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Article

I Fail; Therefore, I Can: Failure Mindset and Robotics Self-Efficacy in Early Adolescence

Calah J. Ford [1,*], Margaret J. Mohr-Schroeder [2] and Ellen L. Usher [3]

[1] Department of Curriculum and Instruction, University of Kentucky, Lexington, KY 40506-0107, USA
[2] Department of STEM Education, College of Education, University of Kentucky, Lexington, KY 40506-0107, USA
[3] Mayo Clinic College of Medicine and Science, Rochester, MN 55905, USA
* Correspondence: calah.ford@uky.edu

Abstract: When students feel successful, they tend to be more confident in their capabilities (i.e., higher self-efficacy), which is associated with improved performance, engagement, and self-regulation. Yet, the way in which learners interpret their experiences is less well-understood. Learners' views of failure (i.e., failure mindset) are potential lenses through which early adolescent learners perceive and interpret efficacy-relevant information. The relationship between failure mindset and self-efficacy may be particularly important to consider in STEM-related domains like robotics where failure is common. The purpose of this study was to investigate the relationship between young adolescents' failure mindset and their robotics self-efficacy development. Using mixed methods, we considered how students' reported failure mindset levels were related to what has made them more or less confident in robotics. We also considered the relationship between failure mindset and robotics self-efficacy. Overall, the findings suggest that early adolescent learners' failure mindset is related to the efficacy-relevant information they pay attention to in robotics, and, in turn, is associated with their reported robotics self-efficacy. The details of these relationships varied between elementary and middle school students. As there is a social push to normalize failures in educational settings, findings from this study offer an important insight into how students may interpret those failures.

Keywords: self-efficacy; failure mindset; early adolescence; robotics; STEM; informal learning; elementary school; middle school

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1. Introduction

Decades of research have supported the notion that when students feel successful, they are more confident in their capabilities (i.e., higher self-efficacy). Higher self-efficacy is, in turn, associated with improved performance, engagement, and self-regulation (e.g., [1–4]). Yet, the way in which learners interpret their experiences (e.g., as successes and/or failures) is less well-understood [5,6]. Students may look at aspects of their performance like perceived difficulty, effort expenditure, score, controllability, and stability of causes (among other things) when determining the success level of an experience [5,7–9]. In this way, what one student perceives as a failure, another may perceive as a success.

However, students not only differentially perceive experiences of success and failure, but they also hold differing beliefs about failure, which have been referred to as *failure mindsets* [10]. For some, failure is a welcomed experience through which individuals believe they will grow and learn. For others, failure is devastating and should be avoided at all costs. Students who believe that failure is a debilitating experience might find their own suboptimal performances to be particularly salient pieces of evidence regarding their capabilities, or lack thereof. This failure-is-debilitating mindset may then lead them to have lower confidence in their own capabilities. Although this relationship between failure mindset and self-efficacy is relevant to student motivation across all domains, it may be particularly important in areas like STEM (science, technology, engineering, and math) where problems can be complex, requiring trial and error or multiple failures on the way to success [11,12]. We focus here on the cross-disciplinary field of educational robotics (i.e., robotics used for educational purposes), which requires technology and computer programming to solve problems that often involve engineering, science, and math. Specifically, we use the lens of social cognitive theory to examine how elementary and middle school-aged students' views of failure are related to their robotics self-efficacy development during a robotics summer STEM camp.

1.1. Social Cognitive Theory and the Sources of Self-Efficacy

Social cognitive theory [13] outlines the reciprocal relationship between behaviors (e.g., studying, performing), environmental factors (e.g., location, culture), and personal factors (e.g., beliefs, mindsets). Social cognitive theory emphasizes the role of beliefs in one's personal capabilities (i.e., self-efficacy) as a guiding force in human functioning and motivation [7]. Self-efficacy is thought to develop largely through learners' interpretations of their direct experiences, vicarious experiences, social persuasions, and physiological or affective states [7]. Other factors such as how much help is available, individuals' self-regulatory abilities, and the difficulty of a task have also been related to learners' self-efficacy development (e.g., [14,15]). As they grow and learn, children perceive and interpret information from these diverse sources and use those evaluations to inform their self-efficacy [7].

Students' direct experiences have been shown to be the strongest predictors of self-efficacy because they provide the "most authentic evidence" [7] (p. 90) of what individuals can or cannot do. When students believe they have been successful in the past, they tend to be more confident in their abilities to do similar tasks in the future (e.g., [14,16,17]. However, most studies have exclusively measured mastery experiences by asking students how well they have done in the past (e.g., "I have always been successful with math" [6]) and have not assessed learners' perceptions of failures or difficulties. Vicarious experiences, social persuasions, and physiological and affective states have similarly been measured with single-direction items. That is, vicarious experiences and social persuasions have been measured using positively worded items, and physiological and affective states have been measured using negatively worded items. Some evidence suggests that learners interpret positive and negative events in different ways. For example, when adolescents were asked to recall something that had raised their confidence in math and science, some described different sources of self-efficacy than when they were asked to recall something that had lowered their confidence [15].

1.2. Mindsets as a Precursor to Self-Efficacy Development

Bandura [7] argued that the predispositions learners hold may lead them to interpret their experiences in different ways. These pre-existing dispositions and beliefs may provide a lens through which students view and frame the experiences that affect their self-efficacy (e.g., [6,18]). For example, Chen and Tutwiler [19] found that children's mindset about intelligence (i.e., whether they viewed intelligence as a fixed entity or something that could grow with effort) could bias the way children interpret their learning experiences in science, which in turn may affect their science self-efficacy. Other evidence has shown that adolescent students reported different sources of self-efficacy depending on their mindset about intelligence [20]. Students who endorsed a more growth-oriented mindset endorsed a greater variety of sources as influencing their self-efficacy than did students who endorsed a more fixed mindset. Furthermore, for students with a more fixed mindset, negative physiological and affective states such as stress were more strongly (and negatively) associated with self-efficacy.

In a similar fashion, students' implicit beliefs about failure—their failure mindset—may affect their self-efficacy development. Bandura [7] contended that, in challenging circumstances, those with initially low self-efficacy "dwell on their personal deficiencies, the formidableness of the task, and the adverse consequences of failure" (p. 39). This preoccupation with one's shortcomings makes individuals less resilient when they experience setbacks, causing them to easily "lose faith in their capabilities". From a social cognitive perspective, self-efficacy and preconceptions about failure are intertwined and related to one's subsequent self-efficacy. To date, however, the relationship between failure mindset and self-efficacy has yet to be investigated.

1.3. Developmental Differences in Robotics Self-Efficacy Development

Self-efficacy is context dependent (e.g., students' beliefs about their math abilities often differ from their beliefs about their science ability). Robotics self-efficacy references students' beliefs about their robotics abilities and has primarily been measured in late elementary and middle school students (i.e., Grades 4–8). Although there are marked differences in the academic, social, and physical experiences of elementary and middle school students (e.g., [21]), researchers have not examined possible differences in how elementary and middle school students develop their self-efficacy in robotics. However, previous research on self-efficacy in other STEM domains suggests that self-efficacy decreases over time, with the most drastic decline occurring during the transition to middle school [22–24]).

The reason for motivational declines is multifaceted. Some researchers have suggested that this decline is because as children age and mature, their self-efficacy beliefs become more calibrated with their actual skills [25] and because research instruments are more suitable for accurately measuring students' self-efficacy beliefs [26]. Others have proposed that age-related personal factors may influence the information students pay attention to. For example, students "may be socialized to fear failure due to their parents' punitive and controlling behaviors and belief that losing will lead to public embarrassment or shame" [12] (p. 224). That is, students who fear failure may also be reluctant to act and less confident in their capabilities. Some researchers have found that as students transition to middle school, they become less confident, specifically in their ability to solve complex problems, which increases their risk of failure [27]. Furthermore, the transition to middle school can be difficult because the "environment emphasizes competition, social comparison, and ability self-assessment at a time of heightened self-focus" [21] (p. 246). For these reasons, early adolescence is an important developmental stage at which to investigate self-efficacy development and failure mindset.

