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Exploring children’s goal orientation in engineering design activities

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Abstract

This mixed-method study focuses on young children's engagement in engineering design activities through the lens of goal orientation. The purpose is to build evidence-based knowledge for educators and researchers to better support children's motivation in engineering. The preliminary results indicate that young children (7-14 years old) have multifaceted goal orientations while engaging in engineering activities, and their goal orientations may be related to the context and setting of the activities (e.g., physical and social environments). The data also indicate differences between families of historically minoritized communities and general museum visitors and caregivers' goal orientations for their children's learning.

Introduction

There is a longstanding problem of the overall lack of diversity in the engineering workforce, and the particular underrepresentation of certain gender, racial and ethnic groups, in engineering education [1], [2]. The issue is even more pressing today given that the nature of engineering itself has been evolving to require more collaborative and culturally-aware responses to the complex challenges faced by modern society [3]. Even though engineering education has been emphasizing changing student demographics over the last ten years, much of the research on how to accomplish this has focused on efforts to shift teaching practices and to better recruit and support diverse student bodies only in existing undergraduate, graduate, and professional training programs, neglecting young learners' needs and access (e.g., [4]). To address this issue, more recent research has emphasized the importance of an early introduction to the engineering field and recommended further programmatic investment and additional research at the primary and secondary education levels [3], [5], [6]. This call matches a related set of findings emerging from motivation research that sought to better understand K-12 students' choice and pursuit of STEM careers [7], [8]. This body of work has indicated consistently that underrepresented children and youth are less likely to develop STEM identities or pursue career pathways than non-minority students, especially in the field of engineering [9], and the choices made by children, especially underrepresented children, to pursue various STEM disciplines are strongly associated with their perceptions of self-efficacy, competence, interest, social support, and the discipline's costs and benefits [10], [11], [12]. Yet, despite the recognition of this issue, limited research has been conducted on young children's motivation in engineering education.

This study aims to address this issue by investigating young children's motivation in engineering through the lens of goal orientation. The importance of students' goal orientation has been well-studied and documented in the formal education field [13] - [16]. Goal orientation focuses on *why* and *how* people are trying to achieve various objectives, and generally can be conceptualized as "an end state that is centered on competence—either developing it (i.e., mastery-oriented) or demonstrating it (i.e., performance-oriented)" [17]. Researchers further crossed the two orientations with approaching positive outcomes or avoiding negative ones, leading to a two-by-two matrix of four achievement goal orientations, namely mastery-approach, mastery-avoidance, performance-approach, and performance-avoidance. Strong evidence has indicated the influence of goal orientation on students' learning outcomes and academic achievement. In particular, studies have consistently shown that mastery-approach goal orientation is positively related to students' deeper learning, self-efficacy, and intrinsic motivation, leading to long-term engagement with STEM professions [17]. Studies also suggested that a performance-approach goal orientation or multiple goal orientations can benefit students' achievement [18], while some studies suggested that performance-avoidance goal orientation may be related to maladaptive learning outcomes, especially for underrepresented students [19], [20].

In engineering education, there are a number of studies that have adopted goal orientation as a framework to investigate engineering students' motivation [21]. Most of these studies, however, targeted graduate, undergraduate, or high school students, and little research has focused specifically on younger children. Meanwhile, research on children's engineering design and design thinking (e.g., [22]) and related motivation constructs, such as identity or attitude (e.g., [23]), has increased in the past few years. Often featuring hands-on, project-based tasks and learning experiences, engineering design activities provide opportunities for children to work on real-world challenges using engineering tools and materials within contexts that focus on problem-solving and systems thinking.

This study aims to bridge these two research fields—goal orientation and engineering learning--to advance our understanding of how to foster young children's engineering education. Given that there is limited prior research in this area, we use a design-based approach to investigate these research questions:

1) What are children's goal orientations while participating in engineering design activities? How are the goal orientations that manifest in engineering design activities related to children's engagement? Is there a difference between minoritized and non-minoritized children's goal orientations?
2) What are the potential factors that may be related to children's goal orientations in informal engineering experiences, such as the caregiver-child interaction, social environment, and the setting of engineering activities?

