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Relationship between High School STEM Self-Competency and Behavior in a Parametric Building Design Activity

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Building designers receive discipline-specific education which prepares them to address distinct design goals, but they may struggle to address criteria not considered part of their profession based on their disciplinary identity. In STEM subjects, such as engineering, high school students' perception of their own competency is positively related to their performance. Although this is beneficial for engineering design, it is unclear how students who identify strongly with STEM prior to professional training may account for non-STEM design objectives compared to STEM-related criteria. This research considers how pre-design students' STEM self-competency can predict their behavior when responding to a building design task with technical and non-technical goals. A study was conducted which asked high school students about their STEM competency and instructed them to develop a conceptual skyscraper design in an age-accessible, digital design environment. The design tool contained a parametric model which provided visual and performance feedback about energy use, daylight, and cost as the students changed skyscraper variables. Students with higher STEM self-competency (SC) selected higher-performing designs, viewed more design iterations, and ranked the building's appearance as their lowest priority. These results inform future design educators about student outlook prior to any professional training and reveal potential limitations in student approaches to multidisciplinary building design tasks.

1.0 INTRODUCTION

Aspects of college students' career choices are influenced by how closely they identify with the subject matter, particularly in STEM fields [1], which may influence them to behave in a way they feel is emblematic of that profession [2]. This is relevant to majors such as engineering and architecture that require collaborative design expertise but can often define and approach their design goals differently [3]. Since design is a complex, challenging endeavor that requires both skillsets, educators in each profession may seek to avoid rigid self-classifications among students. For example, engineering majors can benefit from understanding they can be creative, synthetic thinkers, and architects can learn to incorporate calculations more productively during design.

Recent efforts in engineering education have sought to develop such crossover skills among engineers, including problem-based learning [4], [5] and integrated design studios with architecture students. As an approach to multi-disciplinary design, emerging parametric modeling tools, which can provide both geometric and numeric feedback, have been shown to improve design performance [6]–[8] and are a viable environment for design decision making [9]. It is unclear, though, how the disciplines approach these tools differently because of their varying professional training, outlook, and experience. In addition, little is known about how students may use these tools based on their design aptitudes at various stages of development. It is likely that as students gain training and eventual experience as designers, their approach to using a computational tool will increase in similarity to experts. This could be partially due to improving aptitudes, but it may also be influenced by a learned professional outlook or orientation. However, student perceptions of creativity and technical fields may emerge and even solidify prior to starting college coursework [10]. College-level instructors may thus encounter prior biases when formally teaching design to students for the first time.

Before entering secondary education, students are not yet characterized by an associated future profession—they are not yet "engineering" students. Instead, as the acronym STEM (Science, Technology, Engineering, and Math) has become a widespread term in education to strengthen and grow student awareness of these subjects, strong STEM associations may influence students' thinking about design in unintended ways. While positive exposure to STEM fields can lead to more participation in STEM activities, students may approach design tasks with a narrower, STEM-oriented focus, rather than a comprehensive solution that includes non-technical considerations. Previous research has shown that a student's self-perception of their performance in STEM subjects can positively predict their actual STEM performance [1], but less is known about how STEM-competent students navigate non-STEM goals, particularly if they identify more exclusively within STEM fields.

In response, this research examines how high school students' self-competency in STEM (STEM SC) relates to their design performance, exploration, and priorities when responding to a parametric building design activity. Three research questions are asked:

RQ1: How does student STEM SC relate to their *design performance* in parametric building design? In this study, "design performance" refers to the ability of students to generate solutions that have good performance in quantitative metrics such as low energy usage. Previous research shows that student self-efficacy and performance are positively related both outside of STEM [11] and in STEM [12]. However, this study evaluates performance specifically in a building design exercise with quantitative goals that are simulated within a parametric design tool. This relationship can reflect potential student effectiveness in technical building design, but it does not fully reflect student behavior. The extent of their exploration with the design space can suggest their intended engagement of the task, prompting the second research question:

RQ2: How does high school student STEM SC relate to their *design exploration*? Engaging with many possible solutions can reflect a designer's intent and suggest a level of interest in the material. Hazari acknowledges interest as a measure for identity in STEM subjects [13], and iterative exploration is fundamental to problem-solving [14]. Yet building design tasks often have many goals which may capture designers' interests differently, as they may prioritize some criteria over others. The third research question asks:

RQ3: How does student STEM SC relate to the *design criteria* that they value? In building design, rarely is a single design consideration isolated from holistic problem solving. Multidisciplinary problem-solving is necessary but may be limited if a student with a strong STEM SC does not value goals that are not considered part of traditional STEM criteria, such as aspects of building appearance.

