests that there are statistically significant differences of the perception of difficulty between main topics, $F(5.141,\ 668.374) = 32.522$, $p = 0.000$; therefore, the null hypothesis is rejected. Despite significant, the effect size presented is small ($\eta^2 = 0.2$). In addition, when looking at Figure 1, we can also estimate and compare the means for each main topic.

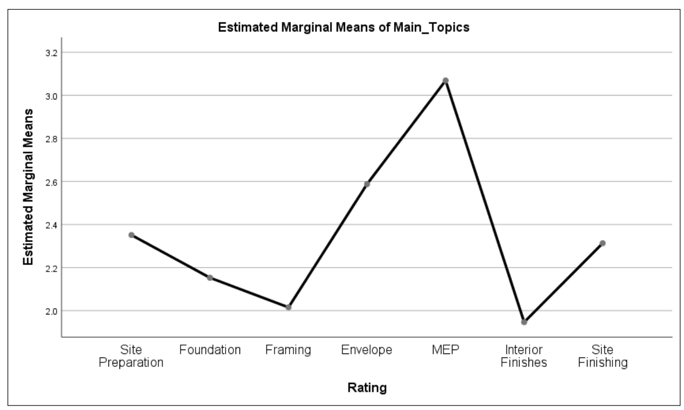

Fig. 1. Means for Main Topics.

2) *Friedman test*

Following the repeated measures, one-way ANOVA, the authors have performed a Friedman test on the ranking data using the following hypothesis:

- Main topic: H_0: $\mu_{T1} = \mu_{T2} = \mu_{T3} = \mu_{T4} = \mu_{T5} = \mu_{T6} = \mu_{T7}$ | H_a: at least one μ_T is different than the others (levels: MEP, Envelope, Site Preparation, Foundation, Framing, Site Finishing, Interior Finishes).

Again, the results indicate statistically significant differences between the levels of main topics (χ^2 (6) = 127.632, *p = 0.000)*. Following up with post-hoc Wilcoxon Signed-Rank test, using a Bonferroni adjustment, which is a conservative method of adjustment, indicates the formation of four different groups within main topics, MEP and site preparation are seen as most difficult and site finishing and interior finishes as least difficult topics to visualize (Table VII).

TABLE VII. DIFFICULT TOPICS – RANKING (N=136)

Main Topic	Groups			
MEP	A			
Site Preparation	A	B		
Envelope		B		
Foundation		B	C	
Framing			C	
Site Finishing			C	D
Interior Finishes				D

C. Students' confidence levels – Descriptive statistics

The evaluation of the levels of confidence perceived by undergraduate construction management students in their abilities to visualize construction methods necessary to build a structure returned a total of 138 responses (n = 138 students).

The breakdown by gender and school year reveals that the study involves an unbalanced design, since there is an unequal number of observations (unequal sample sizes) in each level of the factors (Table VIII). Approximately 25% of the participants were female – this is higher than the 13% found in a previous study of 1,069 construction students [6]. Similarly, about 25% of the participants were in the freshman and sophomore group of students, while about 31% were juniors and 43% were seniors. For the present analysis, due to the low number of respondents, freshman and sophomores were combined into one group "Freshman and Sophomore."

TABLE VIII. RESPONSES BREAKDOWN BY GENDER AND SCHOOL YEAR

Factors	Value Label	N
Gender	Female	35
	Male	103
School Year	Freshman & Sophomore	35
	Junior	43
	Senior	60

The level of confidence of students could range from "extremely confident" (5) to "not confident at all" (1). The average level of confidence considering all the students is between "moderately confident" and "very confident" (M = 3.35, SD = 0.893 – Table IX). Based on the findings, faculty from undergraduate construction management programs could successfully work to encourage students' motivation and self-confidence and adapt their teaching approaches according to students' gender.

Considering only the female students, it is interesting to notice that the group of freshmen and sophomores is more confident (M = 3.09, SD = 0.944) than juniors (M = 2.90, SD = 0.876), and seniors (M = 2.86, SD = 0.949). These findings are contrary to the natural student's predisposition in which the more knowledge the student has, the more confident this student may be in his/her abilities. However, the findings might be consistent with students understanding the intricacies of each topic, and therefore understanding that there is more to be known than what they currently know.

