Discover Education

Research

Girls leading the conversation: harnessing the potential of podcasting for informal and project-based learning

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Abstract
This study aimed to explore the implementation of project-based learning (PBL) principles in informal STEM education, focusing on the experiences of Underrepresented Racially Minoritized (UUREM) girls during a week-long residential STEM summer camp. Utilizing a single case study design, the researchers investigated how PBL facilitates engagement and understanding of STEM concepts through podcasting activities. Participants engaged in immersive exploration, integrating their research on podcasting and interviewing women in STEM fields. Data were collected from participants' podcast recordings, scripts, and collaborative chat logs. The study revealed insights into collaboration, creativity, scriptwriting, recording, and editing among student groups. Overall, the findings underscore the importance of fostering teamwork and enhancing students' creative and technical capabilities in project-based learning environments. Integrating PBL within informal learning environments is crucial for supporting UUREM girls in STEM education. This approach not only fosters engagement but also promotes an inclusive atmosphere where diverse perspectives are valued. The study advocates for the expansion of PBL initiatives in informal learning contexts, emphasizing the importance of diversity and inclusion. By empowering UUREM girls through targeted STEM programs, educators can cultivate a generation of confident and capable learners prepared to thrive in STEM fields.

Keywords Girls in STEM · Informal science learning · Underrepresented girls · Minoritized girls in STEM · STEM learning · Project-based learning

1 Introduction

Project-based learning (PBL) has emerged as an approach to enriching science, technology, engineering, and mathematics (STEM) education, particularly in K-12 settings and teacher training programs [30, 38] and rooted in constructivism, PBL champions context-specific learning, active learner participation, and achieving goals through social interactions and knowledge exchange [30]. Its allure in educational settings lies in student engagement during inquiry-based learning centered around authentic questions within real-world problem contexts, thereby fostering meaningful learning experiences. Although PBL is prevalent in traditional educational settings, its utilization in informal learning environments is still emerging [33]. Informal settings, such as summer camps and afterschool clubs, provide learners with opportunities for hands-on PBL discovery, enhancing comprehension and deepening their commitment to environmental and social responsibilities [27, 30]. Additionally, informal STEM learning environments are becoming more critical in student

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exposure to STEM concepts, especially for underrepresented and underserved racially and ethnically minoritized (UUREM) students [27]; hence, there is a need for a deeper understanding of PBL's implementation in those settings [33].

Research has identified reasons for the underrepresentation of certain racial and gender groups in STEM fields, pointing to issues in higher Education and K-12 Education [20]. For example, studies show that Black and Latinx students in K-12 Education often lack highly qualified teachers and access to advanced math and science courses. These disparities are frequently worse in socio-economically disadvantaged areas, particularly affecting Black and Latina girls due to the intersection of race, gender, and economic status [8, 24]. Additionally, gender equity in STEM education and the American workforce has been a longstanding issue, particularly regarding the underrepresentation of Black and Hispanic girls and women in these fields. Despite the progress made by women of color in the past decade in terms of representation in the STEM workforce and participation in higher education, significant equity gaps remain. These disparities affect all levels of education and worsen the problem of underrepresentation over time. The concept of intersectionality highlights the effects of multiple group memberships, providing a framework to understand the educational inequities Black and Hispanic students face in their STEM journeys [10, 18]. This perspective helps explain their lack of representation in advanced STEM high school courses, STEM degrees, and STEM careers.

To this end, informal learning experiences outside school have contributed to underrepresented students' interest in STEM fields [20]. Our research sought to explore the aspects of STEM learning among middle school UUREM girls. Specifically, we focus on their participation in a week-long, all-girl (grades 7–9) summer STEM camp hosted at a prominent private university where they form the racial and ethnic majority of camp participants. Our study aims to observe STEM learning through a PBL lens as UUREM girls use technology (i.e., podcasting) during the camp (30]. By highlighting UUREM middle school girls' experiences as they participate in a technology-based PBL task in an informal STEM learning environment, this study contributes to the broader conversation on STEM equity (e.g., race, gender, socio-economics, accessibility, etc.).