To answer these questions, a study was conducted at a high school in the Northeastern United States that asked students about their relationship with STEM both directly and indirectly. They then respond to a building design task with three technical criteria and one qualitative criterion. Students worked in a readily accessible parametric modeling tool that collected information about their exploration and performance, while a survey recorded their priorities when designing. Design performance was assessed using simplified performance simulations for building cost, energy use, and artificial light required. These relative metrics were presented back to students during their exploration, allowing them to prioritize between quantitative and qualitative objectives. The resulting correlations can prompt educators to incorporate more intentional multi-disciplinary thinking in K-12 curriculum to better prepare students for complex problems if they pursue design professions.

2.0 BACKGROUND

Considerable research has already been conducted on engineering creative thinking and STEM education. However, less is known about how students' natural approaches to a design task might be influenced by STEM self-competency before initial exposure to formal design training of any type. We use the term self-competency to describe students' perception of what they can accomplish with their abilities, following Susan Harter [15], but applying the concept to more specific academic subdomains. In addition, theoretical frameworks such as expectancy-value theory support that students' expectancy to be able to perform a task, combined with students' value of a task, can predict outcomes of engagement and achievement [16], [17] (CITE). Assessing self-competency also allows us to engage with literature that considers performance-competency as an indicator for identity, which is central to our research, since professional identify formation may influence design behavior.

Further, we consider "exclusive" self-competency by asking students about their abilities in STEM versus non-STEM courses on a continuum. While students may be good at both types of subjects, American architecture and engineering programs usually enforce a binary—with few exceptions, students will largely graduate with professional training and a degree in only one or the other. In this context, the goal is to understand how far a student may be identifying in either direction prior to receiving any formal design training. We thus begin the review with what has been established about engineers and architects' design behavior, before working backwards to how these behaviors may have been influenced earlier in education.

2.1 Design Thinking in Engineering and Architecture

Effective building design requires both technical and experiential considerations, which are addressed by engineers and architects through their disciplinary expertise. Although their distinctions may be less clear with newer digital tools, it has been observed that the professions approach design differently in pursuit of their disciplinary goals [3] and receive distinct professional training. This training is useful when addressing their expert tasks but may cause conflict when addressing multidisciplinary problems. Engineering students mostly follow outcome-based strategies [18] but can struggle to solve open-ended or ill-defined tasks [19], especially if their curriculum has not adequately prepared them for these problem types that occur in the workplace. On the other hand, architecture students are strong at creative thinking, but may shy away from rigorous quantitative analysis [20]. Thus, university-level instructors may need to consider how they promote potential design orientations by the tasks they assign and provide design environments that require diverse approaches to problem-solving.

2.2 Parametric Thinking and Modeling in Design

One context in which design creativity might be stimulated is parametric modeling, which allows designers to generate and consider a wide range of potential solutions. In parametric modeling, variables control characteristics of a building such as height and window size, while performance objectives can be calculated rapidly, sometimes even providing live design feedback depending on the scale of the problem. Design solutions can then be explored by both architects and engineers for qualitative and quantitative properties. These tools have been used in previous research as a viable environment for design decision making [6], [7], [21], [22]. Professionals have also used parametric modelling in practice when iterating design performance analysis, such as ARUP [23] and Foster + Partners [24]. In addition, computational thinking has been incorporated in student education [25], and parametric models have been used as teaching tools to improve learning [26] and support STEM education [27], [28].

Thus, even though exploration in a parametric design tool does not represent a comprehensive design process from start to finish, it is intuitive enough for even K-12 students and can capture some design behavior. Understanding how pre-design students use these tools prior to professional training can inform strategies for their disciplinary education, but grade school students may not have a clear understanding of what is expected of building design fields. A more relatable, generalizable proxy is needed to measure their potential success and identity in building design professions.

2.3 The influence of STEM

In the last two decades, a strong emphasis on STEM subjects has empowered young thinkers, given agency to groups underrepresented in the fields [29], and accentuated STEM recognition early in grade school. Incorporating STEM concepts early can have potential benefits, such as fostering student positive perception of STEM values [30] and increasing interest in STEM related fields for future careers [31], [32], but it could also contribute to challenges in cross-disciplinary problem solving. Children begin to identify their career interests and aspirations as early as elementary school [33]–[35] and greater STEM identity leads students to pursue STEM fields in their career [1]. However, there are also negative stereotypes surrounding STEM, such as it being less creative and boring [10], which can have negative impacts on student pursuit of STEM professions and STEM self-competency. These stereotypes may be influenced by real factors such as the fact that performance in math, often perceived as less creative, is a reoccurring predictor for STEM pursuits when compared to other subjects and influential variables [36], [37]. For pre-engineering students who perform well at math, many may come to college thinking that as a "STEM student" they are only good at solving numerical problems, while pre-architecture students may have negative associations with STEM and be intimidated by calculations. Therefore, how a student perceives STEM can influence their building design pursuits.