Methods

This study is being conducted in a science museum that focuses on exploratory, visitor-centered engineering learning experiences. The museum's immediate local communities are highly diverse, with nearly two-thirds of the current population being foreign-born, 81% of residents speak a language other than English at home [24], 52% are Hispanic, coming primarily from Central and South America, and 34% are Asian. Approximately, 23% of households are living at or below the poverty line [25]. Participants were recruited a) on the museum floor during museum hours (including free hours), and b) through family and/or community programs that specifically invited local families through schools and museum connections (e.g., community appreciation events). The engineering design activities used for data collection included classic museum-based engineering challenges: air-powered vehicles, where children use everyday materials to design and construct a vehicle powered only by air to travel over different terrains, and ziplines, in which children design and construct a means to deliver toy animals or other objects of interest safely from one location to another.

The preliminary data includes 131 family visitor groups with young children ages 7 to 14 years old (M = 9.71, SD = 1.94, 48% female, 37.4% are local, defined by zip codes). Data included child and caregiver surveys, observations, and interviews. The child survey consisted of 10 items with a 5-point Likert scale, targeting children's goal orientation (e.g., I want to show other people how smart I am when I am doing this activity; a performance-approach item) and children's perceived goal orientations of their caregivers (e.g., My parents would like it if I could show that I do better work than other kids.). The caregiver survey consisted of 9 items targeting caregivers' goal orientations for their children (e.g., I would like my child to show others that she/he is good at classwork.). The instruments were developed based on prior goal orientation research (e.g., PALS [26]). The exploratory factor analysis of child survey data indicated that children had an overall performance goal orientation, instead of separate performance-approach and performance-avoidance goal orientations. The mastery avoidance goal orientation was cross-loading with both performance-approach and performance-avoidance goal orientation but is separated from mastery approach goal orientation. The final two-factor model—overall performance goal orientation and mastery-approach goal orientation—yielded a good model fit ($X^2(8) = 12.63$, $p > .05$, RMSEA = .07, CFI = .97, TLI = .94, SRMR = .05, Cronbach's $\alpha = .70$). The caregiver survey data also yielded a good model fit with a two-factor construct—performance-approach goal orientation and mastery-approach goal orientation for their children ($X^2(24) = 45.09$, $p < .01$, RMSEA = .08, CFI = .96, TLI = .94, SRMR = .06, Cronbach's $\alpha = .79$). All models were estimated by using Stata 15.1.

The observation and protocol and interview questions (e.g., What were you thinking about when you were looking at other people's work?) for children's goal orientations were developed based on our pilot data through clinical interviews with children and families at the museum. For engineering engagement, the observed engineering practices are documented via observing and tallying indicators of behaviors exhibited by children engaging with engineering activities (e.g., problem-scooping, iteration, testing, and persistence). The observation protocol was based on recent studies that observed engineering design practices in informal learning environments [27]. The final dataset will include approximately 200 participants when shared at the conference.

Results

Even though the data collection and analysis are ongoing, several patterns have emerged. First, the descriptive statistics indicated that children had both performance and mastery goal orientations while engaging with the activities. In addition, children had a higher score on mastery-approach goal orientation than the overall performance goal orientation ($t(1, 260) = -3.05$, $p < .01$). The Wilcoxon signed rack tests showed that children's scores on perceived performance goal orientation of their caregivers were significantly higher than perceived mastery goal orientation ($z = 3.18$, $p < .01$, $r = .20$), which was opposite from caregivers' goal orientations for their children, showing a higher mastery-approach goal orientation than performance-approach goal orientation ($z = 8.20$, $p < .01$, $r = .51$). Comparing the local families and non-local families, the analysis showed local caregivers had significantly higher scores on performance goal orientation for their children than non-local caregivers ($z = 2.31$, $p < .05$, $r = .20$). We expect these patterns will be strengthened as the number of participants will increase. No difference was found between genders across all variables.