This study examined how UUREM middle school girls learned to apply technical and communication skills (focusing on the "T" in STEM) to conceive and produce a STEM-topic podcast following a PBL task design in a summer camp. A podcast, according to the Joint Information Systems Committee (JISC), is a digital production involving the dissemination of audio documents over the Internet via designated software or applications [19]. In grades 6–8, Next Generation Science Standards (NGSS) Science and Engineering Practices are comprehensive of asking questions, defining problems, and specifying relationships between variables while stressing engineering problems that highlight specific criteria and constraints to understand the impact of STEM on society and the natural world underscores how societal needs, scientific research, and environmental and economic factors shape the use of technology [28].

Our research study aimed to emphasize and elucidate the significance of the six fundamental elements that constitute the core of the PBL methodology and are vital components that guide the design and implementation of compelling PBL experiences. To this end, the research question guiding our research study is:

1. How does integrating a week-long PBL unit at a STEM summer camp foster creativity, script development, recording, editing, and collaboration skills in podcasting among UUREM middle-grade girls?

In the following sections, we describe the literature around PBL, informal STEM learning, PBL in informal learning environments, and podcasting as a tool for student learning. We then describe our methodology and findings and conclude with a discussion and specific recommendations on the role of PBL in informal STEM settings and its implications for formal school settings.

1.1 Project-based learning

In the last 20 years, the literature has supported PBL to serve as a tool for purposeful instruction [30]. Although no single definition for PBL is agreed upon [i.e., 30], there is consensus that six integrated elements are present to be considered as "authentic": (1) a driving question o anchor; (2) situated or anchored inquiry; (3) collaboration and cooperation; (4) scaffolding or the use of cognitive or learning technologies; (5) a final product/artifact; and (6) assessment [30; See Fig. 1].

The driving question should be feasible and interdisciplinary, fostering holistic understanding [13]. Situated inquiry anchors learning in authentic contexts and students' experiences [16]. Collaboration is essential, promoting academic and teamwork skills through structured group roles [39]. Scaffolding, including technology, supports STEM integration and empowers students (30]. The final product reflects comprehensive learning, while formative and summative

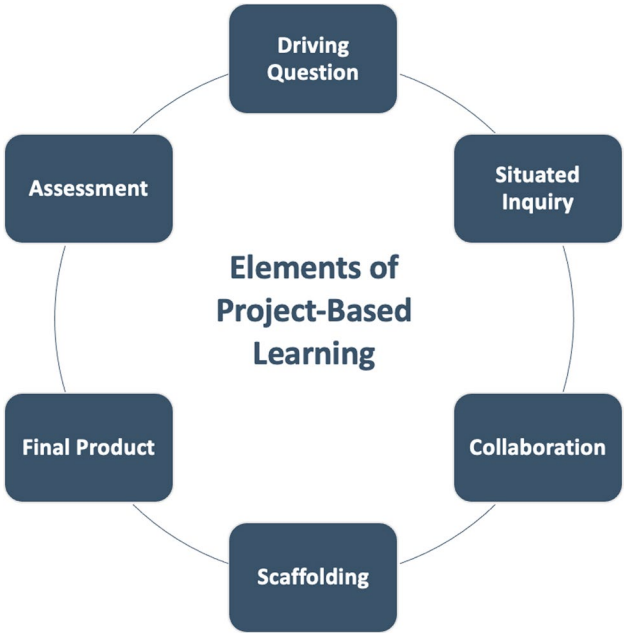

Fig. 1 Elements of Project-Based Learning (PBL). Derived from [30]

assessments provide feedback and evaluate understanding, cultivating lifelong learning skills [4, 5]. These six elements guide our analyses.

1.2 Informal STEM learning

Informal learning is often defined as learning outside of school [32], though Rogoff and colleagues (2016) argue that how learning is organized is more important than where it occurs. They suggest that informal learning environments should include interactive activities, guidance, conversational talk, ongoing engagement, and opportunities for building on individual interests while developing new skills [32]. They also highlight the role of community participation, noting that many public leisure institutions, such as museums and science centers, aim to promote interest-driven learning [32].

For UUREM girls, informal science education is vital due to disparities in access to quality STEM resources, especially in historically marginalized communities [8, 24]. These girls tend to leave STEM fields at higher rates due to the intersectionality of race, gender, and socioeconomic status [18]. Our previous study [26] found that a single-gender camp led to significant increases in STEM identity and ability beliefs, with qualitative data indicating the impact of race and gender on their STEM identities.