Discerning how students think of STEM relies on various social identity theories [38]–[40]. STEM identity has been defined as how well individuals see themselves as an accepted member of STEM [41] or if they think of themselves as a scientist, technology user, engineer, or mathematician [42]. Subdividing identity into three interrelated components, Carlone and Johnson [43] defined STEM identity as *performance* (demonstrate activity), *competency* (knowledgeable in activity), and *recognition* (credible by others). Accounting for a person's sense of choice in self-perception, Hazari [13] built on Carlone and Johnson to add *interest* to STEM identity. Hazari also combined performance with competency to measure an individual's belief about their own abilities to perform and understand a STEM subject. However, both Carlone and Johnson and Hazari focused on only science subjects in STEM. To understand identity more broadly, Dou and Chian [44] surveyed all STEM fields individually, relying on performance-competency as an indicator for identity along with recognition and interest. Their research acknowledged that recognition and interest can be difficult to define depending on a student's understanding of what is involved in STEM fields and students are not yet in career positions for professional recognition. As a result, performance-competency can capture both ability and perception of efficacy, and it is a predictor for better performance [11]. Additionally, greater STEM self-efficacy has been shown to predict improved STEM performance [1].

While some studies have separated engineering from other STEM fields for more specific understanding of the profession [45], [46], this paper also considers differences between engineers and architects, which both contribute to building design. STEM has always included "engineering," but "architecture" was not officially recognized by Congress as a STEM subject until 2019 [47]. It is unclear if the general population is aware of its recent inclusion. Nevertheless, there is a call for more systematic research of how STEM and design relate in education [48], [49].

Based on gaps in the research, this paper examines if STEM SC can predict pre-design student performance and engagement in a building parametric design tool, and how the students prioritize different criteria. How students use parametric tools prior to formal training is important because this is an emerging environment for multi-disciplinary building design.

3.0 METHODS

This paper studies STEM SC and design behavior in an intuitive, age-appropriate design exercise facilitated in an online computational design tool.

3.1 Participants

The IRB approved study was conducted at a public high school in the Northeastern US with 107 ninth and tenth grade participants. The overall high school population is 71.4% white with a total minority enrollment of 28.6%. The school performs between 17-28% above average in the state's annual Mathematics, Reading, and Science proficiency exams with a 91% graduation rate. Of the participants, 50 were boys, 53 were girls, 3 were gender non-conforming, and 1 preferred not to answer. All students were enrolled in the Environmental Sciences or Chemistry class at the high school in either honors or non-honors tracks, based on the school's distinctions of academic rigor. Of the participants, 67 were honors students and 40 were not.

3.2 Design Session

The study protocol was conducted during the school day and lasted 1 hour and 15 minutes. The activity was voluntary and parental consent was obtained. An alternative activity was provided for students who chose not to participate. Students were not graded on their performance, and the activity did not relate to their coursework. The study design included an intake survey, two introduction videos, a design session, and a final survey (Figure 1). The intake survey captured their demographics and STEM SCs; the videos introduced skyscrapers and the design task; the design tool used during the design session recorded the students' design exploration and final design performance; and the final survey asked the students which of the design criteria they prioritized when designing.

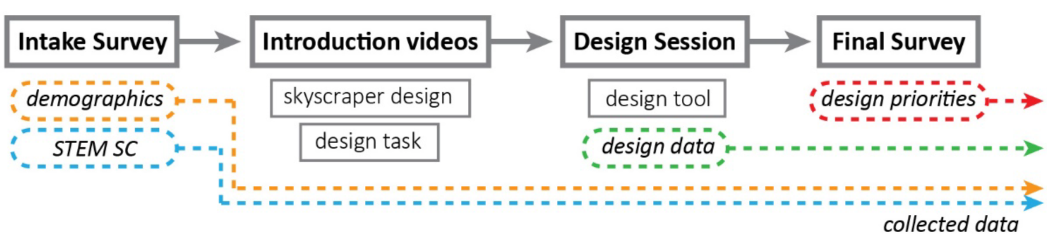

Figure 1. *A summary of the protocol during the design sessions*

3.2.1 Preliminary Material

At the beginning of the study, students completed a survey which collected demographic information and asked about their self-competency in STEM. In this survey, the acronym for STEM was spelled out so the students were aware of which subjects were included in the category of STEM. Self-competency was isolated from other dimensions of STEM identity to narrow potential variations in STEM biases, which can occur with recognition and interest. The participants may not understand architecture or engineering professions specifically to determine their personal interests, nor have they yet entered the professions to be recognized for their efforts. The focus of the research was not disclosed to the students to avoid influencing their perceptions of the questions and research task. They were asked "Which statement most accurately describes you?" and responded by moving a slider between "I am strong in STEM related subjects" and "I am strong in subjects not considered part of STEM," with the slider starting in the middle. When recording their STEM Self-Competency (STEM SC), it was important to not bias student responses with leading phrases that would prompt undue associations.