1.4. Beliefs about Failure

Although some research has explored failure in educational settings, researchers have not yet reached consensus on a single definition of "failure" [28]. However, the word itself tends to hold negative connotations, evoke negative emotions, and is taboo in many settings [12]. Some teachers report avoiding the term "failure" and even protecting their students from situations in which they may fail. However, others have argued that avoiding talking about failure undermines students' development and does not prepare them for the workplace environment where failures and difficulties are commonplace [12]. Some researchers have begun to group the terms "failures," "errors," and "mistakes" to broaden the understanding of what it means to fail (e.g., [28,29]). For the purposes of this paper, we refer to learners' *perceptions of failure*. This decision was made because within students' minds, perception is reality, and their perceptions are expected to influence how they interpret their experiences and form their self-beliefs (e.g., self-efficacy). For example, for one student, a simple error may be experienced as a failure, whereas for another, only a much larger mistake or shortcoming would be perceived as a failure. These different perceptions might influence what students think, do, and feel thereafter.

Although many studies have considered the causal attributions people make and their reactions after a prescribed failure (see [30]), fewer have considered adolescents' beliefs about self-perceived failure and what it means to fail (i.e., failure mindset). Haimovitz and Dweck [10], investigated a similar phenomenon of failure mindsets among adults, finding that adult caregivers' beliefs about failure predicted adolescents' intelligence mindset. However, they did not measure the adolescents' failure mindset but rather their intelligence mindset.

To date, little research has investigated the role of young adolescents' own beliefs about failure or how those beliefs are associated with other motivation constructs like self-efficacy. A small body of work, though, has shown that viewing failure as productive is associated with improved academic performance and perceived competence (e.g., [21,31,32]). Additionally, more recent intervention work has considered whether students' comfort with failure is malleable, and, in turn, whether a higher comfort level with failure is associated with affect and performance. For example, Marks and Chase [33] tested whether an intervention designed to normalize failure would increase fifth- and sixth-grade students' comfort with failure. In their study, students who received the intervention were more engaged with lessons, reported more positive affect in reactions to failure, and performed better. However, students' comfort with failure was not conceptualized in the same way as failure mindset, but rather as students' self-expected reactions to hypothetical failure situations. Therefore, there remains a dearth of empirical studies directly measuring adolescents' failure mindsets in relation to motivation.

1.5. Failure and Motivation in Educational Robotics

According to the United States Department of Commerce [34], STEM occupations are growing at a faster rate than non-STEM careers, and those working in STEM fields earn higher wages. Despite the opportunities found in STEM, many students are not prepared to enter STEM fields or are not interested in careers in STEM [35]. Researchers have attempted to address students' lack of interest in STEM by contextualizing motivation studies in particular content within STEM disciplines (e.g., biology, calculus; e.g., [35,36]. One context that has emerged is that of educational robotics.

Educational robotics refers to "a multidisciplinary, project-driven learning process that encourages students to develop problem solving and teamwork skills and fosters their creativity and logic" [37] (p. 1). Working with robotics has been shown to improve student learning and motivation as well as students' interest in math and science careers (e.g., [38,39]). At the K-8 level, educational robotics engages students in authentic engineering tasks and highlights how to effectively work as a team. When working with educational robotics, students are required to continually solve problems and debug programs through the process of repeated trial and error. Students are typically encouraged to try again and again until their programs work correctly, and the path to completing a challenge in robotics is often littered with many failures.

Despite educational robotics becoming more accessible, most educators and students do not have regular access to robotics. For many, educational robotics kits are only available through camps and clubs [40]. As a result, most studies related to educational robotics have taken place in a camp, club, or competition setting (e.g., [39,41–44]).

Much is known about how engaging with robotics kits improves student skill acquisition (e.g., [45–48]). However, most of these studies are situated in discipline-based educational research, which often focuses on classroom practices and their influence on learning and performance outcomes but neglects cognitive psychology [49]. Consequently, the role of motivation in educational robotics has been of marginal research focus, with most studies considering only interest or engagement (e.g., [40,50]).

Researchers who have investigated a broader range of motivation-related constructs within the context of robotics have considered factors such as goal orientation, task value, and self-efficacy (e.g., [51,52]). Generally, researchers have found that robotics self-efficacy increases with exposure to and experience with robotics [41,42,51]. That is, the more experience students have with robotics, the greater their increase in robotics self-efficacy. Although these initial studies have considered changes in robotics self-efficacy after experiences with robotics, they have not directly investigated the efficacy-relevant information students pay attention to when forming their personal beliefs about their robotics capability.

Furthermore, the prevalence of failure experiences in educational robotics has not been taken into account.

1.6. Purpose Statement

The purpose of this study was to investigate the relationship between young adolescents' failure mindset and their robotics self-efficacy development. We defined the period of young adolescence as immediately before (i.e., Grades 4–5) and after (i.e., Grades 6–7) the transition to middle school. We sought to answer three primary questions.

RQ1 What sources of efficacy-relevant information do young adolescents consider when forming their robotics self-efficacy?
RQ2 What is the relationship between young adolescents' failure mindset and the efficacy-relevant information they consider when forming their robotics self-efficacy? Does this relationship differ by school level?
RQ3 What is the relationship between failure mindset and robotics self-efficacy? Is this relationship moderated by learners' school level?

2. Materials and Methods

2.1. Participants

This study was part of a collaborative project focused on summer informal learning experiences during a STEM camp designed to increase adolescents' STEM literacy and knowledge about STEM careers (see [53]). The camp, which was partly funded by the National Science Foundation, took place at a public, land-grant university in the Southeastern United States. Camp enrollment required a fee, but scholarships and transportation were available to qualified campers to increase accessibility. Participants were 237 elementary school (49%; exiting Grades 4–5) and middle school (51%; exiting Grades 6–7) students (64% boys, 36% girls) attending one of two camp terms. Each camp term comprised five consecutive weekdays from 9 a.m. to 4 p.m. with an extended day available. Participants' race was reported by both parents and campers, then cross-referenced. Campers in our sample were White (62%), Black (15%), Hispanic (9%), Asian (8%), and multiracial (6%). Campers whose racial group has been historically underrepresented in STEM (i.e., Black, Hispanic, or multiracial students) were identified as underrepresented racial minority (URM) campers and represented 30% of the sample.

2.2. Summer STEM Camp

During the 7-hour long day, campers attended a daily 3-hour robotics session (morning or afternoon) during which they worked with a partner to build and program a LEGO® EV3 Mindstorms robot. Partners were assigned by camp administrators on the first day and were matched by gender (i.e., boy or girl), school level (i.e., elementary or middle), and URM status (i.e., is URM or is not URM). Although all students were matched by grade level, sample constraints required some students to only be matched by either gender or URM status. This matching was intended to boost feelings of belonging for participants [54].

On the first day of camp, campers built a LEGO® robot by following a booklet of instructions. The instructions were diagrams and pictures with no words. An instructor was available to assist as needed, but campers built the robots at their own pace. At the end of this session, the instructor introduced the campers to programming software that enabled them to program their robot's behaviors. The instructor then demonstrated the basics of coding. On Days 2–4, campers programmed their robot to perform various tasks and complete challenges (e.g., go through a maze or deliver colored blocks to designated areas). On these days, the instructor introduced a task challenge and rules. Campers then worked independently with their partners to complete the challenge.

On the final day of camp, campers attempted to program their robots to complete tasks on the First LEGO® League (FLL) Hydro-Dynamics map [55]. FLL is the competitive venue for LEGO® robotics. Each year, a new map with complex challenges is released, and each challenge on the map is assigned a certain number of points. The map used at this camp was from a previous year, and campers' challenges were based on the hydrodynamics within a fictional town. Campers worked together with their partner to fix broken pipes, flush toilets, and perform other related tasks. Although the map and point system are from a competitive venue, the camp challenge was not set up as a competition. Campers were encouraged to try whichever challenges were interesting to them, and though some campers tracked their own points, no score was given to the campers based on their performance.

2.3. Procedure

Campers completed paper surveys during their first and final robotics sessions of the weeklong camp. Camp leaders read all items and response options aloud as campers responded. Surveys consisted of items assessing campers' failure mindset and robotics self-efficacy as well as three open-ended questions, one of which was not analyzed here. Included in this study are campers' responses to the failure mindset scale and open-ended sources of self-efficacy items on Day 1 and the robotics self-efficacy scale on Day 5.