The correlation analysis (Table 2) showed that children's overall performance goal orientation is related with their mastery-approach goal orientation and their perceived performance and mastery goal orientations from caregivers, (r = .26, .22, & .37, respectively). This suggests that children may have both the overall performance goal and the mastery-approach goal orientation at the same time, or may switch their goal orientations during their engagement with the activity. It is possible that the open-ended informal engineering activities may allow and invite children to express both kinds of goal orientation. In addition, their performance goal orientations were related to their perception of their caregivers' goal orientations for them. It is likely that for young children, when they perceived their caregivers' goal orientation, regardless if it is performance-approach or mastery-approach, they may translate the orientations into an overall concept that is similar to the performance goal orientation (e.g., my parents want me to do good, and/or be better than other children). However, the data also showed that caregivers' reported performance goal orientation for their children is correlated with children's own performance goal orientation, and caregivers' mastery goal orientation for their children is correlated with children's own mastery-approach goal orientation (r = .31 & .28, respectively), implying a connection between caregivers and children's goal orientations that is not directly related to children's perceptions of what their caregivers expect from them. Interestingly, both children's perceived performance and mastery goal orientations were significantly correlated with caregivers' performance goal orientation (r = .26 & .44, respectively) but not with caregivers' mastery goal orientation for their children. This suggested that caregivers' mastery goal orientation (e.g., I want my child to learn about concepts) may not be perceived by young children, but instead, caregivers' performance goal orientation (e.g., I want my children to do well in classes) was likely to be perceived by young children and interpreted it into both performance and mastery goal orientations. In other words, the analyses suggest that young children may tend to think that their parents have performance goals for them. We will use structural equation modeling to further explore the relationship among these variables once the data collection is completed.

In terms of observation, both the performance-approach and mastery-approach orientations were common and easy to observe. Typical indicators for performance-approach orientation included children making comparisons between the quality of their designs with others (e.g., "Mine is better!") or competing to finish their design first. Meanwhile, children often adopted a mastery-approach orientation by expressing intentions to learn about the new materials or tools or by sharing with others what they learned from the activities. The Wilcoxon signed rack test indicated that more mastery-approach goal orientation behaviors were observed than performance-approach goal orientation ($z = 8.18$, $p < .01$, $r = .51$). However, both performance-avoidance and mastery-avoidance orientations were difficult to identify. As children can disengage freely in the museum setting, it is unlikely that they would remain engaged with the activities if they want to avoid comparison or failure. Yet, a few children's avoidance orientations were captured through follow-up interviews. For example, a few children were concerned about their design not being as good or as "cool" as other children's while engaged with the activities. For example, when asked how they feel about testing their vehicles, a child shared that she felt "a bit nervous" when testing in front of other children. Lastly, the observed engineering practices had low correlations with all other outcomes (between -.01 and .15, see Table 2.), meaning the children's engagement with the engineering activities is not related to their goal orientations, and it is not different between genders or local/non-local families. It is possible that the aggregated scores of engineering practices is not sensitive enough to capture differences in children's engagement with different engineering practices. We will hone in on each engineering practice (e.g., iteration, testing, etc.) in the next round of data analysis once the full dataset is collected.

The other noticeable pattern that surfaced from the observations is the potential influence of the social environment on children's goal orientations. The interaction among siblings, family members, and even other children in the same space could impact a child's goal orientation. For example, we observed several times that the oldest child in a family group wanted to ensure their design is the best or better than their younger siblings' designs. Some of the oldest children also shared that their ideas are better than their siblings and their siblings often "copy" their work. We also observed different types of caregiver-child interactions that may contribute to children's engagement with the activities and their goal orientations. For example, caregivers may be directive when helping their children to build and test their designs by calling attention to whether or not their children's designs successfully passed the engineering challenge (e.g., if the designs slid through the ziplines), and as a result contributing to their child's performance goal orientation. Given this is an exploratory study, we are using an inductive approach [28] to generate themes of these social interactions to triangulate factors that may contribute to children's goal orientations in these engineering design activities.