We followed a similar question structure from a previous study of STEM competency which provided statements such as "I think I am very good at: Figuring out science activities," and students responded with how closely they agreed [50]. While agreement style of survey questions are legitimate forms of data collection, in the context of our study, this type of question may suggest a "yes" response as affirmative, while a "no" may be viewed as negative. Therefore, our question about STEM SC was intentionally phrased in a neutral way to enable students to emphasize strengths in different areas. Self-competency in STEM is not inherently exclusive and if a student felt like they identified with both statements, they could place the slider in between the options. In answering the third research question, students who view themselves more exclusively in a STEM context may be limited in their approaches to consider multidisciplinary design criteria. In addition, providing a concise question as opposed to a multi-faceted questionnaire also avoids student survey fatigue as a part of the study session. Although the slider was not presented numerically to students, results were captured in discrete settings.

The students were shown an 8-minute video made for the study that presented skyscraper design ideas and focused on building characteristics of energy, daylighting, cost, and appearance. The video advised that skyscrapers are advantageous when they are larger because that increases the square footage, but that increases costs. A building with a larger surface area also allows for more natural daylight through windows, reducing the need for artificial light during working hours, but this larger building will also use more energy. Participants were shown ten examples of built skyscrapers, illustrating a range of form and color, to explain how appearance is also an important part of skyscraper design to give a city or building tenant an identity.

3.2.2 Design Task

The design task asked students to present a solution for a new skyscraper in Austin, TX that would serve as a high-performance office building for Google. To help focus their design efforts, the students were advised to minimize three technical goals of energy use, artificial light, and cost, but were also provided the freedom to prioritize between each. These goals are the study's Objective Metrics. The quantitative goals had inverse relationships such that no perfect design exists where all three criteria can be minimized. They were also told that Google wanted a visually appealing design as a non-technical design goal.

3.2.3 Design Tool

A digital tool was developed that allowed the students to work in 3D modeling space without previous modeling skills and provided the students with live performance feedback about their designs. The tool also collected data about the students' design behavior and performance of their final design. Participants used a custom website created for the study using a file hosting platform called Shapediver [51]. The Shapediver API was used to embed a pre-built Grasshopper file which defines 3D geometry, variables, and design performance values. The skyscraper model with surrounding site context had eleven variables and provided quantitative feedback for the three objectives through a dynamic bar graph which changed with the variables. Seven of the variables edited the geometry of the skyscraper and four of the variables changed aspects of the exterior enclosure panels.

All variables impacted at least one performance metric, except for the color of the panels, which related only to the buildings' appearance. The underlying values of the performance bars, not shown to the users, were calculated based on the intuitive behavior of a building with similar features. These simplified relationships prevented the need for running full simulation programs to supply quantitative feedback, avoiding design fatigue. The quantitative objectives have different dimensions of measurement and were thus normalized and presented in graphical form for easy student interpretation. The students' goal was to minimize the objectives, but since the objectives have inverse relationships, no solution minimized or maximized all. An overview of the tool is provided in Figure 2, showing the website interface with the skyscraper model and performance bars, along with the design variables. As the students worked in the tool, the website collected data about how often they changed each variable and recorded the final objective values at the end of the session. The final objective values were averaged to measure the Objective Performance.

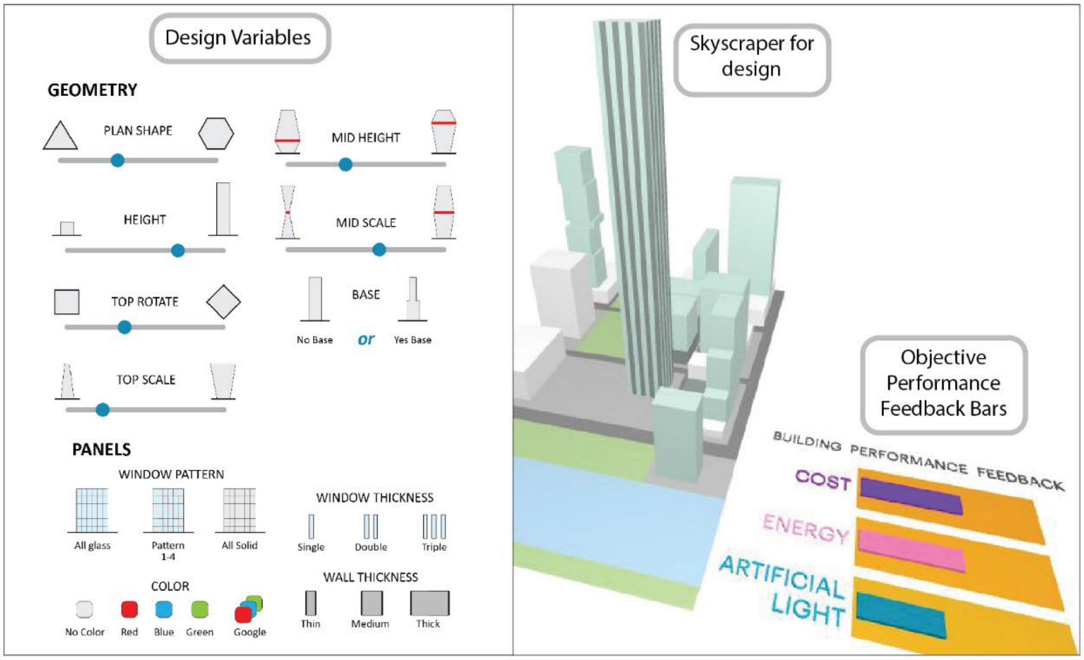

Figure 2. *Sample of the design tool showing the 11 variables and the modeling space with the skyscraper and performance feedback bars*

As the students worked in the tool, the website collected data about how often they changed each variable and recorded the final objective values at the end of the session. The final objective values were averaged to measure the Objective Performance.