2.4. Data Sources

A six-item *failure mindset* scale ($\alpha = 0.77$) was adapted from Haimovitz and Dweck [10] for use with early adolescents. Campers were presented with a question stem (e.g., "When I fail…") and then selected from a series of possible responses using options ranging from 1 (e.g., *I always learn less*) to 4 (e.g., *I always learn more*). Response options differed by question but maintained a parallel format. That is, for each failure mindset item, the left-most response option represented the failure-is-debilitating mindset, and the right-most option represented the failure-is-enhancing mindset. In this way, lower scores on the failure mindset scale represented a less adaptive failure mindset and higher scores represented a more adaptive mindset.

The decision to develop response options by question as opposed to having campers rate their level of agreement with varying statements was made for several reasons, as outlined by Gehlbach and Brinkworth [56]. First, asking respondents to discern their level of agreement with a statement is cognitively taxing and can result in unnecessary errors. Second, the exact meaning of *Strongly Disagree* is often unclear. Finally, by using question-specific response options, we were able to measure positive and negative valence within the same item.

Two open-ended *sources of robotics self-efficacy* items, adapted from Usher et al. [15], asked campers about experiences that have raised or lowered their robotics self-efficacy (i.e., "Describe something that has happened to you that made you feel [MORE/LESS] confident in robotics".). Campers were given unlimited space to respond. Responses were then imported into MAXQDA 2018 [57], which permits researchers to code text responses and group data into themes.

Three *robotics self-efficacy* items ($\alpha = 0.81$) were developed according to Bandura's [58] guidelines (e.g., "How confident are you that you are able to make a robot do easy things?"). Campers responded using a Likert-type response format from 1 (*I know I cannot*) to 4 (*I know I can*). The survey administrators explained the scale by modeling their own confidence judgments for accurately jumping into a hula-hoop placed on the floor at different distances. This mental exercise was intended to help campers conceptualize the self-efficacy rating scale [58].

2.5. Analyses

We used a concurrent, mixed-method design [59] to consider the relationship between failure mindset and robotics self-efficacy development. We first considered the relationship between campers' failure mindset and their self-reported sources of robotics self-efficacy. We then investigated the relationship between failure mindset and robotics self-efficacy at the end of camp. We also considered whether any potential relationship between failure mindset and robotics self-efficacy development was moderated by school level (i.e., elementary or middle).

Descriptive statistics including means, standard deviations, and correlations were examined for the failure mindset and self-efficacy scales. We also conducted an exploratory factor analysis (EFA) for the adapted failure mindset scale using the weighted least squares with mean and variance (WLSMV) estimation method with Geomin oblique rotation. We used maximum likelihood (ML) estimation techniques to run a parallel factor analysis. All analyses were conducted in MPlus 8 [60]. A visual analysis of the scree plot containing actual eigenvalues from the WLSMV estimator as well as mean and 95th percentile eigenvalues from the parallel analysis were analyzed to consider the dimensionality of the failure mindset scale.

Finally, an additional failure mindset variable was created. Campers whose failure mindset level was one or more standard deviations above or below the sample mean were considered as having a failure-is-enhancing or failure-is-debilitating mindset, respectively. This categorization was used in conjunction with the qualitative analyses described below.

2.6. Coding Process

Responses to the open-ended questions were imported into MAXQDA [57]. The initial coding scheme, adapted from Usher et al. [15], comprised 16 codes that were later refined using grounded theory (see Table 1) [61].

Table 1. Codelist for open-ended responses.

Code Assigned	Description
Direct experience	One’s own success or failure
Prior exposure	Experience with robotics, no performance level indicated
Access	Having access to robotics through school, clubs, or home
Social modeling	Observing others
Social comparison	Comparison between self and others
Competition	Competing with others, usually on a team
Social persuasion	Evaluative messages from others
Physiological state	How one feels physically/emotionally
Help availability	Having (or not having) help
Collective efficacy	Working with a partner or team
Self-regulation	Studying, paying attention, persisting
Ability judgments	One’s natural ability, talent, or skill
Interest, liking, value	Enjoyment of content
Task difficulty	How easy or difficult work is
Temporal	How recently one has worked with robotics
“Nothing”	Use of word “nothing”
Other	Anything not listed above

Three codes (i.e., class content, physical environment, pedagogical experiences) were removed from the initial coding guide because campers did not report these sources as having affected their robotics self-efficacy. Five new themes were also identified. First, the idea of feeling more or less confident because of a strong or weak partner or group was a recurring theme. These types of responses were coded as *collective efficacy*. Second, many responses referred to prior experience, or the lack thereof, with no qualification of success or failure. These types of responses were differentiated from mastery/failure experiences and coded as *prior exposure*. There was one nuance to this code when campers reported a lack of prior exposure. We determined that when campers reported that having no prior exposure made them feel less confident, we could ascertain that the lack of exposure was actively making them feel less confident. However, when campers responded that they had no prior exposure to the question of what had made them more confident, we determined that, in these cases, students had indicated that *nothing* had raised their confidence because they had yet to be exposed to the content. Third, a *temporal* code was added to the code list to characterize campers' descriptions of how much time had elapsed since their last robotics experience, causing them to feel less confident. Fourth, many students described that having *access* to robotics made them feel more confident. Finally, many students referenced *competitions* in their responses. Two codes, *Uninterpretable* and *I Don't Know*, were also assigned where appropriate but were not included in analyses. A final list of codes with condensed coding definitions is presented in Table 1.

This code list was independently applied to camper responses (n_{more} = 237; n_{less} = 237) by two researchers over three week-long rounds in batches of 140-200 responses. Each response was coded by each researcher, and then the codes were compared. Any discrepancies were discussed and resolved. In this way, every response was carefully scrutinized, and the final codes assigned were agreed upon by both researchers. During this process, the researchers looked across coding categories to refine and clarify codes and identify themes [62].

Once all responses were coded, we tabulated coding frequencies by counting the number of times a code was used for a particular group of campers. Proportions were then calculated by dividing that number by the total number of participants in the group. That is, the proportions reported represent the portion of campers from the group in question whose response was coded with at least the code in question. This method is intended to prevent an artificial lowering of proportions for groups of participants who provide more complex answers [15].

2.7. Mixed Method Analyses

We first looked at overall trends in response patterns to the open-ended questions. Then, we considered response patterns by the quantitative measures of school level (i.e., elementary or middle school) and failure mindset. These analyses quantified qualitative data with proportions. However, we sought to maintain the richness of the data by highlighting direct quotations throughout the results section.

We next considered the relationship between failure mindset at the beginning of camp and robotics self-efficacy at the end of camp using hierarchical linear regression models. In Step 1, we included personal demographic factors (i.e., gender, race, and school level). We included gender and race as controls because, just as preconceptions like failure mindset may influence the way in which learners interpret efficacy-relevant information, students' personal demographic factors may also play a role in self-efficacy development. Specifically, cultural stereotypes in the U.S. "portray women and non-White minorities as less skilled and academically oriented than White men, especially with regard to mathematics, science, and technology" [63] (p. 78). As a result, individuals who have been historically underrepresented in STEM-related fields may be more likely to doubt their STEM-related capabilities. In Step 2, we added failure mindset as an independent variable predicting robotics self-efficacy. Change in R^2 was measured and tested for significance. Finally, in a second model, an interaction term of significant demographic factors and failure mindset was added to the previous model.

3. Results

Composite means were created for both the failure mindset and robotics self-efficacy scales after checking for univariate and multivariate normality. Failure mindset and robotics self-efficacy were positively correlated, $r(215) = 0.25$, $p < 0.001$. Independent samples t-tests revealed no significant differences in failure mindset by gender ($t(235) = -0.83$, $p = 0.410$, $d = 0.11$), race ($t(235) = -0.51$, $p = 0.613$, $d = 0.09$), or school level ($t(235) = -0.07$, $p = 0.946$, $d = 0.02$). We also found no significant gender ($t(214) = 1.19$, $p = 0.234$, $d = 0.17$) or race ($t(214) = 1.15$, $p = 0.250$, $d = 0.17$) differences in campers' robotics self-efficacy. However, significant school-level differences emerged, indicating that elementary campers reported higher robotics self-efficacy at the end of camp ($M = 3.51$) than did middle school campers ($M = 3.33$), $t(214) = -2.37$, $p = 0.019$, $d = 0.33$.

