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Innovation Article

Evaluating How Exposure to Scientific Role Models and Work-Based Microbadging Influences STEM Career Mindsets in Underrepresented Groups

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Abstract—Underrepresentation of female students and specific racial/ethnic groups persists in STEM despite decades of intervention. Evidence suggests a need to encourage interest in STEM fields at the middle-school level. Adolescent career aspirations are influenced by exposure to role models and mindsets, such as a sense of perceived personal capacity. The purpose of this study was to measure how exposure to role models and work-based microbadging affects students' mindsets related to pursuit of STEM careers. Middle school students rated their intent to pursue a STEM career before and after completing a series of Quest-Challenge pairs featuring role models, including a biomedical engineer, in the Couragion application, along with their confidence, motivation, and enjoyment through in-app surveys. Data from students in well-represented and underrepresented STEM demographics were compared. Intent to pursue a STEM career increased after Couragion app intervention. Divided into demographic groups, increases were observed in students from underrepresented racial/ethnic groups and female students. Students reported increased confidence, motivation, and enjoyment after interacting with the app. Additionally, students reported confidence in STEM career success and motivation to apply themselves academically. This study showed increased intent, confidence, motivation, and enjoyment in middle school students related to STEM careers. The Couragion app intervention effectively improved metrics that inform students' future academic and professional decisions. Widely implementing this type of intervention during middle school could help narrow the representation gap in STEM fields.

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INTRODUCTION

The underrepresentation of women and racial and ethnic groups, including blacks or African Americans, Hispanics or Latinos, and American Indians or Native Alaskans, in science, technology, engineering, and mathematics (STEM) fields is persistent[57] and continues to limit national potential for growth and innovation. These disparities also perpetuate a mismatch between the demand for and supply of engineering professionals in the workforce.[13] In 2016 the U.S. Bureau of Labor Statistics reported a deficit of approximately 30,000 engineering jobs compared to engineering undergraduate degrees awarded in the same year.[58] Women and underrepresented racial and ethnic groups constitute a substantial and growing portion of the United States (U.S.) civilian labor force that could contribute to filling this gap. In 2019 women were 47% of this population; Hispanics or Latinos, 17.8%; blacks or African Americans, 12.6%; and other groups combined, 10%.[82] It is imperative to

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recruit and retain these students to develop a diverse, globally competitive STEM workforce.

Studies on STEM career aspirations highlight the importance of early-student interest in STEM. Students interested in pursuing a STEM career in the eighth grade have been shown to be more likely to earn a degree in a STEM field.[51] Exposure to STEM content in middle school is also positively associated with obtaining a STEM-related occupation.[79] Likewise, achievement, confidence,[54] and perceived personal capacity[16,81,88] in middle school students were key factors in predicting persistence in STEM career aspirations. The present research examined how exposure to scientific role models and work-based microbadging through the Couragion app influenced intent, confidence, and motivation to pursue STEM careers among early adolescent female and underrepresented racial and ethnic groups compared to well-represented groups.

STEM Identity in Middle School

Within the framework of expectancy value theory, identity can be conceptualized as (1) perceptions related to skills, characteristics, and competences, and (2) perceptions related to personal values and goals.[23,24] During adolescent identity development, students seek clues in their surroundings about the adult they are likely to become.[25] Students who develop STEM identities see themselves as able to participate in STEM careers based on the intersection of their interests, abilities, race, gender, and culture.[9,14,66] STEM identity has been linked to behavioral outcomes, such as choosing a major, as well as persistence to complete a degree, in STEM.[64] Unfortunately, many STEM careers are still perceived as predominately white and male. As a result, girls and students of color struggle to see themselves as potential STEM professionals and fully construct STEM identity.[9,14,36,66]

Most students have decided what they do not want to do in a future career, i.e., which careers do not fit within their perceived identity by age 13.[11] Unfortunately, these decisions lead to a measurable decline in scientific interest, particularly in girls, in early adolescence.[3,5,67,69,74] A study of a nationally representative sample of eighth graders showed that male students were more likely than female students to persist in science and engineering career aspirations, while students from underrepresented racial/ethnic groups were less likely to aspire to these careers than their well-represented peers. Interestingly, students in these underrepresented racial/ethnic groups were equally likely to persist in science and engineering career paths if they aspired to those careers in eighth grade.[54] Female students who identify with STEM early in school are more likely to choose careers in STEM fields.[12] One promising way to encourage STEM identity and improve mindsets related to pursuing a STEM career is exposure to role models during middle school.

Exposure to Role Models

One way to correct perceptions in the middle school classroom is to introduce female and underrepresented students to STEM professionals with genders, races, and/or ethnicities that match their own identities.[42] STEM outreach programs that incorporate career exploration through role model experiences improve students' intent to pursue careers in those fields, especially among female students.[61] Role models portray what to expect in a certain career, give students a more accurate understanding of the personalities of real scientists and engineers, and create a vision of a STEM professional that they can identify with and perhaps inspire to pursue that career.[49,50,52] Extensive research has shown that female role models can inspire female students to pursue STEM careers.[19,20,27,47,53,63,65] As an example, Gonzalez-Perez *et al.* found that role model sessions increased female students' enjoyment and sense of importance, as well as their expectations of success in math and preference for a STEM career. Interestingly, female students who learned that STEM professions require skills not stereotypically associated with STEM—like teamwork, communication, and social skills—showed an increase in intent to pursue STEM.[27] Indeed, stereotypes about who can work in STEM fields and what it takes to succeed there contribute strongly to the gender disparity in STEM intent.[72] Dubetz and Wilson developed the Girls in Engineering, Mathematics and Science (GEMS) program in 2006 to offer hands-on activities to female middle-school students, designed and led by female instructors, and found that students' interest in math and science increased by an average of 35% after attending a GEMS event.[22] Merritt *et al.* recently studied the influence of role models on students in early adolescence, an important age group in the process of identity development. Female role models who led science workshops increased identification with science among early-adolescent girls from underrepresented ethnic backgrounds, even when the role models were from well-represented backgrounds.[55] Lindstrom *et al.* surveyed high school students and educators regarding their perceptions on career and college preparation: participants identified relationships between students and adults who could inspire, guide, and mentor them as one of the most important strategies to support academic readiness.[48] Results from a large meta-analysis of lab and field studies found that students from underrepresented racial/ethnic groups showed improved performance and interest in STEM when exposed to in-group role models; mentors similar in race and ethnicity to their students can have a large impact.[44] To better understand the experiences and beliefs of underrepresented students interested in STEM fields, Kricorian *et al.* surveyed adults in STEM careers (71% female and 96% ethnic minority) about their belonging, identity, mindset, and views on STEM participation. This study found that over 60% of participants knew someone of their gender or ethnicity who served as a STEM role model and over 50% asserted that meeting a STEM professional of their gender or ethnicity would be encouraging in their pursuit of STEM.[43]