3.3 Assessment

This study focused on STEM Self-competency and the three Objective Metrics as proxies for student design behavior because of their relevancy to building design thinking and the population of interest. Linear regression models of the study's Objective Metrics vs STEM SC were used to determine if STEM SC is a predictor for the Objective Metrics. *Design performance* was determined by how well the students minimized the task's design criteria. STEM design performance is a part of STEM identity [43] and is a proxy of quality in creativity for the SVS and CAT methods. The number of *design iterations* can also positively reflect model engagement since iterative exploration is considered intrinsic to creative problem-solving [14] and can also account for a student's interest in the subject material. Prioritization of objectives, particularly "appearance" as a non-STEM goal, was measured directly through a survey. Collectively, these assessments suggest how pre-design student perception can predict their design behavior in the parametric building tool and incorporate multi-disciplinary design in the future.

4.0 RESULTS

A sample of final design screenshots is shown in Figure 3. Although this study did not investigate visual performance of the students' designs, the samples are presented to show the range of visual solutions, by color, shape, and window patterning, that the students developed in the parametric space.

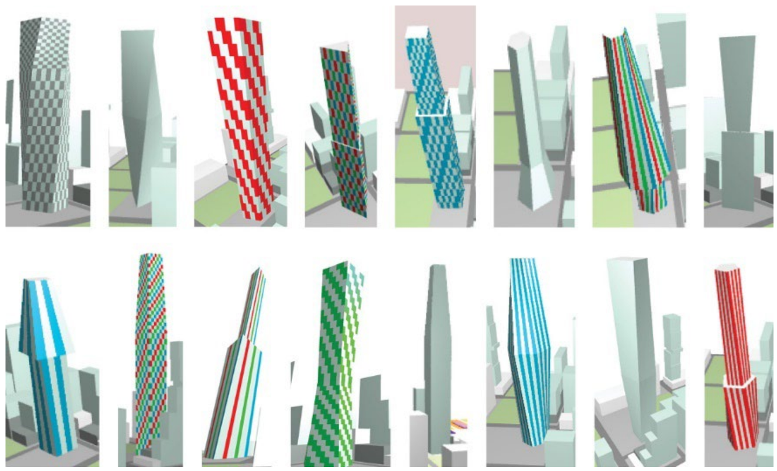

Figure 3. *A sample of 16 final designs provided by the student*

Figure 4 shows the distribution of STEM SC of the students where 0 indicates that the students reported more exclusive strong performance in STEM subjects and conversely 10 indicates that the students reported strong in subjects that are not considered part of STEM. The histogram of students' STEM SC leans slightly towards STEM related subjects with a median value of 4 and a mean of 4.45. A normal, centered distribution was not expected since STEM SC is not necessarily well distributed across all populations, and the study was conducted in an Environmental Science class.

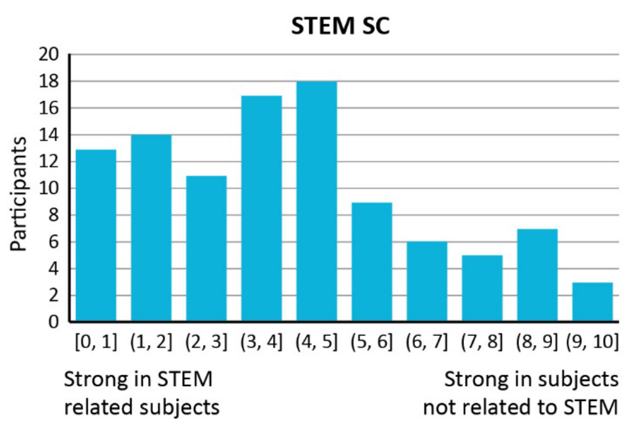

Figure 4. *Histogram distribution of the students STEM SC*

4.1 Design Performance and STEM SC

Because the goal of the design task was to minimize the objectives, a *larger Objective Performance* value indicated a *poorer performing design*, where a smaller Objective Performance was desired. Figure 5 shows a histogram of the Objective Performance values and a plot of STEM SC and Objective Performance. The *p*-value for the Regression Analysis of students' STEM SC and Objective Performance is $p=0.001$, so there is sufficient evidence at the $\alpha=0.05$ level to conclude that STEM SC can predict student performance. The left end of the x-axis indicates students who identified more closely with STEM and the right are those who identified more with non-STEM subjects. Students who associated themselves more closely with STEM subjects had quantitatively better performing designs.