TABLE IX. DESCRIPTIVE STATISTICS FOR CONFIDENCE ABILITY

Gender	School Year	Mean	Std. Deviation	N	Percentage
Female	Freshman & Sophomore	3.09	0.944	11	8%
	Junior	2.90	0.876	10	7%
	Senior	2.86	0.949	14	10%
	Total	2.94	0.906	35	25%
Male	Freshman & Sophomore	3.25	0.897	24	17%
	Junior	3.42	0.867	33	24%
	Senior	3.65	0.795	46	33%
	Total	3.49	0.850	103	75%
Total	Freshman & Sophomore	3.20	0.901	35	25%
	Junior	3.30	0.887	43	31%
	Senior	3.47	0.892	60	43%
	Total	3.35	0.893	138	100%

Considering only the male students, seniors are more confident in their abilities to visualize construction methods necessary to build a structure (M = 3.65, SD = 0.795), followed by juniors (M = 3.42, SD = 0.867), and by the group of freshmen and sophomores (grouped together) (M = 3.25, SD = 0.897). These results confirm the trend that the more knowledge the student has, the more confident he/she may be in his/her abilities.

Overall, male students are more confident in their abilities (M = 3.49, SD = 0.850) than females (M = 2.94, SD = 0.906), who are under the overall average level of confidence. The values for skewness and kurtosis presented in Table X show that the distribution of confidence level in ability by gender for both female and male students is non-normally distributed. However, for female students, the distribution is slightly more normal than the male students' distribution.

TABLE X. DESCRIPTIVE STATISTICS FOR CONFIDENCE LEVEL IN ABILITY BY GENDER

Gender		Statistic	Std. Error
Female N=35	Mean	2.940	0.153
	Std. Deviation	0.906	
	Skewness	0.117	0.398
	Kurtosis	-0.567	0.778
Male N=103	Mean	3.490	0.084
	Std. Deviation	0.850	
	Skewness	-0.247	0.238
	Kurtosis	-0.116	0.472

As for the school year, senior students are the most confident (M = 3.47, SD = 0.892), followed by juniors (M = 3.30, SD = 0.887), and the group of freshmen and sophomores (M = 3.20, SD = 0.901). These results are coherent, since senior students have a better comprehension of construction topics and may feel more confident in their abilities to visualize construction methods necessary to build a structure. A test for skewness and kurtosis value showed that the distribution of confidence ability by school year for the three different groups is non-normally distributed.

D. Students' confidence levels – Inferential statistics

A two-way ANOVA helps to clarify how the levels of confidence perceived by undergraduate construction management students in their abilities to visualize construction methods necessary to build a structure differ by students' gender and school year. In this case, the dependent variable is the student's level of confidence in their abilities to visualize construction methods necessary to build a structure and the two factors are: (A) student's gender and (B) student's school year.

1) Assumptions to compute the three-way ANOVA

Normality – for big sample sizes ($N \geq 25$) the normality test would be unnecessary. However, considering the study sample sizes are not equal, with some sample sizes being quite small (female freshman & sophomore N=11/ female junior N=10/ Female senior N=14), the authors checked the normality of the data using the Kolmogorov-Smirnova test on gender and year. Results from those tests revealed that the normality assumption is violated and that it would be necessary to collect more data to correct for the unbalanced sample sizes. A higher number of female and freshman & sophomore participants is necessary, so that all the sample sizes are big enough ($N > 25$) to overcome issues related to eventual non-normal distributions.

2) Analysis of variance (ANOVA)

A two-way analysis of variance (Table XI) is used to test the hypothesis for the main effects of gender, and school year and the interaction effect between gender and school year:

- Gender: H_0: $\mu_F = \mu_M$ | H_a: $\mu_F \neq \mu_M$ (levels: F – female/ M – male).
- School year: H_0: $\mu_{FS} = \mu_J = \mu_S$ | H_a: at least one mean of the levels in school is different from other means (levels: FS – freshmen & sophomore/ J – juniors/ S – seniors).
- Interaction: H_0: there is no interaction effect between student's gender and school year | H_a: there is an interaction effect between student's gender and school year.

TABLE XI. ANOVA - TESTS OF BETWEEN-SUBJECTS EFFECTS

Dependent Variable: Confidence Ability						
Source	***Type III Sum of Squares***	***df***	***Mean Square***	***F***	***Sig.***	***Partial Eta Squared***
Corrected Model	10.786[a]	5	2.157	2.890	0.016	0.099
Intercept	1032.619	1	1032.619	1383.550	0.000	0.913
Gender	6.138	1	6.138	8.225	0.005	0.059
School_Year	0.198	2	0.099	0.133	0.876	0.002
Gender * School_Year	1.792	2	0.896	1.200	0.304	0.018
Error	98.519	132	0.746			
Total	1656	138				
Corrected Total	109.304	137				