We next created the failure mindset categorical variable. Campers whose failure mindset was one or more standard deviations above the group mean (i.e., $M \geq 3.53$) were considered as having a failure-is-enhancing mindset (n = 30). Campers whose failure mindset was one or more standard deviations below the group mean (i.e., $M \leq 2.63$) were considered as having a failure-is-debilitating mindset (n = 30). Campers with moderate failure mindsets were not included in the mixed-method portion of the analyses.

3.1. Sources of Robotics Self-Efficacy

The sources of self-efficacy in robotics have not previously been investigated and reported. For this reason, we took a qualitative approach for RQ1 (i.e., what sources of efficacy-relevant information do young adolescents consider when forming their robotics self-efficacy?). This allowed themes outside of the typical four sources to emerge (e.g., [14,15].

We first considered the proportion of camper responses for the full sample that related to the four main hypothesized sources (i.e., direct experiences of mastery and failure, vicarious experiences, social persuasions, physiological and affective states) and then considered other themes. As noted above, proportions were calculated as the total number of times a code was assigned divided by the total number of responses in a given group. All proportions are presented in Figures 1–3.

Direct experiences of failure were the most common source of lowered confidence. However, direct experiences of mastery were not the most common source of raised confidence. Prior exposure and access to robotics were reported as increasing confidence in higher proportions than direct experiences of mastery. Interestingly though, having limited prior exposure or limited access did not lower confidence in similar proportions. Failure experiences, on the other hand, more often lowered confidence than mastery experiences raised confidence. One elementary school girl noted that her confidence was lowered after facing *many* failures. “I failed 26 times in a row to make a robot move around to complete a challenge. This made me discouraged, thus, feeling less confident”. This same camper highlighted how an objective failure might be perceived as a success, noting that “I did a vex robotics competition. This made me feel confident, because I feel like I can do more things after losing 9–5. Even though I lost, I still am proud”.

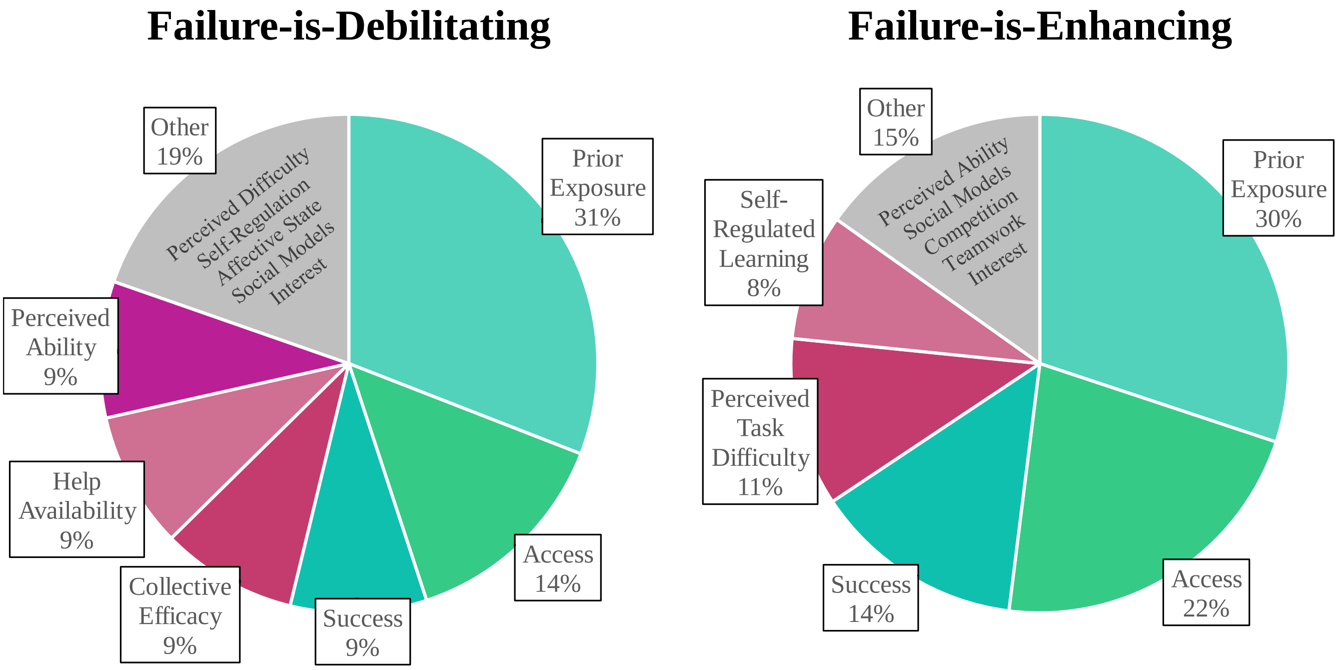

Figure 1. Sources that RAISED robotics confidence by failure mindset. Note. Codes assigned to less than 10% of the sample were grouped into one category of “Other”. Those codes are listed in the “Other” portion of the graph.

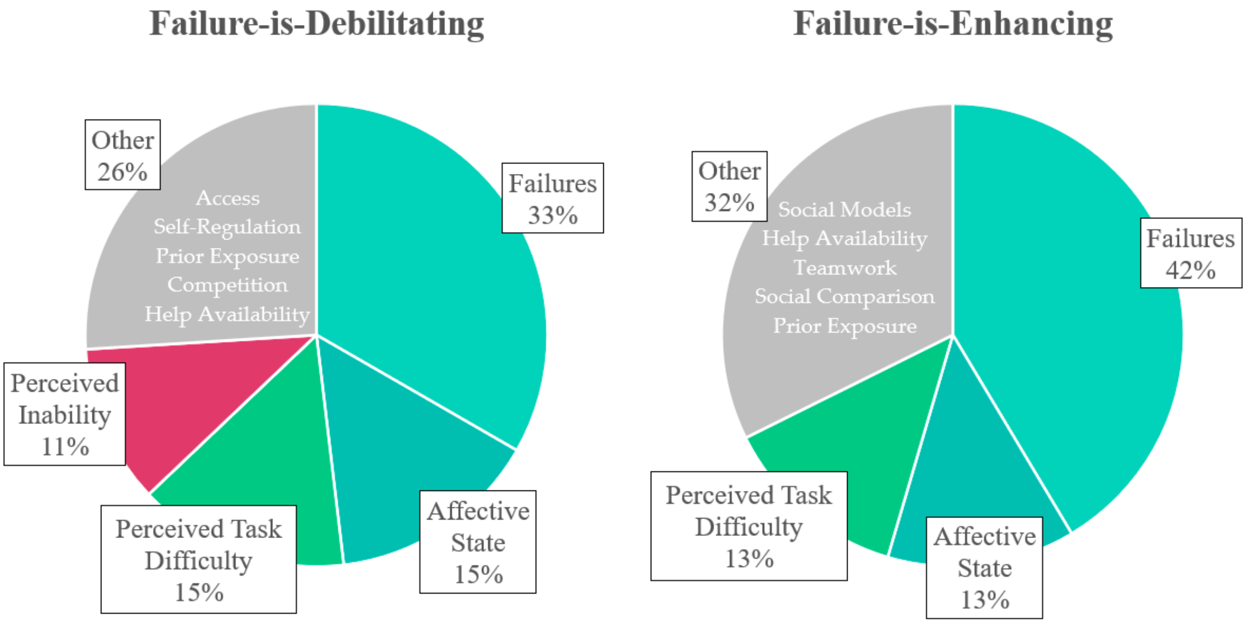

Figure 2. Sources that LOWERED robotics confidence by failure mindset. Note. Codes assigned to less than 10% of the sample were grouped into one category of “Other”. Those codes are listed in the “Other” portion of the graph.