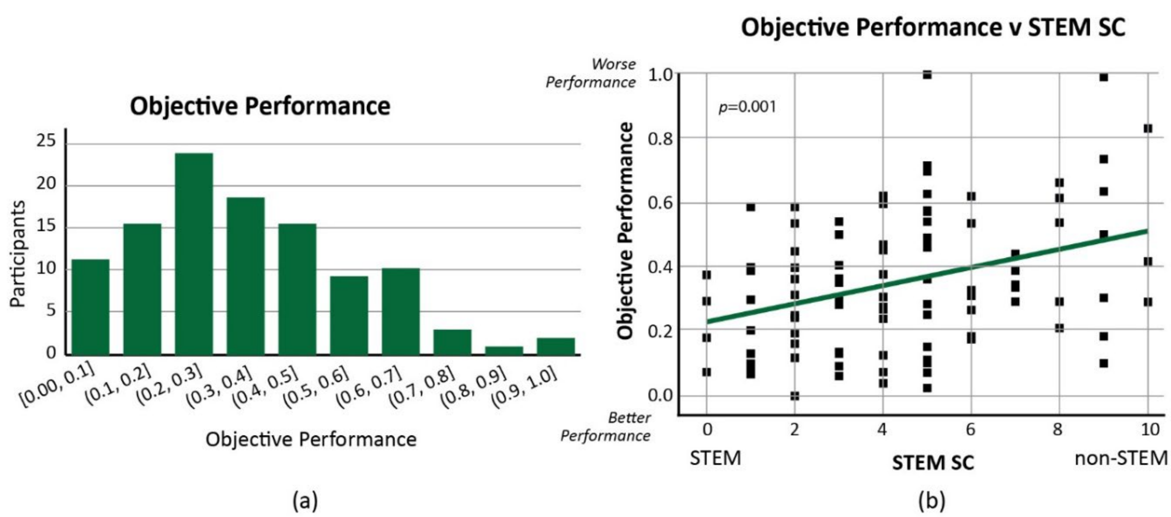

Figure 5. *(a) the distribution of Objective Performance values and (b) a plot of Design Performance v STEM SC, showing the regression line of the data*

4.2 Design Exploration and STEM SC

This research is also interested in understanding the relationship between STEM SC and student exploration in the parametric design tool. Figure 6 shows the distribution of iterations, with the fewest number being 8 and the greatest being 259, and a plot of STEM SC versus Iterations. The *p*-value for the regression analysis of students' STEM SC and Iterations is $p=0.008$, so there is sufficient evidence at the $\alpha=0.05$ level to conclude that STEM SC can predict the number of iterations students considered in the design task. The left end of the x-axis indicates students who identified more closely with STEM and the right are those who identified more with non-STEM subjects. From the regression line, closer STEM identifying students explored more iterations.

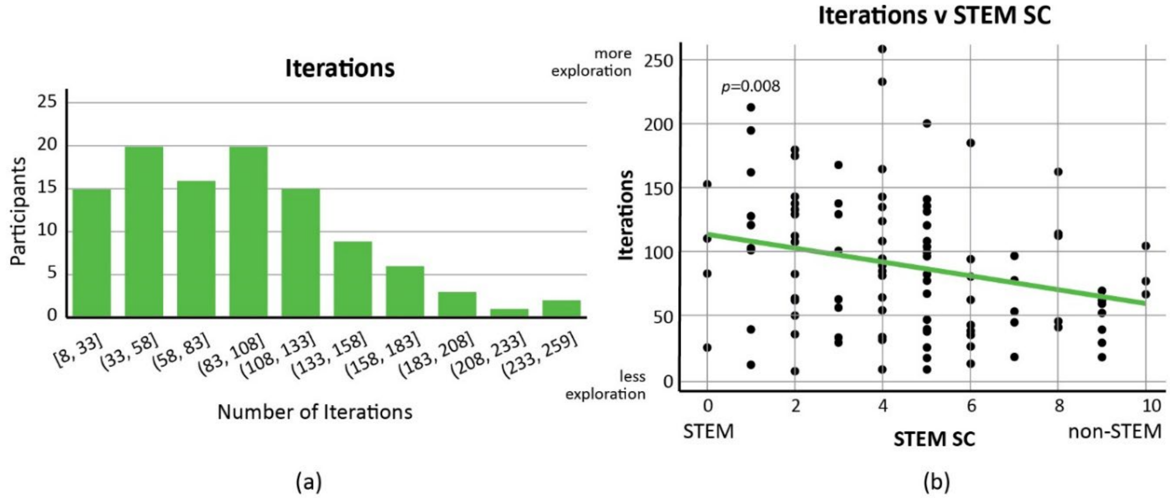

Figure 6. *(a) the distribution of iterations and (b) a plot of iterations v STEM SC, showing the regression line of the data*

4.3 Design Focus and STEM SC

How the students ranked criteria in order of importance was also recorded. Figure 7(a) shows the number of students who ranked each criterion by priority. A rank of 1 is the highest rank while 4 is the lowest. While a greater number of students ranked "appearance" as their most important criterion compared to the other criteria, "appearance" was also the lowest priority for a larger number of participants. Figure 7(b) shows a plot of STEM SC to appearance rank with the fitted regression line and the p-value of the Regression Analysis. With a p-value of $p=0.062$, STEM SC does not predict Appearance rank; adjusting to a $\alpha=0.10$ level would indicate significant prediction. In the context of this research, it is worth considering the positive relationship between higher STEM SC and ranking appearance as a lower priority.