The ANOVA suggests that for the main effect of gender there is a statistically significant difference between the levels of confidence perceived by male and female undergraduate construction management students in their abilities to visualize construction methods necessary to build a structure, $F(1, 132) = 8.23$, $p = 0.005$; therefore, the null hypothesis is rejected. As for the main effect of school year, there is not a statistically significant difference between the levels of confidence in their abilities perceived by freshman and sophomore, junior and senior students, $F(2, 132) = 0.13$, $p = 0.876$; therefore, the null hypothesis is retained. The interaction effect between gender and school year is also statistically non-significant, $F(2, 132) = 1.20$, $p > 0.05$; therefore, the null hypothesis is retained. Fig. 2 confirms non-statistically significant interactions between female and male students and the different school years. It also shows that for male undergraduate construction management students, the level of confidence in their abilities increases according to the school year, while for females the situation is the opposite, that is, the level of confidence in their abilities decreases according to the school year.

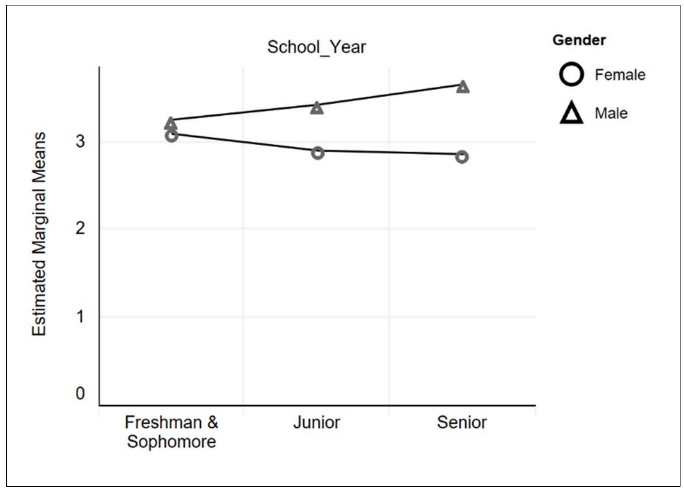

Fig. 2. Means of Confidence Ability by School Year and Gender.

The last procedure is to measure the size effect, i.e. to estimate how much variation in the dependent variable (students' confidence in their abilities) is explained by the gender (independent variable). Table XI provides the partial eta-squared for gender ($\eta^2 = 0.059$). However, we will measure the effect size based on the omega squared (ω^2), which is considered a lesser biased alternative to eta-squared, especially when sample sizes are small. The estimated omega-squared ($\omega^2 = 0.049$) reveals that only 4.9% of the variation is the students' confidence in their abilities is accounted for by the gender, therefore suggesting a very small size effect.

IV. DISCUSSIONS AND CONCLUSIONS

This study provides a list of topics deemed most difficult to visualize by construction management students. In addition, it allows for a better comprehension on how confident undergraduate construction management students are with regard their abilities to visualize construction methods necessary to build a structure based on information they read in plans and specifications.

First, the study showed which topics and subtopics were perceived as most difficult to visualize by students. Mechanical, electrical and plumbing (MEP) was rated as most difficult topic to visualize for students. Along the same lines, the ten sub-topics rated as most difficult to visualize by students also are related to MEP content. On the other hand, topics perceived as easiest were usually related to interior finishes.

Related to confidence, male students are more confident in their abilities than females. As for the school year, senior students are the most confident, followed by juniors, and the group of freshmen and sophomores. When gender and school year are analyzed as a set, it is interesting to notice that the group of the female freshman and sophomore students is more confident than juniors and seniors. These findings may be considered a little contradictory because usually, students feel more confident in their skills as their knowledge increases [10]. Students were not able to provide further input in the survey, but previous research on students' confidence suggests the influence of human interactions [10], [11]. Therefore, this may reflect inappropriate faculty-student or student-student interactions impacting negatively on how female students perceive their abilities in a program highly dominated by male students [10], [11].

Considering the male students, seniors are more confident in their abilities to visualize construction methods necessary to build a structure followed by juniors, and by the group of freshmen and sophomores, which is coherent with previous research suggesting that junior and senior students are more likely than freshman students and sophomores to have confidence in their abilities [10].

The study also revealed that the student's perceived levels of confidence in their abilities to visualize construction methods differed by student's gender but the estimated effect size of gender on the variation of students' confidence in their abilities is small. No statistically significant difference for the effect of school year on students' confidence in their abilities and no statistically significant interaction between gender and school year were found.