Discussion

This study provides a unique opportunity to use the goal orientation framework to explore children's engagement with informal engineering design activities. Since the data collection is still ongoing, the following discussion is based on the results from the preliminary dataset. Compared to prior research conducted in formal education that often focuses on semester-long impacts, the preliminary results show that children often have mixed and dynamic goal orientations while engaging in much shorter engineering design activities. However, young children conceptualized an overall performance goal orientation and a mastery-approach goal orientation, instead of having the theoretical two-by-two matrix of four goal orientations typically applied to formal educational settings. For the overall performance goal orientation, the merge of performance-approach and performance-avoidance goal orientation may be due to the nature of the informal learning environment and of the design activities, in which children are constantly testing and iterating their design publicly, and therefore have ample and dynamic opportunities to compare their designs with others. In addition, given that there are no standardized outcomes or scores to identify success in these activities, children were free to choose what they would like to compare with others and which performance goals they focused on. For example, in the air-powered vehicle activity, a child may be concerned about whether their vehicle moved across the track like other children's designs (i.e., performance-avoidance) and at the same time also want to ensure their vehicle looks the coolest (i.e., performance-approach). For mastery goal orientations, the mastery-avoidance goal orientation was closely related with performance orientations. This may be due to the overarching component across these survey items, such as fear of failure (see [17]). Mastery-avoidance may also be challenging for young children to reflect on since it requires a sense of their own learning ability. What was clear in our preliminary data is that children seemed to have little difficulty in understanding and separating performance-approach and mastery-approach goal orientation.

While no differences in goal orientations were observed between local and non-local children in the current dataset, there was a difference between caregivers' self-reported goal orientations for their children, in which local caregivers often focused more on performance-approach goal orientation than non-local caregivers. In contrast, children perceived a higher performance-approach goal orientation than a mastery-approach goal orientation from their caregivers, and their perceived goal orientations were significantly correlated with caregivers' performance goal orientation but not mastery goal orientation. The differences between local and non-local caregivers' goal orientations for their children matched our prior experiences engaging with local, immigrant families who often come to museum experiences with their own set of beliefs about learning and education, and expectations for how they should interact and engage with museum exhibits and educators [29], [30]. This is particularly important as our qualitative data indicated that children's goal orientations may be influenced by their families and social environments, similar to findings in prior studies [31]. These findings highlight the continuing work for museums and science centers to better understand and support caregivers' agency and embrace diverse and inclusive approaches in their science communication with families.

In terms of engineering education, the study illustrates the complexity of young children's experiences and motivation while engaging with engineering design activities. Even in the one-time, drop-in informal learning setting, most children we targeted in this study actively tested and iterated their designs, focusing on one or more challenges in their designs (e.g., the size of the carrier that needs to fit the animals and the carrier's attachment to the ropes in Zipline activity), using various tools and materials (e.g., cardboard, string, chopsticks, etc.). This experience of designing, constructing, and testing solutions to engineering problems may build on children's prior knowledge as well as their attitudes and motivation toward STEM [22], [23]. In addition, this study extended our understanding of children's motivation in engineering by looking beyond classrooms and investigating how caregivers and siblings may also play a significant role in shaping children's engineering learning experiences. As the engineering field has increasingly emphasized the importance of early exposure to design thinking and problem-solving, more research is needed to better understand how these early experiences may support and contribute to children's motivation and foster engagement with engineering and STEM career paths, especially for historically underrepresented children [3], [5].

By using the mixed-study approach, this study provides a unique opportunity to investigate young children's goal orientations in the context of engineering design activities. As we are still in the process of data collection, the results will be updated and presented at the conference. We will also share strategies and lesson-learned about selecting and designing engineering activities that may encourage different goal orientations, which can be beneficial for program, exhibit, or activity developers and designers. Limitations of the project design and study method will also be discussed. The results will yield new insights for future researchers and educators to better support children, especially historically minoritized children, to engage with engineering and pursue STEM career paths.