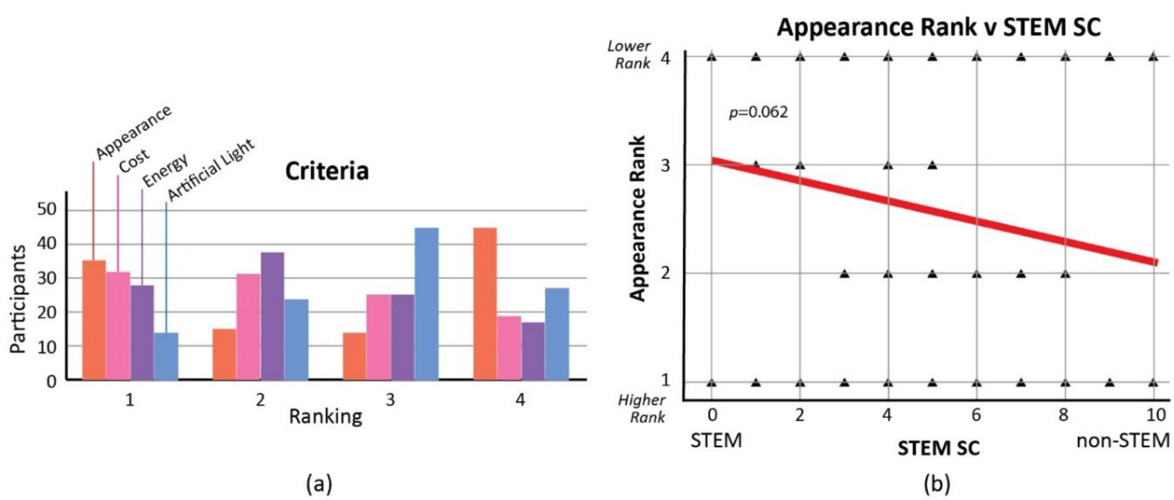

Figure 7. *(a) the number of participants who ranked each criteria and (b) the fitted line plot of the regression analysis for Appearance Rank v STEM SC*

4.4 Additional variables for future consideration – gender and honors courses

Although they are not the main focus of this study, there has been considerable recent interest in how STEM identity relates to both gender [38], [52] and participation in honors-level courses [53]. In this section we provide preliminary consideration of these factors as they may complicate our narrative. However, the intention here is to stimulate further discussion and research rather than present new claims. Excluding the small number of alterantive responses, the p-value for the Pearson Correlation between Class Type and Gender was p=0.215, which can be considered nearly uncorrelated, so we investigated the variables seperately without concern for collinarity between the groups.

Linear Regressions of the variables were run for each of the study's objective metric on STEM SC for Class Type and Gender. Table 1 shows each of the p-values for each regression. Values that are significant at a α=0.10 level of significance are bolded. For Honors students and Boys, their STEM SC was significant in predicting their Objective Metric, while STEM SC was not a predictor of the Non-honors students and Girls.

	Iterations	Objective Performance	Appearance Rank
Honors	**0.005**	**0.002**	**0.085**
Non-honors	0.971	0.239	0.794
Boys	**0.005**	**0.000**	**0.098**
Girls	0.411	0.257	0.214

Table 1. P-values of linear regression analysis of the study's Objective Metrics vs STEM SC, with values of significance bolded

5.0 DISCUSSION

Overall, the findings suggest that more exclusive self-competency in STEM does relate positively to performance and model exploration in a parametric building tool while designing, which is advantageous if these students pursue STEM or building engineering careers. However, the study suggests that strong STEM SC could bias their ability to value qualities not considered part of STEM, leading to challenges in multi-disciplinary problem solving later in their education or careers. Examining the results by research question describes the relationship in more detail.

RQ1: How does student STEM SC relate to *design performance* in parametric building design? Students who expressed greater exclusive self-competency with STEM developed better performing designs, based on the tasks three quantitative criteria. It was expected that students who had greater STEM SC would navigate the technical objectives better than Non-STEM SC students, however, it was possible that the parametric building modeling tool would prompt different results in a new design space. It is necessary to also consider to what extent the students engaged with the tool.