Foundational research has shown that role models can positively influence others without close relationship or direct contact.[26,50,53] Remote exposure to role models through written descriptions, audio, and video recordings works well to intervene with a wide variety of students from underrepresented demographics.[44,75] Couragion, for example, is an app that provides insight into the working lives of STEM professionals through an interactive student-led journey. Students complete Quests, which consist of three conversational interviews with a STEM professional, as well as work-based Challenges that enable students to use their new knowledge of a specific STEM career to solve authentic problems and gain practical skills. A major focus of the Couragion platform is the use of diverse role models to build perceived personal capacity in students. As such, the team has previously studied the impact of a role model's gender and ethnicity on students' performance, joy, motivation, and confidence. Students interacted with videos of role models who mirrored a diverse demographic (70% of role models are female and 40% are from communities of color) and completed work-based challenges to receive microbadges in practical occupational and employability skills. Microbadges are small graphic acknowledgments of specific skills and competencies, often used in the context of workforce readiness. Work-based microbadges represent achievements and confer a feeling of accomplishment.[17] The data (unpublished) indicated that when a student and role model shared the same gender, the student's overall performance score was 6% higher. Similarly, shared diversity resulted in overall performance scores being 8% higher. Such data supported Couragion's research premise that role models who mirror the students' demographics was important to influence student success. Within the Couragion app, Impact Measures were gathered as students completed Challenges. Students were asked to rate their level of agreement to three statements: (1) I enjoyed learning these skills; (2) I am motivated to do better in my STEM assignments after completing this challenge; and (3) Learning these skills makes me feel more confident about pursuing STEM careers. Together, these three areas measured joy, motivation, and confidence. Research shows that students who reported higher engagement in exploring their options before committing to a STEM career path were likely to start the semester feeling more competent, perceiving higher value, and believing that investing effort into STEM classes was worthwhile.[64]

Engagement, Capacity, and Continuity

In 2004 Jolly *et al.* reviewed research and evaluation efforts, as well as certain interventions, in quantitative disciplines that focus on student success in STEM. Three factors emerged that must be present for student success: (1) engagement, (2) perceived personal capacity, and (3) continuity.[40] Engagement can be defined as having an awareness of, interest in, or motivation related to STEM careers. Perceived personal capacity means a student perceives they have the knowledge and skills needed to advance to increasingly rigorous studies in STEM. Finally, continuity describes the institutional and programmatic opportunities and resources available to the student. Confidence and perceived personal capacity greatly impact students' achievement in STEM fields; for decades, researchers have studied students' beliefs about what it takes to be competent in STEM, including what motivates different genders to choose educational and career pathways.[30,68,71,85–87] Recent studies have shown that social belonging is critical for women in STEM fields and the same level of social belonging sufficient for male students to persist in STEM may not be enough for female peers.[4,45] This evidence supports a concept known as the vulnerability hypothesis: students who most risk academic failure will be affected most by their perceptions of and experiences in academic settings. Therefore, underrepresented groups in STEM will rely more on a sense of belonging and engagement to perceive their capacity to succeed in STEM compared to well-represented groups.[35] This hypothesis extends to underrepresented racial/ethnic groups. Walton and Cohen studied the difference in attitudes towards computer science of Black and White undergraduate students. Black students were more pessimistic about succeeding in computer science when they were led to think they would have few friends in that field compared to Black students who were not led to think that. White students were not more or less confident about success when their sense of belonging was threatened.[84] Kang *et al.* found that perception of self in relation to science strongly predicted personal identification with STEM careers in middle school girls of color.[41] Encouraging underrepresented students' identification with STEM careers provides crucial engagement and self-efficacy that will influence their future academic and professional decisions.

Recent research has shown that gender is the most important predictive variable in engineering major declaration.[46] Students at the undergraduate level may struggle to pursue engineering because of lack of preparation, a sense of disappointment, doubt, and misconceptions about engineering—all of which indicate insufficient engagement and capacity for success.[29,37,56,62] Gottfried and Plasman found that female high school students are less likely to express interest or enroll in engineering courses than male students of the same age. This has a major impact on future engineering career choices: participation in engineering in high school was linked to completion of an engineering degree and more strongly linked to completion for female than male students.[28] Additionally, a study of first-year college students found that inadequate preparation and lack of access to educational opportunities before college negatively affected persistence in STEM majors for students from underrepresented racial/ethnic groups.[15] Results such as these indicate that programs cultivating engineering interest should be introduced early in students' lives to ensure engagement, increase capacity, and provide continuity.[39]

The current study aims to understand how exposure to diverse role models and work-based microbadging in middle school influences student mindsets toward pursuing a STEM career. The questions posed by the Couragion app during the student-led journey were informed by the model of participation in STEM activities presented by Weber and based on the Engagement, Capacity, and Continuity (ECC) Trilogy established by Jolly *et al*. in 2004.[40,88] Weber operationalized the ECC Trilogy and analyzed middle school and high school students' responses to survey questions, comparing results from male and female students. The responses from this study provided evidence to support the ECC Trilogy. Specifically, both female and male students who indicated initial interest in engineering careers responded to survey items with high engagement, perceived personal capacity, and interest in participating in technology- and engineering-related programs.[88] Couragion adapted the Likert-scale questions from this study to measure student interest in STEM careers before and after completing Quest and Challenges within the app.