Informal learning settings, like STEM camps, can be especially beneficial for Black girls, who often succeed in out-of-school contexts [1, 21]. These settings allow UUREM girls to connect with peers and role models from similar backgrounds, providing support and inspiration [9, 20]. Studies on Black middle school girls' science engagement [7], afterschool STEM clubs [37], and community-centered programs [17] emphasize the importance of diverse experiences in shaping science identities. However, Çolakoğlu et al. [9] argue that while informal STEM learning has potential, it often fails to reach underserved students, perpetuating existing inequities. Next, we explore literature on PBL in informal STEM settings.

1.3 PBL in informal STEM learning environments

PBL in STEM settings is familiar; however, research on PBL in informal and out-of-school learning environments is still necessary. With growing support for including and studying science learning in informal settings, the NRC (2009) published *Learning Science in Informal Environments: People, Places, and Pursuits* to provide an outline and guidance for future directions. The authors offer two frameworks for expanding upon science learning within informal settings [27]. The first strand is for the learner to "experience excitement, interest, and [a] motivation to learn about phenomena" [27, p.4]. The second is for the learner to think as a science learner and to develop a scientific identity [27]. PBL, described earlier, has the potential to achieve both strands within informal learning settings to broaden participation for UUREM students.

Roberts et al. [32] explored students' perceptions of STEM learning through a PBL unit in an informal STEM summer camp. The study used a phenomenological approach to collect data through reflection forms, interviews, session reflections, and content reflections. Their analysis employed an inductive approach, capturing participants' lived experiences in the informal STEM learning environment. They concluded that the informal nature of the STEM camp facilitated greater engagement with STEM subjects and increased access to STEM learning [31]. Moreover, students reported their ability to transfer their knowledge to other subjects in a traditional school setting due to their participation in the camp. Participants' reflections also suggested that hands-on activities extended to minds-on (e.g., critical thinking exercises, problem-solving tasks) activities, enhancing the overall learning experiences.

1.4 Student-created podcasts

The true potential of podcasts, akin to any technological tool, emerges when placed in the hands of students, offering valuable educational benefits such as imparting research skills, effective communication, public speaking proficiency, and the ability to captivate an audience through audio [6; 36]. Initiatives like seventh-graders producing podcasts during writing classes illustrate this trend, integrating topics like *photosynthesis* and *school bullying* [36]. Podcasts allow students to express and publish their ideas to a broader audience beyond the classroom, fostering a sense of ownership and pride that motivates them to invest effort in producing high-quality content [12]. Engaging in this way cultivates essential workplace skills, including research proficiency and coherent verbal expression.

Despite challenges such as the learning curve and time constraints, the educational benefits of podcasts for students outweigh such concerns [6]. Teachers embracing podcasts have observed students actively participating in their learning, creating meaningful and challenging learning environments [6; 12]. As the full impact of this emerging technology is yet to be fully understood, a growing need for research to comprehensively explore how podcasts influence student learning is essential. The existing research on podcasting in education predominantly focuses on higher education settings or explores student attitudes toward podcasting concerning language skills [15, 23]. The literature lacks studies investigating podcast creation within informal STEM settings, especially concerning UUREM girls. This gap highlights the unexplored research at the intersection of student-created podcasts, informal STEM learning, and gender equity in STEM education that could be facilitated through PBL. More importantly, such literature could offer researchers valuable insights into UUREM girls, contributing to their interest in understanding and applying innovative and inclusive educational practices with technology.

2 Research design

We employed an explanatory single case study design [40] to explore how and why specific processes unfolded within the context of a week-long residential STEM summer camp for middle school girls. The design was chosen to provide a comprehensive, in-depth examination of the complex interactions between various components of the camp's PBL-based curriculum, focusing on podcast production as a tool for STEM learning. The explanatory case study design allowed us to explore the mechanisms driving the participants' engagement with STEM concepts and technologies, as well as their interactions with mentors and role models.