RQ2: How does student STEM SC relate to their *design exploration*? The students who identified with greater STEM SC considered a greater number of iterations within the design space. Creating more iterations can reflect greater interest in the activity, as students may iterate while divergently exploring the design space to generate and consider very different options. If the number of design iterations did not vary by STEM SC, it could be that the design tool limited creativity or that the tool or task were not responsive to STEM identity. However, the students' STEM SC did predict interaction exploration indicative of engaged, creative problem-solving. It is worth noting that creating more iterations alone does not fully capture the students' response to the design task and their perception of non-technical goals, as they might have also iterated repeatedly on only slightly different design outcomes seeking the best possible design.

RQ3: How does student STEM SC relate to the *design criteria* that they value? Student STEM SC did predict "appearance" rank at a $\alpha = 0.10$ level of significance, as students with strong STEM SC ranked it a lower priority compared to the other criteria. This inverse relationship can suggest students with a greater STEM SC may not value visual architectural goals as highly as quantitative goals. This could be a barrier to cross-disciplinary thinking in their professional pursuits.

These conclusions can inform how K-12 educators approach presenting STEM topics. As expected, students who identified closer to STEM had better performing technical designs, but they also ranked "appearance" lower on their priorities. If the STEM-identifying students pursue careers in building design, they may struggle to incorporate non-technical goals in their design. Interdisciplinary design can be challenging to achieve [54] and research has shown that engineers can sometimes struggle to understand other viewpoints, but difficulty with multidisciplinary design is not ubiquitous to all engineers [55]. As observed in this study, the more exclusive STEM-identifying students created more iterations, which indicates greater engagement and may also show an interest in design exploration. For educators, concepts of STEM should be introduced in the context of other dimensions of design so that students can think in a multi-disciplinary way. A summary of the results is shown in Figure 8.

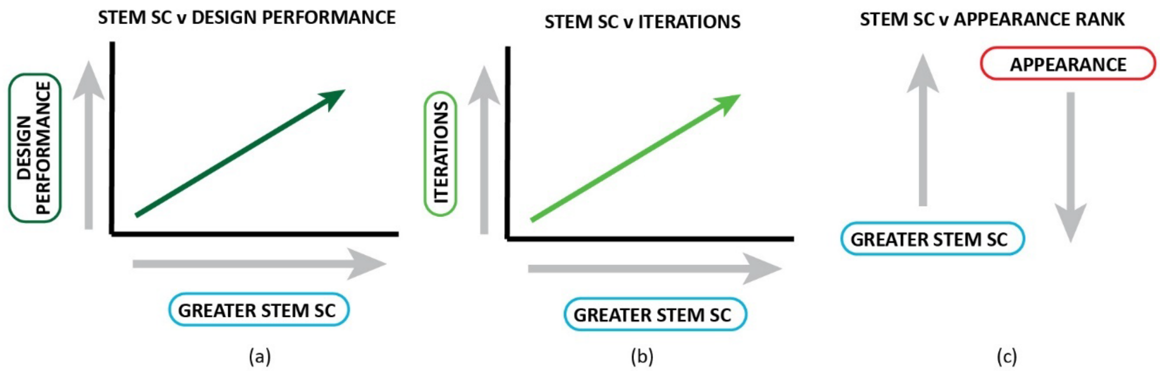

Figure 8. Graphic summary of the results, with STEM SC relationship to (a) design performance, (b) iterations, and (c) appearance rank

There are several limitations and areas for future work. While this paper focuses on relationships between STEM SC and various characteristics of design behavior, it does not exhaustively consider additional variables that may influence STEM identity in the first place. As shown in our dataset, gender and participation in Honors courses may have even stronger correlations with our Objective Metrics than STEM SC, and there are statistically significant differences in behavior when comparing populations with these characteristics. In addition, the students' enjoyment, as an extension of interest, in responding to the building design task was shown in our dataset and did not predict our Objective Metrics. Such variables likely influence both STEM SC, tool usage, and design behavior in complex ways, but they are left for future study. This paper also relies on a single continuum question to evaluate "exclusive" STEM SC. Future work can incorporate additional assessments of self-competency and/or self-efficacy while determining how they relate to design behavior. Design behavior could likewise be evaluated for different building types and other variables.

6.0 CONCLUSION

This paper presents a design study which investigated how high school student self-competency in STEM relates to design behavior in a parametric building tool. As parametric tools are increasingly used in building design fields, understanding how pre-students navigate parametric spaces is valuable in improving their education as future designers since these tools can challenge them to consider multidisciplinary criteria. The study used a parametric skyscraper design task to collect information about the students' design activity. While a different task may elicit different results based on students' interests, aspects of skyscraper design are reoccurring challenges for architects and engineers, requiring synthesis between technical and experiential design goals. In this study, the students who reported greater self-confidence with STEM subjects developed better performing designs and explored more iterations, but they also ranked "appearance" as a lower priority. These results suggest that varied design approaches that are eventually interpreted as disciplinary differences might seem natural before any formal design training occurs. They also inform educators about gaps in expected student performance in parametric tools and suggest that pre-designer education should emphasize multidisciplinary problem-solving to avoid narrowing student competency for those interested in design professions.

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