Study Purpose and Student Outcomes

The current state of engineering education is understandably concerned with representation in STEM fields, particularly with regards to diversity and equity. Extant literature contains a wealth of information regarding the importance of gender in predicting retention and success in STEM. Some studies have specifically compared STEM career outcomes in students from underrepresented racial/ethnic groups with their peers in well-represented racial ethnic groups, but these studies often use gender-matched samples (all male or all female students). Moreover, this type of research is often focused on undergraduate or high school students, with less emphasis on STEM attitudes in adolescent students. The study presented here decouples gender and racial/ethnic groups in the data to explicitly measure the effectiveness of an app-based learning tool on influencing STEM mindsets in middle school students. The Couragion app combines role models from diverse, underrepresented backgrounds with practical, work-based learning to improve students' perceived personal capacity in STEM fields. This study sought to better understand the following student outcomes:

1. Does exposure to virtual role models and work-based microbadging through the Couragion app influence students' intent to pursue a STEM career?
2. Do student mindsets toward potential success in a STEM career improve after this intervention?
3. Do these responses vary by gender or racial/ethnic background?

Positionality Statement

The researchers recognize that our subjectivities, training, experiences, and interests influence our investigations. Therefore, to ensure the credibility of this study, we want to make our positionality as researchers transparent.[73,83] We identify as [anonymized].

METHODS

Participants

The 127 students who participated in this study were eighth graders from a public middle school in Colorado. Overall, students enrolled in this school are 89% non-white and 77% economically disadvantaged. The student population includes 46% female and 54% male students. Study participants were 52% female and 47% male. Some students did not specify a gender and were therefore exempted from analyses that compared gender. Participants identified with various racial and ethnic backgrounds (3% American Indian or

Alaska Native, 3% Asian, 3% Black or African American, 68% Hispanic or Latino, 1% Multiracial, 11% White, and 6% Other). For this study, students were categorized into two groups—those from groups recognized as underrepresented racial and ethnic groups by the National Science Foundation ($n = 108$; American Indian or Alaska Native, Black or African American, Hispanic or Latino, Multiracial and Other) and those from well-represented groups ($n = 19$; Asian and White).

Procedure

The research protocol was determined to be exempt from review by the Colorado Multiple Institutional Review Board under Category 1—research conducted in established or commonly accepted educational settings. All eighth-grade students ($n = 285$) engaged with the Couragion app as part of their science classes. Data were only collected from students who returned a permission slip signed by a parent or legal guardian ($n = 127$).

All participants created a Couragion account. The Couragion app is generally available for purchase and use in additional research studies. Upon registration, students entered their racial/ethnic background, gender, intent to pursue a STEM career, and answered a series of questions that helped the software identify careers that fit each student. Students were then encouraged by their science teachers to complete at least three Quest-Challenge Pairs, beginning with the Biomedical/Materials Engineering Challenge. Couragion created an educator guide to accompany all Quest-Challenge pairs and provided training to help educators implement these activities in the classroom. Career Quests were video interviews with role models who mirrored a diverse demographic (70% female and 40% from communities of color). Each Quest was comprised of three video interviews. The videos were structured around a conversational interview guide. Following each Quest, students answered a series of reflection questions related to the information presented in the video. The questions were sourced directly from the facts and information presented within the video content. Each Career Challenge was specifically designed to enable students to practice work-based skills related to a Career Quest (Fig. 1a). Challenges included a variety of app engagement features tied to core academic standards, such as micro-lessons (Fig. 1b), mastery quizzes, skill practices, multiple-choice questions, video viewing, whiteboarding, data entry, task organization, and image selection (Fig. 1c). Following completion of Career Challenges, students were awarded new microbadges based on their performance (Fig. 1d). Couragion was the primary means for STEM career exploration in the classroom.

Challenges included industry scenarios, micro-lessons, comprehension quizzes, interactive experiences, demonstration concepts, skill practices, and contextual activities that mirror the real world with built in-app assessments of student mastery. For each of the ten Challenges, students engaged in virtual work-based learning while earning micro-credentials in three occupational and three employability skills—all tied to core academic standards. Each Challenge attempt takes 45 minutes to complete and students were encouraged to repeat the Challenge until they reached mastery. The accompanying Quest for each Quest-Challenge pair was a video-based, experiential learning activity that introduced students to a diverse, near-peer role model who taught students about that career. The role model interviews were 10-15 minutes long. Couragion used the National Career Clusters Framework as an organizing tool for curriculum design and instruction.[59] There are 16 Career Clusters in the framework and role models represented each cluster. The Biomedical/Materials Engineering Challenge, for example, focused on the following occupational, employability, and essential skills: biological systems, medical technologies, engineering design, information gathering, industry standards, and spatial reasoning. The type of tasks that students completed to practice these skills included the following: selecting a research article, beginning a traceability matrix, reviewing a toxicity evaluation, preparing pattern prototypes, and assessing scratch assay test results. The educator guide provided to science teachers included three lesson plans that covered completion of the 'Biomedical Engineer' Career Quest, completion of the 'Biomedical Brainiac' Challenge, and completion of a 'Biomedical Engineering' My Journey Activity. These lesson plans included supplemental exercises and pre-readings. The guide also included an Appendix that details the answers for the 'Biomedical Brainiac' Challenge.

Measures

Students responded to survey questions in the Couragion app. Survey questions assessed confidence, enjoyment, and motivation after each Challenge completion (Fig. 2) and intent to pursue a STEM career after three Challenges. Challenges available to students were Biomedical Brainiac, Product Boss, Digital Dynamo, Electrical Expert, Data Champ, Mechanical Maestro, QA Hero, UX Guru, and SysAdmin Star. Students were encouraged to interact with Biomedical Brainiac and at least two other Challenges of their choice. After students completed at least three Quest-Challenge pairs, data from students with parental

FIGURE 1. Representative screenshots of the Biomedical/Materials Engineering Challenge. (a) The challenge overview described a work-based project related to the Biomedical/Materials Engineering career. (b) Micro-lessons taught students specific knowledge and skills required to complete the project. (c) Students completed tasks based on skills taught in the micro-lessons to unlock work-based microbadges. (d) New skills and microbadges acquired by students were recorded on the Brag Page.

permission were analyzed. Completed Quests included Robotics & Computer Vision Engineers, Metal Fabricator, Biomedical Engineer, Product Manager—Software, Aviation Planner, Quality Manager, Manager of City Operations, Zookeeper, Large Mammal Hoofstock, Climate Dynamics Researcher, Electrical Engineer, Director of Nursing, Graphic Designer, Injection Molding Engineering Manager, Pain Technician, IT Manager, Head of Engineering—Toys, Mechanical Engineer, Park Ranger. Advertising Technology Data Analyst, Welder, Digital Media Specialist, Financial Advisor, Metal Fabricator, Engineer Technician—Physics/Laser, Quality Manager, STEM Educator, Cancer Researcher, Software Developer—Applications, Game Developer, and Operations Geologist—Oil & Gas.