A. Implications for teaching

Based on the findings, faculty from undergraduate construction management programs can successfully work to encourage students' motivation and self-confidence. This can be done by providing additional learning scaffolds for certain topics deemed most difficult by construction management students, such as MEP related topics. Given the visual nature of most construction management students, that scaffolding should try to incorporate visual information.

Related to gender, our research suggests that instructors can adapt their teaching approaches according to students' gender. This is aligned with previous literature that has identified the implications of gender differences for learning in other disciplines and in engineering [10], [23]. One suggestion based on previous research involves improving task clarity and organization to increase women's confidence levels [10]. However, despite being identified as a relevant factor in learning in other disciplines and to account for differences in spatial visualization [24], there is still a lack of in-depth understanding of how gender affects learning construction management and related disciplines that warrants further investigations.

The authors are currently working to develop short videos that can aid the learning process of construction undergraduate students. The videos will cover the most relevant topics identified in the research, considering the information related to the students' confidence in their abilities to visualize construction methods.

B. Limitations

The unequal samples sizes of the different groups analyzed (gender, school year) may require collecting more data to correct for non-normal distributions. More data may result in a higher number of female and freshman & sophomore participants, so that all the sample sizes have more than 25 participants.

The research may not reflect the undergraduate construction management students' perceptions from all geographical areas of the United States, because the majority of the responses for the surveys (73%) came from students attending construction programs in the Midwest part of the United States, with a total of 54% of the responses from the state of Indiana.

In addition, the survey format was adequate to obtain information from many students and cover a large geographical area. However, more qualitative information can help understand the reasons for difficulty of each topic and therefore also provide meaningful information into how and which visualization material can help students.

C. Suggestions for further studies

Suggestions for further studies are to replicate the study in the hopes of achieving a better distributed sample size in terms of geographical location; to collect qualitative data related to perceptions of difficulty, construction topics and visualization of construction plans; to further research the effect of gender differences in learning construction topics; and more longitudinal studies on the levels of confidence of female construction students during their undergraduate degree and early career.

REFERENCES

[1] R. Felder and R. Brent, "Understanding Student Differences," *Journal of Engineering Education*, vol. 94, no. 1, pp. 57–72, 2005.

[2] T. S. Abdelhamid, "Evaluation of teacher-student learning style disparity in construction management education," *Journal of Construction Education*, vol. 8, no. 3, pp. 124–145, 2003, doi: 10.1016/0021-9673(94)00953-7.

[3] T. Hawk and A. Shah, "Using Learning Style Instruments to Enhance Student Learning," *Decision Sciences Journal ofInnovative Education*, vol. 5, no. 1, pp. 1–19, 2007, doi: 10.1007/978-3-642-11486-1_13.

[4] D. A. Kolb, *Experiential Learning: Experience as the Source of Learning and Development*. Englewood Cliffs: Prentice-Hall, 1984.

[5] R. Felder and L. Silverman, "Learning styles and teaching styles in engineering education," *Journal of Engineering Education*, vol. 78, no. 7, pp. 674–681, 1988.

[6] E. A. Holt, C. Chasek, M. Shaurette, and R. Cox, "The Learning Styles of Undergraduate Students in CM Bachelor's Degree Programs in the U.S.," *International Journal of Construction Education and Research*, vol. 14, no. 1, pp. 4–21, 2018, doi: 10.1080/15578771.2017.1342718.

[7] D. A. Kolb, R. E. Boyatzis, and C. Mainemelis, "Experiential Learning Theory: Previous Research and New Directions," *Perspectives on cognitive, learning and thinking styles*, vol. 1, no. 216, pp. 227–247, 2000, doi: 10.5465/AMLE.2005.17268566.

[8] S. M. Ahmed, C. Yaris, R. U. Farooqui, and M. Saqib, "Key Attributes and Skills for Curriculum Improvement for Undergraduate Construction Management Programs," *International Journal of Construction Education and Research*, vol. 10, no. 4, pp. 240–254, Oct. 2014, doi: 10.1080/15578771.2014.900833.

[9] A. Bandura, *Self-efficacy : the exercise of control*. New York : W.H. Freeman, 1997.

[10] C. L. Colbeck, A. F. Cabrera, and P. T. Terenzini, "Learning professional confidence: Linking teaching practices, students' self-perceptions, and gender," *Review of Higher Education*, vol. 24, no. 2. pp. 173–191, 2001, doi: 10.1353/rhe.2000.0028.

[11] L. J. Sax, "Mathematical self-concept: how college reinforces the gender gap," 1994.

[12] C. Leaper and C. R. Starr, "Helping and Hindering Undergraduate Women's STEM Motivation: Experiences With STEM Encouragement, STEM-Related Gender Bias, and Sexual Harassment," *Psychology of Women Quarterly*, vol. 43, no. 2, pp. 165–183, 2019, doi: 10.1177/0361684318806302.