Our study was embedded in nature, meaning that it incorporated multiple sub-units of analysis to gain a more nuanced understanding of the camp's influence on learning outcomes. These sub-units included specific elements such as mentorship, hands-on projects, and exposure to diverse role models, all of which played critical roles in shaping the girls' experiences. By examining these components individually, we uncovered how each contributed to the overall impact of the PBL model on the participants' STEM engagement.

The case study design is particularly suited for contexts like informal learning environments, where various factors—such as limited timeframes, varying participant backgrounds, and dynamic instructional methods—interact to produce diverse outcomes. By focusing on both the holistic experience of the camp and the specific sub-elements, this design enabled us to capture the complexity and richness of learning that emerged in this informal PBL setting. Additionally, the design facilitated an explanatory approach, helping us describe what happened and explain the underlying reasons and mechanisms for how these learning processes unfolded.

2.1 Context and participants

Our case study [40] investigated the impact of participating in a PBL experience on STEM learning for UUREM middle school girls, who comprised most participants. The study occurred within a week-long, all-girls residential STEM camp held at a private university in the Southwestern US. The camp is administered annually by a community-based nonprofit that aims to make STEM studies and careers more accessible for UUREM middle school girls by exposing them to university life as future STEM majors. A total of 59 girls attended and participated in the camp. Girls were grouped by grade level (7th, 8th, and 9th); the result was eight groups, with approximately seven girls in each group.

The overarching themes were structured throughout the camp's activities [see 26 for a detailed explanation]. The curriculum aimed to encompass the holistic development of young girls and has been hosted at various universities. The researcher obtained ethical approval from the university's Institutional Review Board (IRB) and secured parental consent and student assent.

2.2 Project-based learning: a girls and women in STEM podcast

Following NGSS, our study's participants worked collaboratively in small groups following the PBL process to produce a podcast. Specific activities included researching topics of interest, interviewing women in STEM fields, recording and editing with audio/visual software, publishing the final podcast on Spotify®, and sharing their productions and learning with community members at the end of the summer camp. This PBL task leveraged digital media throughout the learning process and as an integral component of the summative assessment. The driving question for the PBL unit the girls completed was, "How can we use podcasts to explore a technology-based interest area of our group?".

The researchers and science educators collaborated to craft the PBL experience by adopting an emerging technological approach—podcasting. Within this learning context, girls embarked on individual and collaborative journeys involving immersive exploration and investigating podcasting concepts. The students integrated their research on various facets of podcasting and interviewed women in STEM fields (see Table 1 for the project overview; See Appendix A for connections to PBL).

The girls took on the roles of producers and editors to craft their podcast episodes. The culmination of their efforts was a podcast, a reflection of their podcasting experience (See Fig. 2 for an overview of the production timeline).

The project reached its zenith when the UUREM girls presented their podcasting creations to community members, sharing their discoveries and insights with an audience.

Table 1 Project Overview

Project Overviews	Tasks for Students
Learning Objective	- You will create a short podcast by interviewing a woman in STEM. The podcast will be based on themes you have explored about the metaverse during The GEMS Camp
Career Connections	- Understand the linkages between secondary, higher education, and career - Develop and practice written and verbal communication skills to inform, entertain, or persuade - Work collaboratively and professionally with peers and adults - Use technology effectively to inform or persuade an audience
Vocabulary	- Podcast, sound engineering, tone, dialogue
Production Process	- Pre-Production - Production - Post-Production
Product Task	- 5–10-min audio podcast (.wav,.aiff, mp3 file) - Art cover (.jpeg or.png format) - 15-s intro and outro music (.wav,.aiff, mp3 file) - Uploaded to an online digital platform (YouTube, etc.)
Guiding Question	- How can we use technology to express our interests while learning?