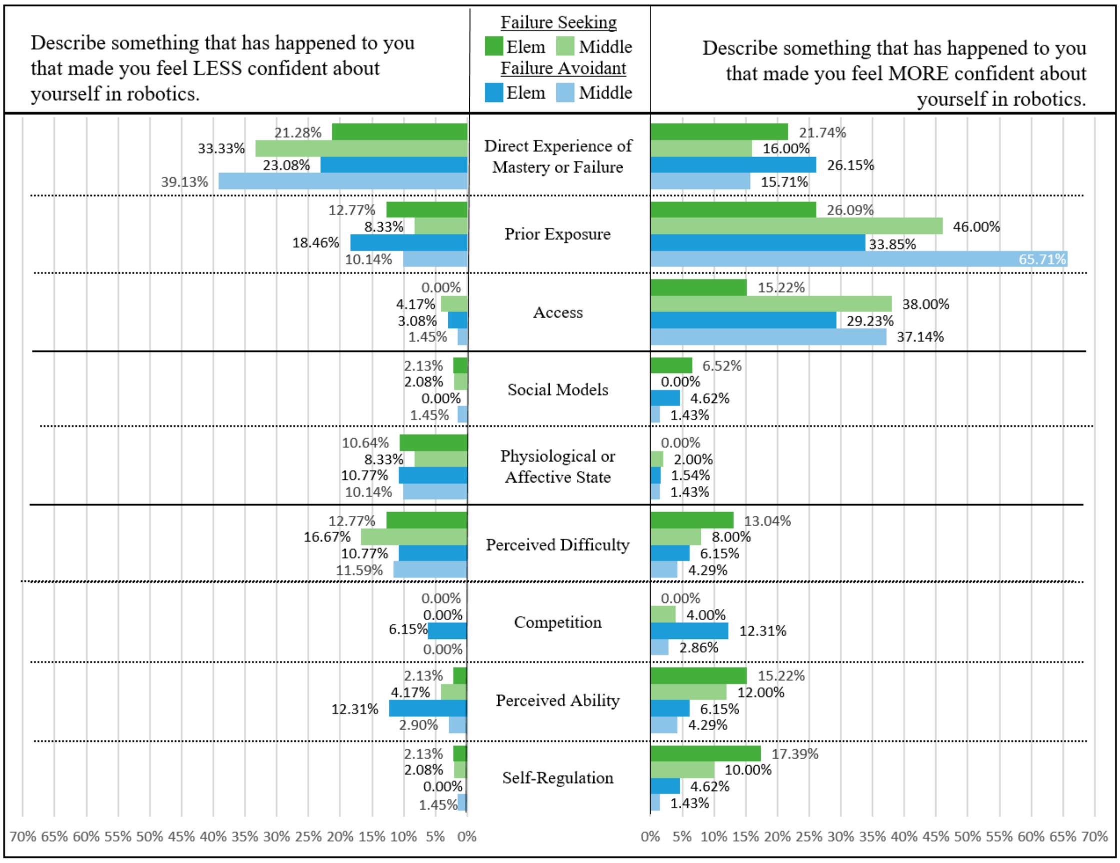

Figure 3. Proportions of responses coded by source for elementary and middle school failure-seeking and failure-avoidant campers. Note. Green bars to the left (n_{elem} = 47; n_{middle} = 48) and right (n_{elem} = 46; n_{middle} = 50) represent confidence-lowering and -raising experiences of students identified

as failure-seeking. Blue bars to the left (n_{elem} = 65; n_{middle} = 69) and right (n_{elem} = 65; n_{middle} = 70) represent confidence-lowering and -raising experiences of students identified as failure-avoidant. Only codes with proportions that indicate failure orientation or developmental differences are displayed for aesthetic purposes.

Combined, the codes related to social sources (i.e., social models, social persuasions, and social comparison) were mentioned more often as confidence-raising than as confidence-lowering. Still, social comparison lowered the confidence of students like this elementary school boy who recalled feeling less confident "when I failed 7 times in a row and *others did it first try*" (emphasis added). Campers also looked to their physiological and affective states when forming their robotics self-efficacy, more often stating that feeling stressed or nervous lowered their confidence than that feeling happy or excited raised their confidence.

Students also pointed to other sources of their confidence beyond the four hypothesized ones. Perceived difficulty was reported as both raising and lowering confidence in similar proportions. Conversely, competition, working with a partner, perceived ability, self-regulation, and an interest in robotics were all more likely to raise a camper's confidence than to lower it. One elementary school girl highlighted the power of working with an experienced partner, indicating that, "My partner has done this so I feel more confident".

3.2. Failure Mindset and Sources of Robotics Self-Efficacy

We next investigated RQ2 (i.e., what is the relationship between young adolescents' failure mindset and the efficacy-relevant information they consider when forming their robotics self-efficacy; does this relationship differ by school level?). We first compared the most common sources of self-efficacy across the two failure mindset groupings, and then considered possible developmental differences. Codes that were assigned to less than 10% of responses in a given mindset group were classified in an "Other" category.

3.3. Confidence-Boosting Experiences

We first considered what made campers more confident in robotics, finding overlap between the two failure mindset groups (Figure 1). Both mindset groups often indicated that prior exposure, access, and success had increased their confidence. One camper with a failure-is-enhancing mindset indicated that, "I've done robotics for the last 5 years. So I've become confident". A camper with a failure-is-debilitating mindset referenced both access and prior success when she said, "I have built one LEGO Mindstorm robot at home and got it to work".

Although these three sources (i.e., prior exposure, access, and prior success) represent the majority of the assigned codes for both the failure-is-enhancing and failure-is-debilitating groups (66% and 53% respectively), there were some notable differences. Campers in the failure-is-enhancing group looked to self-regulated learning and perceived task difficulty when forming their self-efficacy. For example, one camper said that "easier things" boosted his confidence. Another failure-is-enhancing camper said that he was more confident because he knew he could practice more. Conversely, campers in the failure-is-debilitating group referenced the collective skill of the group, availability of help, and their own perceived ability as factors that raise their confidence. As one camper remarked, "Working in a group increases my confidence because when I make a mistake, people will be there to help me understand and fix the issue".

3.4. Confidence Lowering Experiences

We next considered what has lowered campers' confidence (Figure 2). Again, we found similarities between the failure-is-enhancing and failure-is-debilitating groups. Both groups indicated that prior failures, negative affective states, and perceived task difficulty lowered their confidence. One camper with a failure-is-enhancing mindset indicated that a failure led to a negative affective state, noting that, "Sometimes the programming can go wrong if you don't know what you're doing and it can frustrate you". These three experiences (i.e., prior failures, negative affective states, and perceived task difficulty) represent the majority of sources described by both the failure-is-enhancing and failure-is-debilitating groups (68% and 53% respectively).

When we looked for a confidence-lowering pattern unique to mindsets, we found only one. Campers with a failure-is-debilitating mindset often reported that perceived inability lowered their confidence. One camper said her confidence was lowered simply because "I'm not good at coding".

3.5. Developmental Differences in Sources of Robotics Self-Efficacy by Failure Orientation

The interaction of failure mindset and school level was next investigated to consider the second aim of RQ2 (i.e., does the relationship between failure mindset and reported sources of self-efficacy differ by school level?). Due to sample size limitations, we assessed failure mindset differently for this portion of the analysis. Instead of the previously described failure-is-debilitating and failure-is-enhancing mindsets, we looked specifically at students' failure orientation as reflected in students' responses to an item about whether failure should be avoided or sought. Though all items on the scale provide useful information, this item was selected because it was the only action-oriented item in the failure mindset scale. We hypothesized that how campers approach failure was more likely to influence their lived experiences than the more generic measure of their feelings about failure. Campers were categorized as either failure-avoidant (n_{elem} = 65, n_{middle} = 70) or failure-seeking (n_{elem} = 47, n_{middle} = 50) based on their answer to the failure orientation question.

Using these intersected groupings (i.e., school level X failure orientation), we then calculated the proportions of codes assigned (see Figure 3). The denominator in these proportions was the sample size of the group in question (e.g., failure-avoidant elementary students). For aesthetic purposes, we only included in the figure sources for which differences in response patterns were found between these groupings of campers. The left portion of Figure 3 represents the proportion of camper responses describing events that lowered their confidence. The right portion of the figure represents response frequencies for what raised their confidence. Green bars represent campers who were classified as failure-seeking and blue bars represent campers classified as failure-avoidant. Finally, the darker shades of color represent elementary school campers and the lighter shades represent middle school campers. Using this representation, we were able to simultaneously investigate school-level differences, failure orientation differences, and the interaction between the two.