[13] W. Edward Back, R. Macdonald, D. Grau, and A. Professor, "An Organizational Approach to Leadership Development for Engineering and Construction Management Project Practitioners," *International Journal of Business,Humanities and Technology*, vol. 2, no. 2, pp. 121–131, 2012.

[14] C. O. Egbu, "Skills, knowledge and competencies for managing construction refurbishment works," *Construction Management and Economics*, vol. 17, no. 1, pp. 29–43, 2010, doi: 10.1080/014461999371808.

[15] K. S. Baharudin, "Construction Management Skills for the Global Market," 2006.

[16] R. U. Farooqui and S. M. Ahmed, "Key skills for graduating construction management students - a comparative study of industry and academic perspectives," in *Building a Sustainable Future - Proceedings of the 2009 Construction Research Congress*, 2009, pp. 1439–1448, doi: 10.1061/41020(339)146.

[17] M. K. C. Hurtado, D. T. Kashiwagi, and K. T. Sullivan, "An Assessment Tool for Using Videos and Rich Media in Construction Man-agement Curriculum-A Case Study An Assessment Tool for Using Videos and Rich Media in Construction Management Curriculum-A Case Study," in *ASEE*, 2014.

[18] G. M. Bodner and R. B. Guay, "The Purdue Visualization of Rotations Test," *The Chemical Educator*, vol. 2, no. 4, pp. 1–17, 1997, doi: 10.1007/s00897970138a.

[19] S. Glick, D. Porter, and C. Smith, "Student visualization: using 3-D models in undergraduate construction management education," *International Journal of Construction Education and Research*, vol. 8, no. 1, pp. 26–46, 2012, doi: 10.1080/15578771.2011.619247.

[20] J. Irizarry, P. Meadati, W. S. Barham, and A. Akhnoukh, "Exploring applications of building information modeling for enhancing visualization and information access in engineering and construction education environments," *International Journal of Construction Education and Research*, vol. 8, no. 2, pp. 119–145, 2012, doi: 10.1080/15578771.2011.647247.

[21] S. Bhattacharjee, S. Ghosh, D. E. Young-Corbett, and C. M. Fiori, "Comparison of Industry Expectations and Student Perceptions of Knowledge and Skills Required for Construction Career Success," *International Journal of Construction Education and Research*, vol. 9, no. 1, pp. 19–38, 2013, doi: 10.1080/15578771.2011.647248.

[22] B. F. Bigelow, D. Bilbo, L. Ritter, M. Mathew, and J. W. Elliott, "An evaluation of factors for retaining female students in construction management programs," *International Journal of Construction Education and Research*, vol. 12, no. 1, pp. 18–36, 2016, doi: 10.1080/15578771.2015.1085927.

[23] A. Duff, "Approaches to learning: Factor invariance across gender," *Personality and Individual Differences*, vol. 33, no. 6, pp. 997–1010, 2002, doi: 10.1016/S0191-8869(01)00208-2.

[24] Y. Maeda and S. Y. Yoon, "A meta-analysis on gender differences in mental rotation ability measured by the Purdue Spatial Visualization Tests: Visualization of Rotations (PSVT:R)," *Educational Psychology Review*, vol. 25, no. 1. pp. 69–94, 2013, doi: 10.1007/s10648-012-9215-x.

APPENDIX

Sub-topics for each category are listed below:

Category	**Sub-Topic**
Site Preparation	Pre-Construction Utilities Site Clearing Building Layout Excavation Connection to Main Utilities Septic Systems Water Wells Retaining Walls
Foundation	Footers Slabs Foundation Walls Foundation Moisture Protections
Framing	Floor Framing Wall Framing Roof Framing Connections between Framing Elements Framing around Openings Stairs
Envelope	Exterior Cladding Insulation Air Sealing Roof Finishes Window & Door Installation Exterior Flashing Exterior Trims Deck
Mechanical, Electrical & Plumbing (MEP)	Air Ducts Electrical Wiring and Panels Drainage System Vent System HVAC Equipment Water Supply Plumbing Fixtures Smart Home Building Systems Energy Efficient Systems
Interior Finishes	Wood Floor Finishes Vinyl Floor Finishes Carpet Floor Finishes Tile Finishes Wall & Ceiling Paint Cabinetry Installing Doors Installing Trims Drywall
Site Finishing	Site Drainage Sidewalks Driveways Landscaping Pools

Note that students were also able to include an "other" option for each topic.