Intent to Pursue a STEM Career

Participants rated their intent to pursue a STEM career using a sliding scale of Strongly Disagree (0) to Strongly Agree (100) both at registration and after completion of three Quest-Challenge pairs.

Confidence, Motivation, and Enjoyment

The degree to which participants agreed with the following three statements: (1) Learning these skills made me feel more confident about pursuing STEM careers, (2) I enjoyed learning these skills, and (3) I am motivated to do better in my STEM assignments after completing this Challenge, was assessed after each Challenge. Students could select disagree, somewhat agree, or strongly agree (Fig. 2).

Established instruments such as the Holland Occupational Themes (RIASEC) were used as a taxonomy of interests based on a theory of careers and vocational choice.[33,34] The measurement scales were informed by the theory of perceived personal capacity and participation in STEM-related activities.[88] The instruments were developed to comply with a pre-/post-measurement model. Other peer researchers have indicated that they believe the instrument measures what it was de-

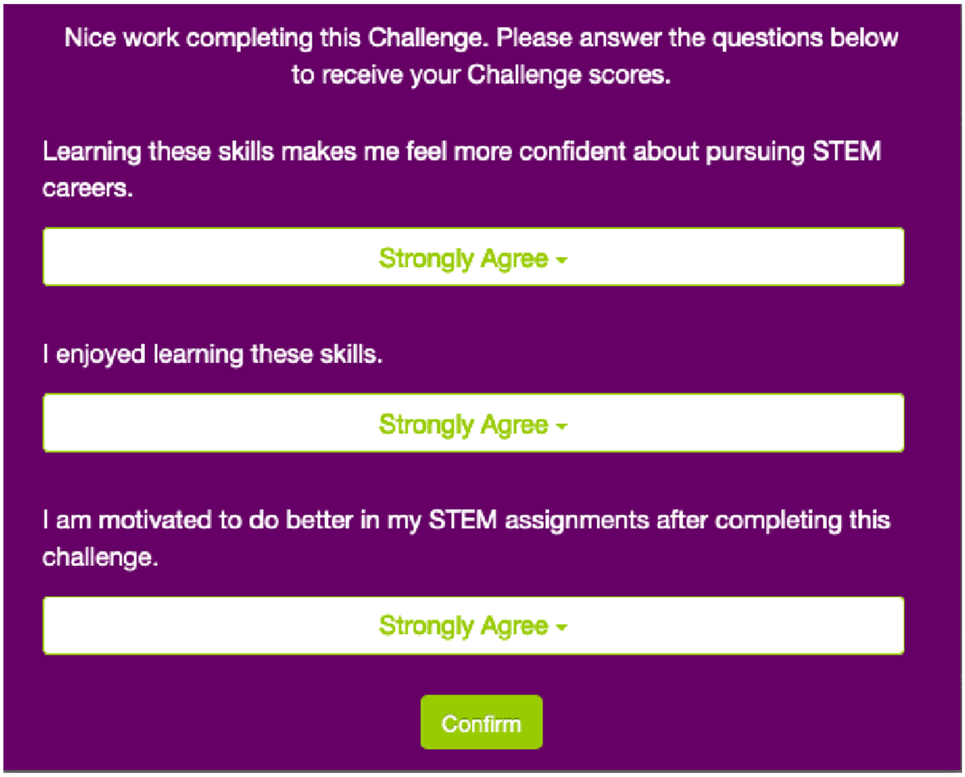

FIGURE 2. Representative screenshot of survey questions evaluating confidence, motivation, and enjoyment after completing each Challenge.

signed to measure. Couragion has collected data from over 10,000 individual users to date.

Competency Score

In-app assessment of challenge responses culminated in an overall competency score. The competency score was a rating of one to five stars based on the number of correct answers given throughout the activities.

Statistical Methods

Data are presented as histograms with nonlinear Gaussian curves fit, or as bar charts divided into percentages (%). Sample medians from histogram data are reported. Gaussian data are reported as mean ± standard deviation (SD) with R-squared (R^2).

RESULTS

After interacting with the Couragion app, average intent to pursue a STEM career increased overall (Fig. 3). Median intent to pursue a STEM career was rated 50 out of 100 by students upon registration in the Couragion app and increased to 61.5 after completing three Quests. Gaussian curves fit over the data also show an increase in intent to pursue a STEM career, with a mean ± SD of 51.26 ± 5.37 at registration ($R^2 = 0.59$) and 63.05 ± 21.37 ($R^2 = 0.79$) after completing three quests.

Intent to pursue a STEM career increased after three Quest completions for students from underrepresented racial/ethnic groups compared to their peers from well-represented racial/ethnic groups (Figs. 4a, 4b). 50 out of 100 students from underrepresented racial/ethnic groups reported a median intent to pursue a STEM career at registration, which increased to 61 out of 100 after three Quest completions. Conversely, median intent to pursue a STEM career among well-represented racial/ethnic groups decreased from 65 out of 100 at registration to 64 out of 100 after three Quest completions. Gaussian curves fit over the data showed a mean ± SD of 51.05 ± 5.59 ($R^2 = 0.45$) and 63.01 ± 20.38 ($R^2 = 0.84$) for underrepresented racial/ethnic groups at registration and after three Quest completions, respectively. Well-represented racial/ethnic groups showed an increase in the Gaussian mean ± SD, from 53.06 ± 5.67 at registration to 56.98 ± 5.80 after three Quest completions ($R^2 = -0.50$ for both). Female students showed an increase in intent to pursue a STEM career after interacting with the app, compared to a decrease in