Fig. 2 Overview of Production Timeline

DAY	PRODUCTION PHASE	TASK
MONDAY	Pre-Production	• Brainstorming Podcast and Member Names • Brainstorming Taglines • Choosing Roles
TUESDAY	Pre-Production	• Researching Guests • Developing Thoughtful Questions • Writing Podcast Script
WEDNESDAY	Production	• Recording Your Podcast
THURSDAY	Post Production	• Editing Your Podcast
FRIDAY	Post Production	• Feedback, Editing, Finishing Your Podcast

2.3 Data collection and analysis

The data used for this manuscript included artifacts produced by the participants, such as their podcast recordings, scripts, and group chats from Microsoft Teams. These artifacts were specifically chosen to assess the effectiveness of the PBL unit in fostering podcasting skills related to creativity, collaboration, and technical production. The first two authors used a comprehensive rubric, developed to align with the learning objectives of the PBL unit, to evaluate five key podcasting components: Creativity, Script, Recording, Editing, and Collaboration. Each component was scored on a scale from 0 (Incomplete) to 3 (Exemplary), with intermediate ratings of 1 (Developing) and 2 (Proficient). The rubric was designed with input from prior research on podcasting and media creation in educational settings, ensuring that the assessment criteria were relevant and valid for this context (see Fig. 3).

The first two authors, both present during the camp, conducted scoring collaboratively, using an iterative debriefing process and discussion to reach a consensus on each score. The process allowed researchers to clarify explicit criteria and share examples. The constant comparative method [11] was employed to systematically identify recurring patterns and distinct differences across the five podcasts analyzed to ensure reliability. The constant comparative method helped ensure the evaluation remained consistent and aligned with the research questions. In addition, Microsoft Teams chat logs were analyzed to provide evidence of collaboration among the participants, supplementing the podcast analysis. Three groups were excluded from the analysis because they did not submit final podcasts for review. This decision was based on the need to assess complete podcasts to comprehensively evaluate the technical and collaborative skills targeted in the PBL unit.

PODCAST PERFORMANCE EVALUATION RUBRIC

	0 = INCOMPLETE	1 = DEVEOPING	2 = PROFICIENT	3 = EXEMPLARY
CREATIVITY	**Creativity and original content are significantly missing or not attempted.**	**Creativity and original content support the purpose of the podcast in an customary way:** *- Traditional point of view* *- Some elements missing* *- Some inaccurate information*	**Creativity and original content support the purpose of the podcast in an innovative way:** *- Interesting point of view* *- Elements are present* *- Accurate Information & succinct*	**Creativity and original content enhance the purpose of the podcast in an innovative way:** *- Unique point of view* *- All elements fit well together* *-Accurate information & succinct*
SCRIPT	**Script was not produced.**	**Limited open-ended dialogue is used to draw general and broad information from the interviewee.** *- Script not segmented* *- Lacks focus or does not flow*	**Some open-ended dialogue is used to draw interesting and broad information from the interviewee.** *- Script divided by segments* *- Evidence of segment notes* *- Lacks focus or does not flow*	**Open-ended dialogue is used to draw interesting and relevant information from the interviewee.** *- Script divided by segments* *- Clear segment notes* *- Fun, focused, and flows*
RECORDING	**Recording was not produced or with excessive noise and distractions that the .**	**Podcast is recorded in an environment with significant background noise and distractions. Podcast length does not meet the requirements.** *- > 20 minutes or < 10 minutes* *- Ineffective communication* *- Some background noise*	**Podcast is recorded in a quiet environment with some background noise and distractions. Podcast length keeps the audience interested and engaged.** *- Not over 20 minutes* *- Some effective communication* *- No background noise*	**Podcast is recorded in a quiet environment without background noise and distractions. Podcast length keeps the audience interested and engaged.** *- Not over 20 minutes* *- Effective communication* *- No background noise*
EDITING	**Editing was not apparent or had excessive noise or dead space.**	**Transitions are not smooth and spaced correctly with some noisy, dead space. Speakers are hard to hear. Intro/outro music are edited, and no extra element is included.** *- Unwanted audio* *- Music at open and close* *- Transitions are not smooth* *- No extra element*	**Transitions are somewhat smooth and spaced correctly without noisy, dead space. All speakers are heard. Intro/outro music are edited, and an extra element like a commercial break is included.** *- Some unwanted audio* *- Music at open and close* *- Transitions are somewhat smooth* *- Extra element present*	**Transitions are smooth and spaced correctly without noisy, dead space. All speakers are heard clearly. Intro/outro music are edited, and an extra element like a commercial break is included.** *- No unwanted audio* *- Music at open and close* *- Segments transition smoothly* *- Extra element present*
COLLABORATION	No Collaborat-ion	**Fair team production effort evidenced by well-rehearsed, smooth delivery in a conversational style.** *- Few team players were accountable* *- Communication was inconsistent* *- Pre-production, production, post-production did not flow*	**Good team production effort evidenced by well-rehearsed, smooth delivery in a conversational style.** *- Most team players were accountable* *- Each person communicated well* *- Pre-production, production, post-production flowed smoothly*	**Excellent team production effort evidenced by well-rehearsed, smooth delivery in a conversational style.** *- Team players were accountable* *- Each person communicated well* *- Pre-production, production, post-production flowed smoothly*