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References

[1] R. N. Coger, J. Cuny, M. Klawe, M. McGann, and K. D. Purcell, “Why STEM fields still don't draw more women,” *Chronicle of Higher Education, vol. 59,* pp. 24-27, 2012.
[2] S. E. Page, *The difference: How the power of diversity creates better groups, firms, schools, and societies*, Princeton, NJ: Princeton University Press, 2007.
[3] National Academy of Engineering, *Surmounting the barriers: Ethnic diversity in engineering education: Summary of a workshop*, Washington, DC: The National Academies Press, 2014.
[4] S. E. Walden, D. A. Trytten, and R. L.Shehab “Research-based recommendations for creating an inclusive culture for diversity and equity in engineering education,” *2018 IEEE Global Engineering Education Conference (EDUCON)*, 1591-1597, 2018.
[5] M. M. Hynes, C. Mathis, S. Purzer, A. Rynearson, and E. Siverling, “Systematic review of research in P-12 engineering education from 2000–2015,” *International Journal of Engineering Education*, vol. 33, pp. 453-462, 2017.
[6] National Academy of Engineering & AMD NextGen Engineer, *Infusing real world experiences into engineering education*, Washington, DC: National Academy of Sciences, 2012.
[7] S. Murphy, A. MacDonald, C. A. Wang, and L. Danaia, “Towards an understanding of STEM engagement: A review of the literature on motivation and academic emotions,” *Canadian Journal of Science, Mathematics and Technology Education*, vol. 19, pp. 304-320, 2019.
[8] M. T. Wang and J. Degol, “Motivational pathways to STEM career choices: Using expectancy–value perspective to understand individual and gender differences in STEM fields,” *Developmental Review*, vol. 33, 304-340, 2013.
[9] National Research Council, *Standards for K-12 engineering education?*, Washington, DC: The National Academies Press, 2010.
[10] A. Bandura, C. Barbaranelli, G. V. Caprara, and C. Pastorelli, “Self-efficacy beliefs as shapers of children's aspirations and career trajectories,” *Child Development,* vol. 72, pp. 187-206, 2001.
[11] M. Ing, P. R. Aschbacher, and S. M. Tsai, “Gender differences in the consistency of middle school students’ interest in engineering and science careers,” *Journal of Pre-College Engineering Education Research,* vol. 4, Article 2, 2014.
[12] M. Sáinz and J. Eccles, “Self-concept of computer and math ability: Gender implications across time and within ICT studies,” *Journal of Vocational Behavior,* vol. 80, pp. 486-499, 2012.
[13] C. Ames, “Classrooms: Goals, structures, and student motivation,” *Journal of Educational Psychology*, vol. 84, pp. 261-271, 1992.
[14] A. J. Elliot, “Approach and avoidance motivation and achievement goals,” *Educational Psychologist*, vol. 34, pp. 169-189, 1999.
[15] A. Kaplan and M. L. Maehr, “The contributions and prospects of goal orientation theory,” *Educational Psychology Review*, vol. 19, pp. 141-184, 2007.
[16] P. R. Pintrich, “A motivational science perspective on the role of student motivation in learning and teaching contexts,” *Journal of Educational Psychology*, vol. 95, pp. 667-686, 2003.
[17] C. S. Hulleman, S. M. Schrager, S. M. Bodmann, and J. M. Harackiewicz, “A meta-analytic review of achievement goal measures: Different labels for the same constructs or different constructs with similar labels?,” *Psychological Bulletin*, vol. 136, pp. 422-449, 2010.