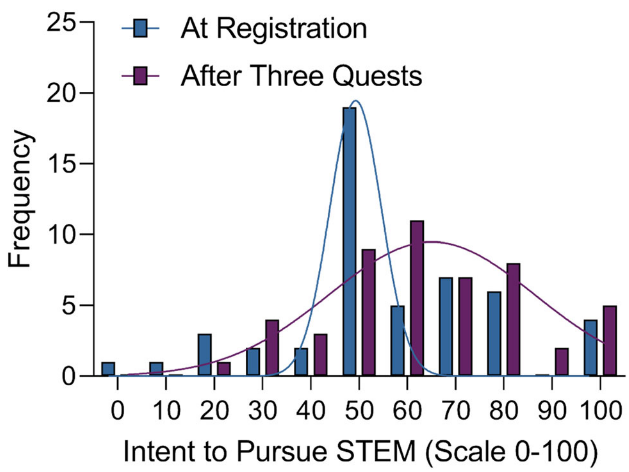

FIGURE 3. Intent to pursue a STEM career increased when comparing responses from all participants after completing three Quest-Challenge pairs to responses received at registration. Histogram with Gaussian nonlinear curves fit, *n* = 50 paired values.

intent among male students, although male students showed overall greater intent (Figs. 4c, 4d). Median intent to pursue a STEM career for female students increased from 50 at registration to 55.5 out of 100 after completing three quests. Curves fit had means $\pm$ SD of 50.61 ± 5.53 at registration and 59.16 ± 25.56 after completing three Quests ($R^2 = 0.74$ and 0.55, respectively). Male students had a median intent to pursue a STEM career of 65.5 out of 100 at registration and 65 out of 100 after three Quest completions. The curves fit over those data had means $\pm$ SD of 66.16 ± 19.52 at registration ($R^2 = 0.55$) and 64.55 ± 11.35 after three Quest completions ($R^2 = 0.77$).

All student groups presented here achieved a median score of 2 out of 5 stars on overall competency. The Gaussian curves fit over data show small differences between demographics. Students from underrepresented racial/ethnic groups scored 2.27 ± 0.77 stars ($R^2 = 0.997$) while students from well-represented racial/ethnic groups scored 2.47 ± 0.69 stars ($R^2 = 0.98$; Fig. 5a). Female students scored 2.24 ± 0.79 stars on competency ($R^2 = 0.99$) and male students scored 2.36 ± 0.76 ($R^2 = 0.99$; Fig. 5b).

Most respondents reported that learning these skills made them more confident in pursuing a STEM career, that they were more motivated to do better in STEM classes, and that they enjoyed learning these new skills following the intervention (Fig. 6). The statement "Learning these skills makes me feel more confident about pursuing STEM careers" was somewhat or strongly agreed with by 76% of students from underrepresented racial/ethnic groups, 80% of students from well-represented racial/ethnic groups, 74% of female students, and 79% of male students. The statement "I am motivated to do better in my STEM assignments after completing this challenge" was somewhat or strongly agreed with by 74% of students from underrepresented racial/ethnic groups, 80% of students from well-represented racial/ethnic groups, 69% of female students, and 81% of male students. Finally, the statement "I enjoyed learning these skills" was somewhat or strongly agreed with by 64% of students from under-represented racial/ethnic groups, 70% of students from well-represented racial/ethnic groups, 64% of female students, and 65% of male students.

Student respondents also reported learning new things about careers, increased confidence in STEM career success, and plans to work harder in their STEM classes (Fig. 7). The statement "I just learned something about careers that I didn't know before" garnered "Yes, A Lot" or "Yes, A Bit" answers from 89.3% of students from underrepresented racial/ethnic groups, 93.8% of students from well-represented racial/ethnic groups, 88.3% of female students, and 92% of male students. The statement "After seeing these careers and role models firsthand, I am confident that I could succeed in STEM-related careers" was responded to with "I am more confident that I could succeed in these types of careers" by 45.5% of students from underrepresented racial/ethnic groups, 33.3% of students from well-represented racial/ethnic groups, 40.5% of female students, and 48.6% of male students. Finally, the statement "I plan to work harder in my STEM classes" received "Totally" or "Probably" responses from 91.6% of students from underrepresented racial/ethnic groups, 66.7% of students from well-represented racial/ethnic groups, 75% of female students, and 100% of male students.

DISCUSSION

Positive Outcomes on Engagement, Capacity, and Continuity

Overall, the eighth-grade students that participated in this study showed increases in intent to pursue a STEM career after completing three Quests in the Couragion app. The decision to engage with this age group was based on research showing that students make choices about pursuing technical fields in middle school,[45] and early adolescence is an ideal time to encourage students to pursue STEM careers.[6,65,89] When broken down by gender, female students in this study showed an increase in intent to pursue a STEM while their male peers exhibited a decrease in intent to pursue a STEM career after interacting with the app. Attitudes towards science become more negative for all