3.6. Differences in Raising and Lowering Confidence

Two codes (i.e., direct experience and prior exposure) presented failure orientation and school-level differences for both what raised and lowered campers' robotics confidence. We first analyzed response patterns for *direct experience of mastery or failure*. When considering experiences that raised campers' confidence, failure-seeking and failure-avoidant middle school campers reported mastery experiences in similar proportions. However, elementary school campers who were failure-avoidant reported mastery experiences slightly more often than elementary campers who were failure-seeking. One failure-avoidant, elementary school girl said that her confidence was raised because, "I made a robot last week in robotics camp, and that made me more confident because I knew I could do it because I already had".

The opposite was found for confidence-lowering experiences. Failure-seeking and failure-avoidant elementary campers indicated that a failure experience lowered their confidence in similar proportions, whereas failure-avoidant middle school campers reported failure as lowering their confidence slightly more often than failure-seeking middle school campers. As one failure-avoidant middle school boy said, "The robots sometimes do not do what I want because I put the wrong code in". For both failure orientations, elementary school campers reported failure as lowering their confidence in similar proportions as they reported mastery experiences raising their confidence. Conversely, middle school campers more than twice as often reported a failure experience as lowering their confidence compared to a mastery experience as raising their confidence. This difference was slightly greater for middle school campers who were failure-avoidant.

School-level differences were found in how many campers indicated that *prior exposure* raised or lowered their robotics self-efficacy. Middle school campers reported that prior exposure raised their confidence nearly twice as often as did elementary campers with the same failure orientation. Conversely, elementary school campers reported that limited exposure to robotics lowered their confidence in higher proportions than did middle school campers with the same failure orientation. One failure avoidant, elementary school boy said he felt less confident because, "This is the first time I have done robotics".

We also detected differences in how often prior exposure was reported by students at the same school level who held different failure orientations. For elementary campers, those who were failure-avoidant reported prior exposure as raising their confidence more often than failure-seeking campers. This same pattern was amplified among middle school campers. One failure-avoidant middle school girl suggested that prior exposure to robotics raised her confidence because, "I know what is expected of me".

3.7. Sources with Differences Only in Confidence Raising Experiences

Five codes were identified as having both school level and failure orientation differences for campers' responses to what raised, but not for what lowered, their robotics confidence. Response patterns found in access, perceived difficulty, perceived ability, self-regulated learning, and social models all suggested that these sources more often raised the confidence of failure-seeking campers compared to failure-avoidant campers, and elementary campers compared to middle school campers. We detail these differences below.

Elementary campers less often indicated that having *access to robotics* raised their confidence compared with middle school campers. However, failure-avoidant elementary campers were almost twice as likely to report access as raising their confidence compared with failure-seeking elementary campers. Conversely, failure-seeking and failure-avoidant middle school campers reported access as raising their confidence in similar proportions. One failure-avoidant middle school boy noted that what made him more confident was that "I have my own EV3 and have been on many robotics teams". As one middle school girl noted, "What's made me less confident is only being able to do robotics once a year since they don't have a strong program at my school".

Failure-seeking elementary and middle school campers were almost twice as likely to report *perceived difficulty* as raising their robotics confidence compared with their failure-avoidant counterparts. However, within failure orientations, elementary campers more often cited perceived difficulty as raising their confidence than did middle school campers with the same failure orientations. One middle school failure-seeking girl said, "Being able to code a VEX Robot had made me more confident in robotics because it seems hard". When considering confidence-lowering experiences, however, all campers reported perceived difficulty as lowering their confidence in similar proportions to each other (10.77–12.77%), with the exception of failure-seeking middle school campers. A larger proportion of these students reported perceived difficulty as lowering their confidence (16.67%). One failure-seeking middle school boy worried that, "Robotics will be really hard, so that makes me a little discouraged".

Some differences were found in how perceived difficulty functioned for students (i.e., as raising or lowering robotics self-efficacy). For both failure-avoidant and failure-seeking middle school campers, perceived difficulty was more than twice as likely to lower their confidence than to raise it. This pattern was not reflected as strongly in elementary students who reported perceived difficulty as raising and lowering their confidence in more similar proportions within failure orientations. Overall, however, trends suggested that perceived difficulty more often lowered robotics confidence than raised it.

Response patterns in the code of *perceived ability* suggested that feeling capable raised the confidence of elementary campers more often than middle school campers. However, within school levels, failure-seeking and failure-avoidant students reported perceived ability as raising their confidence in similar proportions for both elementary and middle school campers. One failure-seeking middle school girl indicated her confidence was raised because robotics, "involves technology, and I'm good with technology". In response to what lowered their robotics confidence, campers reported perceived inability as lowering their confidence in similar proportions to each other across all groupings (ranging from 2.13% to 4.17%) with the exception of failure-avoidant elementary school campers. These campers reported that feeling incapable lowered their confidence in a larger proportion (12.31%). For these failure-avoidant elementary school campers, feeling incapable was reported twice as often as lowering confidence as feeling capable was reported as raising confidence.

We next considered differences in students' reports of *self-regulated learning*. Failure-seeking elementary and middle school campers were three to four times more likely to report that self-regulated learning raised their robotics confidence compared with their failure-avoidant counterparts. Furthermore, within failure orientations, elementary students more often cited self-regulated learning as boosting their robotics confidence compared with middle school campers with the same failure orientation. For example, one elementary school boy indicated that "practice" raised his confidence while "not practicing enough" lowered it.

We found grade level, but not failure orientation, differences in campers' descriptions of how positive *social models* raised their robotics confidence. Failure-seeking and failure-avoidant elementary campers more often reported social models as raising their robotics confidence than did middle school campers. As one elementary school failure-seeking girl wrote, "I have seen 5th graders program robots many times. If they can do it, I can program a robot". All groupings of campers reported poor social models as lowering their confidence in similar proportions.

3.8. Unique Patterns of Differences

For two codes (physiological or affective state and competition), we found notable response patterns, which are described next. All groups of campers reported *physiological or affective states* as raising and lowering their confidence in similar proportions to each other. However, larger proportions of campers indicated feeling that frustration lowered their confidence more than feeling happy raised it. As one elementary, failure-seeking boy said, "Sometimes the programming can go wrong if you don't know what you're doing and it can frustrate you". Some campers found their confidence to be raised through physiological and affective states, like a middle school failure-avoidant boy who said his confidence was raised because, "I spent a lot of time being calm and focused. If I'm calm and relaxed I can focus better".

The code of *competition* did not have failure orientation differences for middle school campers but did for elementary school campers. No elementary campers who were failure-seeking referenced *competitions* as either raising or lowering their confidence. Conversely, failure-avoidant elementary campers reported competition as both raising and lowering their confidence. One failure avoidant, elementary school boy said, "I've been more confident in robotics because last year I was in robotics, and we made the robot get 175 points". Failure-avoidant elementary campers were the only campers to report competition as lowering their confidence. The same boy who indicated his confidence had been raised through competition also indicated that competition had lowered his confidence. He explained, "I feel less confident because last year I didn't make it to states but I was so close with my team". Middle school campers only reported competition as raising their confidence and did so in similar proportions whether they were failure-seeking or failure-avoidant.

3.9. Failure Mindset and Robotics Self-Efficacy

We addressed RQ3 (i.e., what is the relationship between failure mindset and robotics self-efficacy after a robotics summer STEM camp?) using hierarchical linear modeling. The regression model including failure mindset contributed significantly to the prediction of robotics self-efficacy in Step 2, after controlling for demographic variables in Step 1 ($\Delta R^2 = 0.08$, $p < 0.001$). The full model explained 10% of the variance in robotics self-efficacy, $F(4, 211) = 5.89$, $p < 0.001$ (see Table 2). Failure mindset was a significant predictor of end-of-camp robotics self-efficacy ($b = 0.32$, $p < 0.001$), indicating that campers who began camp with a more adaptive (i.e., failure-is-enhancing) mindset about failure reported higher robotics self-efficacy at the end of camp.

Table 2. Linear regression analysis for failure mindset predicting robotics self-efficacy ($n = 216$).