Fig. 3 Summative Assessment Rubric for the Learning Outcomes of their Podcast

3 Findings

This section presents the findings from our summative evaluation of the podcast projects based on the scoring rubric. We assessed central podcasting skills—creativity, scripting, recording, editing, and collaboration—among UUREM

Table 2 Summative Assessment Scores from their Learning Outcomes

Group	Collaboration	Creativity	Script	Recording	Editing
1	3	3	2	2	1
2	2	2	2	0	1
3	2	1	2	3	1
4	3	3	2	3	2
5	2	1	2	2	1
Mean Scores	2.4	2	2	2	1.2

Table 3 Day 1: Group 1 Microsoft Teams' Chat Highlighting the Process of Selecting their Roles

Line	Speaker	Text
3.1	Natasha	How are we going to group up? Are we going to interview a person? THAT'S AWESOME!!!! There are six people here… So we're basically doing it together
3.2	Luna	Yeah, sounds fun, right?
3.3	Natasha	So, the script writer basically writes the introduction and the questions the host and co-host (s) are going to ask, right? Do you want to start organizing ourselves and choosing the roles we're going to play? Technical engineer? I would like to be the scriptwriter…anyone else?
3.4	Luna	((Accepts position by 'liking' the comment))
3.5	Luna	Producer
3.6	Natasha	Okay
3.7	Lola	I can be the researcher
3.8	Natasha	I am writing them down

middle-grade girls. Table 2 shows the scores for each group, offering an overview of their performance. The following subsections highlight strengths, areas for improvement, and unexpected findings from the evaluation.

3.1 Collaboration

Effective group collaboration results in well-executed final products; however, carefully examining students as they collaborate throughout the process is equally worthwhile, enabling a trustworthy evaluation of the group based on the scoring rubric description. In our study, researchers generally scored collaboration positively (Mean of 2.4) across all groups, with Groups 1 and 4 displaying *exemplary* collaborative performance and Groups 2, 3, and 5 demonstrating *proficient* collaborative performance. The researchers examined meeting notes to assign the groups' final collaboration performance when available.

For example, the chat transcript in Table 3 shows how Group 1's members, Natasha, Brianna, and Luna (all pseudonyms), a team of 9th-grade Latinas, used the chat feature in Microsoft Teams throughout the production process. Their approach led them to achieve the highest score in the rubric for collaboration based on the *exemplary* description, "Excellent team production effort evidenced by well-rehearsed, smooth delivery in a conversational style."

Team players were accountable. Eager to begin, the team members first assigned roles early in the project (see Lines 3.3–3.8). Natasha assumes the team's leadership role by documenting others' interests while asserting that she wants to be the team's scriptwriter. At the beginning of Day 2, due to Brianna's Day 1 absence, she immediately writes, "I missed yesterday since I was at the doctors'…what are the other roles?" Natasha then shares:

> Technical Engineer, Script Writer, Producer, Co-Producer, Researcher, Host, and Co-Host. There can be two people at the same job so don't worry. We could use two researchers. I know we [have] Lola as our researcher, but if we have two, they might find different information.

Brianna secures her role by exclaiming, "Yeah, I can do research;" then Natasha responds with the final team member assignments: "Brianna-Researcher; Luna-Producer/Co-Host; Lola-Researcher; Nadia-Technical Engineer/Host; Natasha(me)-Script Writer/Co-Producer/Ad person." Their exchange reflects the team members' commitment to hold themselves accountable while completing the PBL task by effectively communicating with each other.