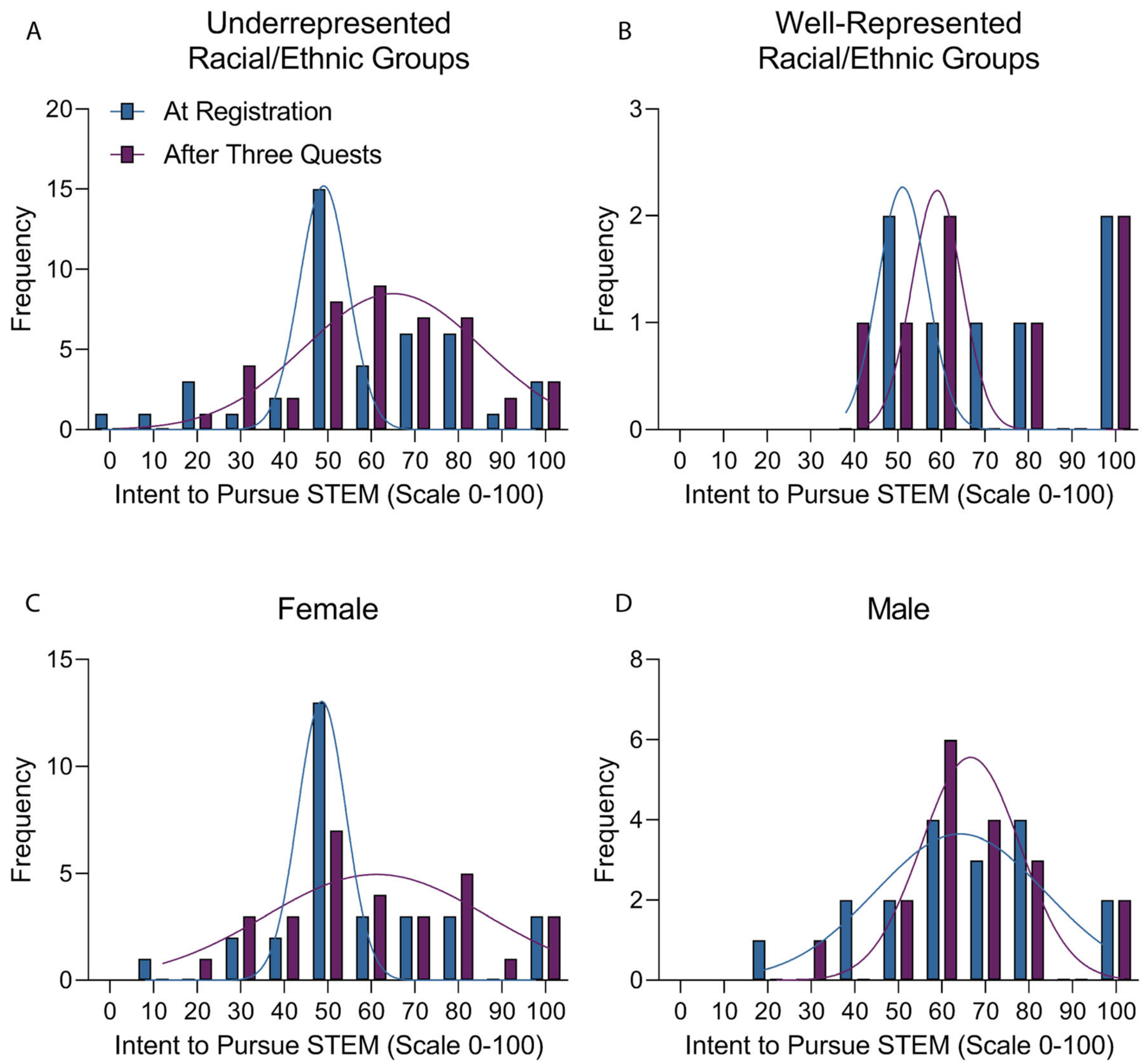

FIGURE 4. Student intent to pursue STEM careers at registration and following completion of three Quest-Challenge pairs broken down by demographic. (a) Intent to pursue a STEM career among students from underrepresented racial/ethnic groups increased from 50 to 61 out of 100 after completing three Quests. (b) Students from well-represented racial/ethnic groups saw a slight decrease in intent to pursue a STEM career from 65 at registration to 64 after three Quest completions. (c) Female students' median intent to pursue a STEM career increased from 50 at registration to 55.5 out of 100 after completing three Quests, while (d) male students' intent to pursue a STEM career decreased from 65.5 to 65 between registration and the three Quest completion outcome. Data presented as histograms with Gaussian curves fit; *n* = 43 for underrepresented, *n* = 7 for well-represented, *n* = 18 for males, and *n* = 30 for females.

students between seventh grade and ninth grade in the absence of intervention, and the change is more pronounced for female than for male students.[5] In the context of that study, these findings indicate that exposure to a combination of role models and work-based microbadging had a positive effect on student intent to pursue a STEM career, especially for female students.

Mau *et al.* showed that STEM outreach programs can be especially impactful for female students and underrepresented racial/ethnic groups when deciding whether or not to pursue a STEM career.[10] The findings reported here aligned with previous research and showed that students from underrepresented racial/ethnic groups reported a greater increase in intent to pursue a STEM career than students from well-represented racial/ethnic groups after using the Couragion app. Choice may play less of a role in STEM pursuit for students from interdependent cultures, which are often underrepresented in STEM, than for students from independent cultures that are well-represented in STEM.[38] Stephens *et al.* have shown in multiple studies that the choice is not always valued for students from lower socioeconomic backgrounds.[76,77] Students from underrepresented racial/ethnic groups and female students may value communal goals that focus on

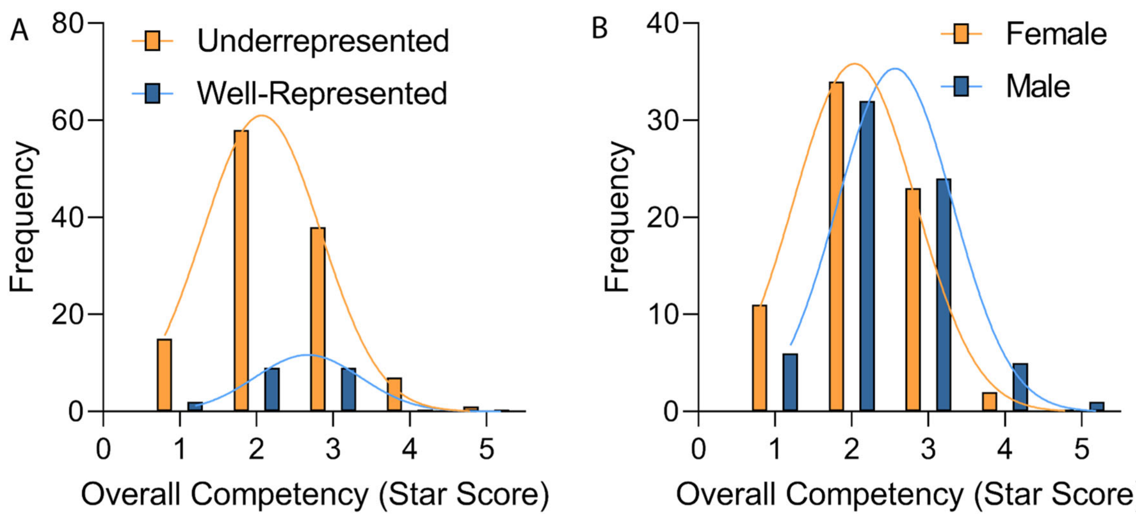

FIGURE 5. Overall competency on a star score scale of 1–5. All demographics had a median star score competency of 2. (a) Students from under- and well-represented racial/ethnic groups. (b) Students by gender. Histogram with Gaussian nonlinear curves fit; *n* = 19 for underrepresented, *n* = 20 for well-represented, *n* = 70 for female, and *n* = 68 for male.