Model 1			
Variables	***B***	**SE *B***	β
Failure mindset	0.32 **	0.08	−0.07
Gender	−0.10	0.08	−0.09
School level	0.17 *	0.07	0.15
Race	−0.08	0.08	0.25
R^2		0.10	
F		5.89 **	
Model 2			
Variables	***B***	**SE *B***	β
Failure mindset	0.50 **	0.11	0.40
School level	1.35 *	0.51	1.22
School level * failure mindset	−0.38 *	0.16	−1.09
R^2		0.11	
F		8.78 **	

Note: Gender: female = 1. School level: elementary = 1. Race: underrepresented minority in STEM = 1. * $p < 0.05$. ** $p < 0.001$.

We next investigated whether the relationship between failure mindset and end-of-camp robotics self-efficacy varied as a function of school level, our final research question. A regression model including failure mindset, school level (i.e., elementary camper = 1), and the interaction between the two (i.e., failure mindset X school level) explained 11% of the variance in robotics self-efficacy (Table 2). Gender and race were not included in this model because they were nonsignificant in the previous model. The model revealed that elementary campers' robotics self-efficacy was predicted to be 1.35 points higher than that of middle school campers. However, failure mindset was more strongly related to the robotics self-efficacy of older campers than to that of younger campers, as indicated by the significant interaction term ($B = -0.38$, $p = 0.019$). As shown in Figure 4, as middle school campers moved from believing that failure is debilitating to believing that failure is enhancing, the associated change in self-efficacy was larger in magnitude than it was for elementary school campers.

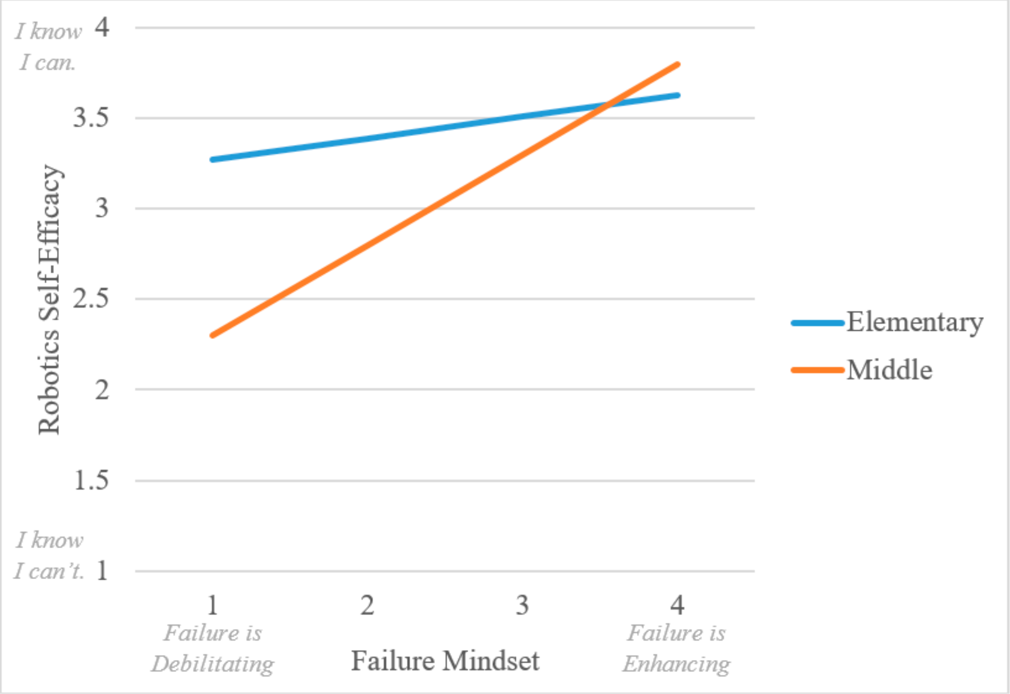

Figure 4. Failure mindset predicting robotics self-efficacy by school level.

4. Discussion

A recent push to normalize failure in the learning process has led many teachers to implement more failure opportunities within their classrooms. However, little is known about how young adolescents view these failure opportunities or how they might be related to young adolescents' academic confidence. The purpose of this study was to investigate developmental differences in the relationship between early adolescents' failure mindset and robotics self-efficacy development. Using the lens of social cognitive theory, we considered failure mindset as a preconception students hold as they move through their lives and examined how that preconception might frame the way elementary and middle school STEM campers perceive efficacy-relevant information. We then investigated how these beliefs adolescents hold about failure might influence their beliefs about their robotics capabilities as well.

Although the sources of robotics self-efficacy reported by campers were aligned with those identified in previous research, one notable nuance emerged. Students more often reported prior exposure and access to robotics as increasing their confidence than they did mastery experiences (i.e., success). This finding may be associated with the availability of educational robotics kits. Educational robotics kits are becoming more accessible, but for many adolescents, these kits are still only available through camps and clubs. This limited access may lead to adolescents having fewer opportunities for success. Prior research has well established that when students feel successful, they feel more confident in their abilities (e.g., [1,2,15,39]). But what happens when students have limited direct information about their ability to succeed? Our findings suggest that in these cases, students may feel more confident simply by being exposed to a task, even if they believe their performance was subpar.

This could have major implications for students who have limited exposure and access to robotics due to low socioeconomic status or underfunded school districts. Educators need to consider how to bring robotics materials, which are often costly, to students who may otherwise not have access to them. This study took place at a STEM camp where students were actively participating in robotics (i.e., every student who took part in this study had access to robotics). Future studies should consider these same questions (i.e., describe something that has happened to you that made you feel [MORE/LESS] confident in robotics) in different contexts where the access to robotics may be more varied. In these other contexts, more students may refer to limited exposure and lack of access as lowering their robotics confidence.

Also of note, campers more often reported failures in robotics as lowering their confidence than they reported success as raising their confidence. As mentioned above, young adolescents tend to have limited exposure to robotics [40]. Because robotics, like most STEM fields, requires many rounds of trial and error [11], the ratio of success to failure might be skewed toward failures, meaning that this finding may suggest that young adolescents may simply have had more failure experiences in robotics than successful ones.

However, further investigation revealed that this unbalanced ratio of reported failure and success was unique to middle school students. Furthermore, middle school students who were failure-avoidant reported failures as lowering their robotics confidence in slightly higher proportions than did their failure-seeking peers. We have no reason to believe that middle school students would fail more often than elementary school students. In fact, we would expect the opposite (i.e., as students age, their skills should improve, leading them to make fewer mistakes). Similarly, students' approach to failure would be expected to have the opposite effect of that seen here. That is, we would expect students who report avoiding failure to do just that: avoid failure. Our findings instead show these students reporting failures more often. For these reasons, we believe that the unbalanced ratio of reported failures and successes reflects cognition as opposed to a quantitative difference in the number of times adolescents have failed.

Working from this understanding, we believe that these findings suggest that as students transition from elementary to middle school, failures take on new, important meanings. Middle school campers seemed to more often notice and internalize failures than did elementary campers. They also less often noted that success raised their confidence. Why might this be the case? Middle school work increases in difficulty, so there is a possibility that these differences reflect more challenging work that results in more perceived failures. However, we do not believe that is what is reflected here. Instead, we think the findings of this study support what others have noted, which is that as students age, failures become more stigmatized, shifting from a natural part of learning to an indicator of inability [12,21]. That is, elementary students are given more freedom to fail, and mistakes are expected. The transition to middle school comes with higher expectations, and mistakes are often viewed more harshly both by students themselves and those around them [12,21].

Middle school and elementary school campers alike looked to prior exposure and access to robotics as confidence-raising experiences. Of note, however, were differences in failure orientations. For both school levels, failure-avoidant campers more often indicated that their confidence was raised through prior exposure and access than did their failure-seeking counterparts. This finding may support the notion that young adolescents who are less comfortable with failure feel more confident in less ambiguous situations, which, in their minds, may pose a smaller risk of failure. That is, having a sense of what to expect may increase their confidence in their ability to succeed. This is important for educators to consider. Students may approach tasks with more confidence if they are given a preview of what to expect or time to explore before stakes are attached to performances. This may be especially important in middle school, where half of the failure-seeking and nearly two-thirds of failure-avoidant campers reported that prior exposure made them feel more confident in robotics.