Each person communicated well. Group One's chat also showed how the members effectively communicated when generating potential names for the podcast and the show's topics as the camp went on. Proposed topics ranged from cyberbullying, social media, and mental health. The group then compiled a list and voted on their favorite topic to begin production:

Natasha:	Cyberbullying—3 votes Screentime—2 votes Mental health—2 votes Sharing knowledge—1 vote Being able to communicate—1 vote Figuring out who you are—1 vote Sharing positivity—2 votes

Each of the six girls in the group submitted their vote by placing a number following their topics of interest. After the poll, the group narrowed down to three topics, "cyberbullying, screentime, and mental health." Finally, they agreed on "Social Media and its Effect on People."

Pre-production, production, and post-production flowed smoothly. Group Two also achieved the highest score for collaboration in the rubric, evidenced by the description of "well-rehearsed and smoothly delivered content" and "presented in a conversational style." Like Group One, these team members actively participated and conveyed ideas coherently throughout the production process. Their collaboration was particularly evident in their script, as the student co-hosts maintained a fluid conversation with multiple speakers interjecting in an engaging manner:

Student Host 1:	One, hypothetically, just say that your company was under attack
Student Host 2:	Do you think your software would be good enough to show the attacks or minimize how much damage they do to your company?
Adult Guest:	Okay, so hypothetically, that is a really good scenario. I personally see that the company should have its own security systems, that they should protect their companies, the employer, or the employers' information from the outside world, that will at least minimize the hacking. If my company is getting hacked, or if I am working on a company and working in a company that is very secure, they have a very secure environment. They have very nice safety features; security is very tight, they're technically very strong

Their collaborative approach not only facilitated the development of high-quality content but also enhanced the overall listening experience for the audience.

The positive collaboration dynamics observed among the student groups highlight the importance of fostering teamwork and practical communication skills in educational settings. Educators can further support collaborative efforts by providing opportunities for students to practice teamwork and communication in PBL activities. Additionally, incorporating structured feedback mechanisms can help students reflect on their collaborative experiences and identify areas for improvement in future projects.

3.2 Creativity

Creativity was pivotal in shaping the quality and effectiveness of the podcasts produced by five student groups in this study. Through an assessment of their respective podcasts, distinct patterns emerged, revealing varying levels of creativity across the groups. Groups 1 and 4 demonstrated exemplary levels of creativity, as evidenced by their innovative podcast content and presentation approaches. Group 4 utilized their unique perspective to introduce original content that enhanced the podcast's purpose. They engaged the guest speaker in a discussion about her experiences as a woman in the STEM field, offering a fresh and insightful angle to the conversation.

Moreover, the co-hosts demonstrated creativity in their questioning techniques by seamlessly integrating their experiences as middle school girls interested in STEM careers, thus adding depth and relevance to the discussion. For example, one of the student hosts asks the following question, "To all the young people listening who may want to get into the

STEM field, or maybe they just need some words of advice, what would be some words of wisdom that you would like to share with them?" The guest goes on to answer:

> I just encourage everyone to believe in yourself. And don't let anyone tell you that you can't do something. If you set your mind to do something, you're going to be able to accomplish it. But don't believe negative things that people say about you, right? Everybody's going to make mistakes. Everybody's going to have some challenges and obstacles that they must overcome. But you matter, okay? And you're important to our future and you must believe in yourself so that you can press forward even when times are hard. So, that would be my advice: believe in yourself. Don't give up and know that you can do it.

While the question posed by one of the student hosts may not seem particularly innovative on the surface, it demonstrates a level of thoughtfulness and inclusivity by inviting the guest to offer advice specifically aimed at young people interested in entering the STEM field. However, a more nuanced approach to questioning could have enhanced the creativity of the segment. Group 2 exhibited proficient levels of creativity, although they did not reach the exemplary standards Groups 1 and 4 set. Their podcast demonstrated a thoughtful approach to content development and presentation, with questions that effectively addressed the podcast's theme and objectives (see Table 4).

While Group 2 introduced some innovative elements to their podcast, such as engaging storytelling techniques, there remained opportunities for further creativity and originality in their approach. For example, one of the student hosts sets up the background of their podcast around hacking:

> I think it's a good time to go over today's case. This case is about someone who was named to be the most wanted hacker in America. He started hacking *when he was only 12* (original emphasis). But one day when he was 16, he had stolen $1 million worth of software from a company.