FIGURE 6. Assessment of confidence, motivation, and enjoyment. 76% of underrepresented students and 74% of female students reported learning these skills made them more confident in pursuing a STEM career. 74% of underrepresented students and 69% of female students reported increased motivation to do better in STEM classes following the intervention. 64% of underrepresented students and 64% of female students reported they enjoyed learning these skills. Sample sizes: *n* = 20 for well-represented racial/ ethnic groups, n = 119 for underrepresented racial/ethnic groups, *n* = 68 male students, and *n* = 70 female students.

helping others rather than valuing independence and choice, which are more likely to affect male students and well-represented racial/ethnic groups.[2,21,80] These factors may have contributed to the increases observed in underrepresented students' intent to pursue STEM careers. Additionally, work-based microbadges awarded by the Couragion app celebrated various facets of students' personae, including communal values not stereotypically associated with STEM fields, like being team-oriented. Celebration of interdependence could provide continuity in attitudes towards STEM and is one possible reason that students from underrepresented demographics showed positive outcomes after interaction with the Couragion app. Prior research has

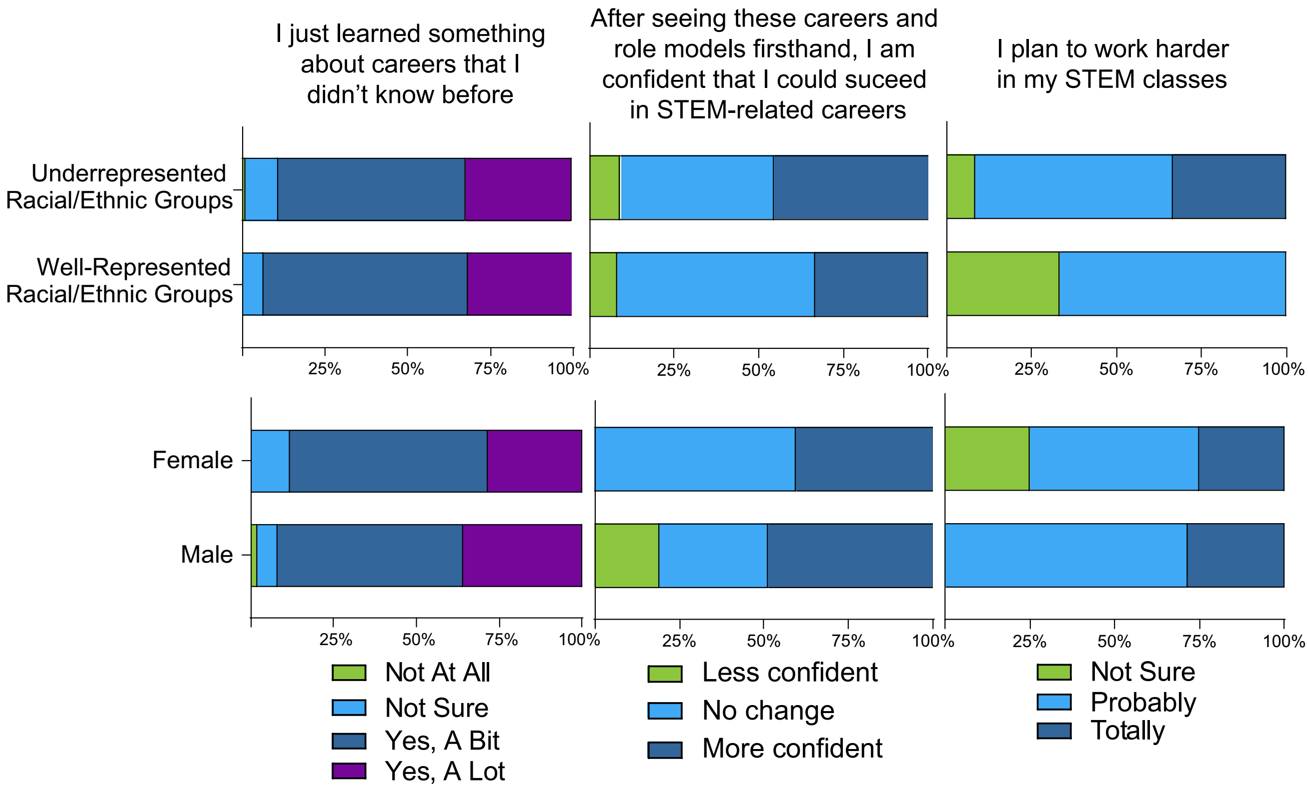

FIGURE 7. Assessment of learning, confidence in success, and academic motivation. 89.3% of underrepresented and 88.3% of female students reported learning something new about careers. 45.5% of underrepresented and 40.5% of female students reported more confidence that they could succeed in STEM-related careers. 91.6% of underrepresented and 75% of female students reported plans to work harder in their STEM classes. Left: *n* = 95 students from underrepresented racial/ethnic groups, *n* = 16 students from well-represented racial/ethnic groups, *n* = 60 female students, and *n* = 50 male students. Middle: *n* = 67 students from underrepresented racial/ethnic groups, *n* = 12 students from well-represented racial/ethnic groups, *n* = 24 female students, and *n* = 24 male students. Right: *n* = 12 students from underrepresented racial/ethnic groups, *n* = 3 students from well-represented racial/ethnic groups, *n* = 8 female students, and *n* = 7 male students.

shown that eighth grade students from underrepresented racial/ethnic groups who aspire to STEM careers are equally as likely to pursue those careers six years later as their classmates in well-represented racial/ethnic groups.[54] These results are promising and may impact students' future career decisions.

Couragion has shown that student outcomes were most improved when role model exposure and microbadging occurred simultaneously. The combination of Quests (virtual role models) and Challenges (microbadging) was key to positively improving mindsets toward pursuing a STEM career. Couragion's curriculum provided educators with two primary options for implementation: students completed Challenges only or students completed Quest/Challenge pairs. Unpublished research conducted by Couragion compared outcomes from students that completed Challenges only or students that completed Quest/Challenge pairs. Data showed the best option for achieving the highest outcomes was to implement Quest/Challenge pairs together. Students were asked to rate their level of interest in pursuing the given career featured in the Challenge (interest). Completing the Quest/Challenge pairs together resulted in the highest interest levels—interest grew 24% with that curriculum option. From a performance standpoint, those completing the Quest/Challenge pairs together received a Challenge score that was 16% higher than those who completed just the Challenge. In the study presented here, capacity for success in STEM careers was measured by overall competency star score, which did not differ between under- and well-represented racial/ethnic groups or between male and female students. Taken together, the results from this study and previous research by Couragion confirmed an increase in vocational engagement, capacity, and continuity connected to STEM careers after the intervention.