For both failure orientations and school levels, campers tended to report that their confidence in robotics was lowered because they found the tasks to be difficult. However, some campers reported that completing hard tasks made them feel more confident. Campers who were younger and/or failure-seeking more often indicated that completing difficult tasks boosted their confidence. This may again reflect a stigmatization of failure as students transition to middle school. Older students may perceive difficulty as a failure as opposed to a natural part of learning. Similarly, failure-avoidant campers might feel threatened by a difficult task that may lead to a failure for them. Furthermore, failure-seeking campers may simply be more confident in their ability to overcome difficulties. That is, around one-eighth of failure-seeking campers reported a sense of innate ability as raising their robotics confidence, whereas only around half as many failure-avoidant campers said the same.

One possible explanation for these failure orientation differences in perceived difficulty and ability is self-regulation. Failure-seeking campers reported that being self-regulated made them feel more confident in their robotics abilities around four times as often as their same school-level, failure-avoidant counterparts. Findings from this study did not allow us to disentangle if campers were more confident because they were self-regulated or if being confident in their ability to solve robotics problems led them to persist and better regulate their efforts. The tie between this cognition and behavior is important to investigate further because it may explain important differences in performance outcomes if young adolescents who fear failure are also not effectively using the learning resources available to them.

Surprisingly, elementary campers looked toward social sources to raise their robotics confidence more often than did middle school campers. This does not align with previous work that suggests that the transition to middle school is fraught with heightened awareness of learners' social structures and their place within them [12,21]. However, elementary students also less often reported having prior exposure and access to robotics. The increased awareness of social models, therefore, may instead suggest that when young adolescents have limited direct experience within a context, they more often look toward social models or vicarious experiences. Vicarious experiences are one of the four main hypothesized sources of self-efficacy [7] but have proven difficult to effectively measure given the subconscious manner in which they tend to function [64]. This study provides some insight into how vicarious sources may be of increased importance for younger students or those who have limited direct experiences within a context.

As a final note on the sources of robotics self-efficacy, we were surprised by the response pattern found for the source of competition. For most camper groups, competition was a relatively nonsignificant source of robotics confidence. However, competition seemed to be more important to elementary failure-avoidant campers. We are unsure why this was the case because, intuitively, one might expect that failure-avoidant adolescents would be put off by competitions, which by their very nature result in winners and losers. Furthermore, these students reported competitions as both raising *and* lowering their confidence (the only participant group to do so), which suggests these students were not only aware of competition when they lost or failed, but also when they won. These findings suggest that perhaps failure-avoidant elementary students turn to competitions (i.e., social comparison/ranking) as an indicator of ability (i.e., to answer the question: can I do this?). This is juxtaposed to their failure-seeking peers, who often reported that their confidence was influenced by more internal factors such as feeling capable, being self-regulated, and completing difficult tasks.

In addition to considering the relationship that failure orientation and school level may have with the efficacy-relevant information that early adolescent campers paid attention to, we also investigated how failure mindset and school level might influence reported levels of robotics self-efficacy after a weeklong STEM camp. We hypothesized that failure mindset might frame the interpretations of efficacy-relevant experiences that adolescents perceive, as explored above, and thus influence self-efficacy.

Although the strength of the relationship was moderate, we found that adolescent campers' failure mindset predicted their robotics self-efficacy. Specifically, campers who believed that failure is enhancing reported higher robotics self-efficacy at the end of camp. Conversely, those who endorsed a failure-is-debilitating mindset at the start of camp reported lower robotics self-efficacy at the end of camp.

Findings from this study also point to developmental differences in early adolescents' beliefs about failure and their self-efficacy in robotics. As have researchers in other domains, we found that older campers had lower self-efficacy compared with younger campers (e.g., [22–24]). We also found that the relationship between failure mindset and robotics self-efficacy was stronger for older campers than for younger campers, despite having similar failure mindset scores.

This significant interaction between school level and failure mindset may have several explanations. Perhaps elementary students simply cope better with failure (e.g., [65]). Conversely, elementary-aged children may be more often protected from failure [12]. If students are not facing failures, it is likely that their failure mindset will not play a significant role in their motivation.

Finally, elementary and middle school students may define failure differently. When considering their beliefs about failure, we allowed campers to determine for themselves what they might consider to be a failure. This was an intentional decision. Our hypotheses were based on the idea that failure mindset might be related to self-efficacy, in part, because of its influence on how students interpret their direct experiences. When students interpret these experiences, they will judge their performance against their own standard of failure. Therefore, whatever students may have considered as a failure when completing items regarding their beliefs about failure is likely the same standard of failure by which they judged their performances. In this way, allowing students to self-define failure maintained the same within-student definition of failure between the two measurements. However, by allowing students to self-define failure, developmental differences in what it means to fail may have gone unnoticed.

Overall, our findings suggest that teachers and directors of informal learning experiences might benefit from paying attention to how their students interpret failure. Identifying students who believe that failure is debilitating and attempting to reframe those beliefs to more adaptive ones might improve those students' confidence. In our study, there were no differences in failure mindset between elementary and middle school students, which may suggest that beliefs about failure are relatively stable over time. However, previous research has found that STEM lessons that were intentionally developed to facilitate failure in a positive and productive way resulted in improved skill development and problem-solving [32]. Targeting a failure mindset with similar intervention designs may help inform practices that promote a failure-is-enhancing mindset.

5. Limitations

We recognize several limitations to this work. First, this study took place in an informal learning environment where stakes are low. More research is needed to understand how students' beliefs about failure might be related to their self-efficacy in more formal learning environments such as in STEM classrooms, where stakes are higher and failures tend to bring more serious consequences. Second, although we accounted for gender, race, and school level in our quantitative analyses, our modest sample size prevented us from considering how campers' intersectional identities may affect their beliefs about failure or their robotics capabilities.

Third, the data in this study are entirely self-reported. As a first step toward understanding the role of failure mindset in students' motivation, this was an appropriate method to use. The findings in this study highlight the existence of a relationship between students' beliefs about failure and their confidence in robotics. To our knowledge, this relationship to date has not been investigated. However, moving forward, non-self-report data such as performance or task re-engagement might be included in future studies.

Finally, we would be remiss to not acknowledge the self-selective nature of an informal learning environment like a summer camp. The young adolescents in our sample may have wanted to attend a summer STEM camp due to their own pre-existing skills and interests, or they may have been encouraged to do so by their parents or teachers. Regardless, campers at this camp might not represent "typical" students.

6. Conclusions

Our study took place in a summer, week-long, informal learning setting and was specific to robotics. Self-efficacy is highly contextualized and may develop differently in different domains [14]. Campers' beliefs about their abilities in robotics may not be related to their beliefs in other areas or learning environments [66]. Future studies might consider the relationships investigated in this paper in other domains (e.g., math, science) or learning environments (e.g., schools, competitions).

Both qualitative and quantitative results suggested that there are developmental differences in the relationship between how students view failure and the development of robotics self-efficacy. Generally speaking, middle school students seemed more keenly aware of their failures and that salience was reflected in their robotics self-efficacy. Conversely, younger students may view failure more favorably, seeing it as a natural part of the learning process.

We chose to assess failure mindset in a domain-general way following the method used by Haimovitz and Dweck [10]. However, learners' views about failure may also differ across domains. More research is required to determine whether students' views of failure depend on the domain in which failure is considered. For example, learners' beliefs about failure may be different in domains where trial and error are commonplace than in domains where mistakes are less tolerated.

Personal cognitions (e.g., self-efficacy) and preconceptions (e.g., failure mindset) offer a lens through which experiences are interpreted (e.g., [6]). However, the data in this study raise important questions about the sequencing and reciprocal nature of learners' beliefs. For example, do young adolescents' beliefs that failure is debilitating cause them to focus on failures, thus lowering their self-efficacy over time? Alternatively, do children with low self-efficacy more often view failure as debilitating because it reinforces their already suffering self-belief?

Assessing the relationship between robotics self-efficacy and failure mindset is a first step toward a better understanding of how children's views of failure influence their academic motivation. We also investigated whether school level (i.e., elementary and middle school) affects the relationship between failure mindset and self-efficacy. Although much is still to be discovered, this initial step in understanding failure mindset in an informal learning context shows promise. Our evidence shows that failure mindset matters in the development of robotics self-efficacy in early adolescence.

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