[18] J. M. Harackiewicz, K. E. Barron, P. R. Pintrich, A. J. Elliot, and T. M. Thrash, “Revision of achievement goal theory: Necessary and illuminating,” *Journal of Educational Psychology,* vol. 94, pp. 638–645, 2002.
[19] P. R. Hernandez, P. Schultz, M. Estrada, A. Woodcock, and R. C. Chance, R. C. “Sustaining optimal motivation: A longitudinal analysis of interventions to broaden participation of underrepresented students in STEM,” *Journal of Educational Psychology,* vol. 105, pp. 89-107, 2013.
[20] J. L. Meece, E. M. Anderman, and L. H. Anderman, “Classroom goal structure, student motivation, and academic achievement,” *Annual Review of Psychology*, vol. 57, pp. 487-503, 2006.
[21] D. Heo, S. Anwar, and M. Menekse, “The relationship between engineering students’ achievement goals, reflection behaviors, and learning outcomes,” *International Journal of Engineering Education*, vol. 34, pp. 1634-1643, 2018.
[22] L. D. English and D. T. King, “STEM learning through engineering design: Fourth-grade students’ investigations in aerospace,” *International Journal of STEM education*, vol. 2, pp. 1-18, 2015.
[23] K. Bethke Wendell, and C. Rogers, “Engineering design-based science, science content performance, and science attitudes in elementary school,” *Journal of Engineering Education*, vol. *102,* pp. 513-540, 2013.
[24] United States Census Bureau, “2017 American Community Survey,” Suitland, MD: United States Census Bureau, 2017. Available at: https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml.
[25] New York City Department of Health (NYCDOH), “Community health profiles 2015: Queens community district 4: Elmhurst and Corona,’ New York, NY: NYCDOH, 2015. Available at: https://www1.nyc.gov/assets/doh/downloads/pdf/data/2015chp-qn04.pdf.
[26] C. Midgley, M. L. Maehr, L. Z. Hruda, E. Anderman, L. Anderman, K. E. Freeman, M. Gheen, A. Kaplan, R. Kumar, M. J. Middleton, J. Nelson, R. Roeser, and T. Urdan, *Manual for patterns of adaptive learning scales,* Ann Arbor, MI: University of Michigan, 2000.
[27] S. M. Letourneau and D. Bennett, “Using narratives to evoke empathy and support girls’ engagement in engineering,” *Connected Science Learning*, vol. 3, 2020.
[28] D. R. Thomas, “A general inductive approach for analyzing qualitative evaluation data,” *American Journal of Evaluation*, vol. 27, pp. 237-246, 2006.
[29] A. DiBianca Fasoli, “To play or not to play: Diverse motives for Latino and Euro-American parent–child play in a children's museum,” *Infant and Child Development*, vol. 23, pp. 605-621, 2014.
[30] H. R. Tenenbaum and M. A. Callanan, “Parents' science talk to their children in Mexican-descent families residing in the USA,” *International Journal of Behavioral Development*, vol. 32, pp. 1-12, 2008.
[31] D. Vandewalle, C. G. Nerstad, and A. Dysvik, “Goal orientation: A review of the miles traveled and the miles to go,” *Annual Review of Organizational Psychology and Organizational Behavior*, vol. 6, pp. 115-144, 2019.

Table 1. Descriptive statistics

Variable	**Mean**	**SD**	**Range**	**Shapiro-Wilk W**
Child survey				
Age	9.71	1.94	7-14	.99
Overall performance GO	3.33	.69	1.5-5	.99
Mastery approach GO	3.60	.76	2-5	.99
Perceived performance GO	3.71	.92	1-5	.95**
Perceived mastery GO	3.38	.95	1-5	.99
Observed performance GO	.76	1.05	0-4	.91**
Observed mastery GO	1.78	.91	0-4	.99
Observed engineering practices	2.47	1.05	0-4	.99
Caregiver survey				
Caregiver performance GO	3.64	.87	1-5	.98*
Caregiver mastery GO	4.50	.57	3-5	.93**

Note. GO = goal orientation. **p* < .05, ***p* < .01

Table 2. Correlation among variables

Variable	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1. Overall performance GO	.26*	.22*	.37**	.04	.06	.02	.31**	.06
2. Mastery approach GO		.16	.02	.00	.13	.15	-.07	.28**
3. Perceived performance GO			.44**	-.02	.07	-.03	.26**	.04
4. Perceived mastery GO				-.06	-.08	-.04	.44**	-.05
5. Observed performance GO					.02	-.01	.05	.09
6. Observed mastery GO						.11	.00	-.02
7. Observed engineering practices							-.02	.13
8. Caregiver performance GO								.12

9. Caregiver mastery GO	

Note. GO = goal orientation. $*p < .05$, $**p < .01$