Student Confidence, Motivation, and Enjoyment

The results of this study demonstrated that exposure to scientific role models and work-based microbadging increased confidence, motivation, and enjoyment among all students. Low sense of belonging and lack of enjoyment have been shown to play an important role in students' decisions to opt out of STEM fields, as well as low academic performance in those fields.[45] Conversely, the findings shown here suggested that the Couragion app encouraged students' STEM identity through positive outcomes on confidence, motivation, and enjoyment. As part of the unpublished study mentioned previously, Couragion determined that the combination of role model exposure and work-based microbadging, as opposed to microbadging alone, was key to improving student metrics. For students who experienced the curriculum in this way, agreement with the joy indicators showed a growth rate of 9%, agreement with the motivation indicators showed a growth rate of 15%, and agreement with the confidence indicators showed a growth rate of 11%. In the study presented here, students from underrepresented racial/ethnic groups responded more positively to the statement ''I plan to work harder in my STEM classes'' than students from well-represented racial/ethnic groups, showing greater motivation and capacity to succeed. Female students responded more positively than male students to the statement ''After seeing these careers and role models first-hand, I am confident that I could succeed in STEM-related careers'', demonstrating greater self-efficacy, engagement, and continuity in STEM.

Generally, students from groups underrepresented in the STEM workforce (race/ethnicity or gender) do not experience the same levels of early life encouragement in STEM fields as students from well-represented groups.[7,78] Because of this, lower levels of confidence, motivation, and enjoyment might be expected from underrepresented students. These findings back up previous literature that has shown exposure to female role models can improve female students' interest, performance, and motivation in STEM fields.[19,47,53] Interaction with female role models reduces gender stereotypes, increases enjoyment, improves expectations of success, and increases intent to enroll in STEM among female students.[27] Prior research also suggests that a more diverse pool of role models, in terms of gender and racial/ethnic groups, can positively influence student self-efficacy and self-identity with STEM, leading to increased motivation to pursue careers in STEM fields.[1] The results presented here contribute to an existing body of work showing that exposure to role models in early adolescence effectively improves students' attitudes towards STEM.

Limitations and Future Directions

The main limitations of the research presented here revolve around representativeness of the study population. Students in one grade at one middle school in Colorado were surveyed by the Couragion app. There were no longitudinal components in this study and it is difficult to confidently apply the observed increased confidence, motivation, and enjoyment to actual pursuit of STEM fields in the absence of a follow-up study. The eighth-grade class investigated in this study is not representative of all eighth graders and consists of a particularly disadvantaged student population. Future research could follow adolescent students who engage with the Couragion app through high school and into college to obtain concrete data on the ability of this intervention to increase STEM pursuit. Also, a broader student population (different grades, schools, and states) should be examined in the context of the Couragion role model experience and work-based microbadging to further understand the impact of this technique on student attitudes and performance. A baseline level of interest in STEM careers was established at registration with the app, but no registration baseline was measured for confidence, motivation, and enjoyment. The high levels of these metrics observed would be more meaningful when compared to a pre-intervention baseline. Finally, validated assessment tools to measure perceived personal capacity and participation were reviewed during initial Couragion research and development, but assessment tools for belonging and self-efficacy were not. New research questions could be incorporated to address these key metrics as well. Couragion is a flexible system that can be updated and reconfigured to reflect information from validated assessments updated since the original app was created.

CONCLUSIONS

This study has positive implications for the population engaged by the Couragion application. Students' decisions to major in STEM at the college level are highly influenced by interest, identity, and self-efficacy.[31,51,70] Additionally, encouraging engineering participation before college can help students understand these fields and improve sense of belonging and expectations of success.[18] Intent to pursue a STEM career was significantly increased for all students after the Couragion app intervention, which indicates an increase in engagement and continuity that could translate to future academic decisions. Female students and students from underrepresented racial/ethnic groups showed more positive outcomes than their well-represented classmates. Students also responded positively to statements addressing confidence, motivation, and enjoyment, which demonstrated improvements in STEM identity, capacity, and engagement. These findings suggest that role model interventions and work-based microbadging could help close the representation gap in the STEM workforce. Recruitment and retention of women and underrepresented racial/ethnic groups in STEM careers would better serve the population as a whole.[8] Creativity, innovation, and quality of solutions produced to benefit society would be enhanced by a more diverse STEM workforce.[32,60]

AUTHOR CONTRIBUTIONS

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by LF, MR, DDH, and CMM. Drafts of the manuscript were written by DDH and CMM. All authors read, edited, and approved the final manuscript.

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DATA AVAILABILITY

The de-identified and processed data required to reproduce these findings are available here: Davis-Hall, Duncan; Farrelly, Laura; Risteff, Melissa; Magin, Chelsea (2022), "Evaluating how exposure to scientific role models and work-based microbadging influences STEM career mindsets in underrepresented groups", Mendeley Data, V2, https://doi.org/10.17632/bxvms662px.2.

CONFLICT OF INTEREST

DDH has no conflicts of interest to disclose. LF was the Co-Founder, Chief Operating Officer, and a paid employee of Couragion Corporation during the research performed in this report. She is also an unpaid Board Trustee for Mackintosh Academy Boulder, a K-8 School that was not involved in the research project. MR was the Co-Founder, Chief Executive Officer, and a paid employee of Couragion Corporation during the research performed in this report. She is currently employed by MindSpark Learning, the company that acquired Couragion Corporation. CMM is an unpaid Board Member for the Colorado Bioscience Institute.

CONSENT TO PARTICIPATE

Written informed consent was obtained from parents or legal guardians.

CONSENT FOR PUBLICATION

N/A.

ETHICAL APPROVAL

The research protocol was determined to be exempt from review by the Colorado Multiple Institutional Review Board under Category 1—research conducted in established or commonly accepted educational settings.

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