Being a data analytics intern, the guest might not be the most appropriate choice for a podcast that aims to delve into professional hacking or computer programming. While the guest could potentially contribute insights related to data analysis, their expertise may not align closely with the podcast's theme, which focuses on the story of a hacker. For a podcast on hacking, it would be more suitable to have a guest who has experience or expertise directly related to the topic, such as a professional hacker, cybersecurity expert, computer programmer, or someone involved in cybersecurity law enforcement. These individuals would likely offer more relevant and insightful perspectives, enhancing the authenticity and credibility of the podcast. So, in this case, the guest's background in data analytics, while valuable, may not be the best fit for contributing to the theme of the podcast, which revolves around the story of a hacker.

In contrast, Groups 3 and 5 struggled to achieve the same level of creativity observed in the other groups. Group 5 followed a more traditional interviewing style, lacking follow-up questions and failing to *fit all elements well together* to enrich the dialogue:

Student Host:	What is it like being an operations analyst? And how does it feel gender-wise? What advice would you give young women who also want a STEM career?
Adult Guest:	Well, this might be a long answer, but I can give [you] plenty of advice. One of them is staying in school, for sure. Obtaining good grades, developing good relationships with your teachers, also explor[ing] different career paths. So, you know, when you're in high school, you're getting into, like, what maybe you want to do, [and] explor[ing] different things. Also, in college, do the same thing. Look for cheap and affordable resources to develop your learning. I like to think that learning doesn't just stop between school hours. Learning also happens even after school and work hours. I think the last piece of advice that I can give is to get a mentor. Someone who can help guide you, answer questions whenever you have them, and tell you what you need to do throughout high school and college. And it doesn't just have to be one person. I had different mentors over the years that have helped me at various points in my life. So yeah, I think that's the advice that I can give
Student Host:	So, what is your work environment like as a woman in STEM? What motivated you to choose your job?

In this case, the podcast segment displays a degree of creativity in its approach to interviewing. The interviewer begins by posing multiple questions in one go, perhaps aiming to cover a broad range of topics efficiently. However, the girls' approach could be seen as overwhelming for the guest, potentially limiting the depth of the responses. Despite this, the guest provides a detailed and insightful answer, offering valuable advice for young women interested in STEM careers.

The conversation transitions smoothly to discussing the guest's work environment as a woman in STEM, indicating a cohesive flow between topics. However, as noted, there's a missed opportunity for a follow-up question regarding mentorship, which could have added a unique perspective and practical advice for the audience, particularly for girls

Table 4 Overview of Each Group's Theme and Example Questions

Group	Theme	Example Questions
1	Effect of Social Media on Girls	We chose this topic because it's a problem that affects most kids and teenagers. And also, because it affects them in many ways—physically, mentally, and emotionally. [Guest], you work a lot with education technology companies. How have you seen any change over the years? What do you see on social media that is a very positive thing that affects children's grades but in a positive way?
2	Hacking	Do you think it'll be difficult to hack into large tech companies? Can hacking be used for good or bad? Or is it just bad?
3	Evolution of Women in STEM	How did you get to where you are now? And did you face any challenges as a woman? Do you feel as if women from when you were our age, as from right now, have things changed for women?
4	Women Empowerment	What are some of your responsibilities for the company? So, what do you do outside of STEM and your work? Do you think the arts have a place in STEM?
5	Women in a STEM Career	Can you give us a brief description of your job? Your job is in the STEM field, which is sadly dominated by men, because of this, what struggles have you had to deal with?

attending the summer camp. While the podcast demonstrates elements of creativity, such as addressing important topics and eliciting thoughtful responses, there is room for improvement in ensuring that each component fits together seamlessly, providing accurate information, and being succinct in the approach to questioning. Adding a follow-up question on mentorship would have enhanced the segment's creativity by providing a unique perspective and practical advice, aligning with the overarching goal of the podcast. These findings suggest that both groups may benefit from additional support and guidance to enhance their creative capacities in future podcast projects.

3.3 Script

All five groups' evaluation of scripts produced yielded consistent results, each receiving a score of 2 (Proficient). Their uniformity suggests a baseline level of competence in scriptwriting among the student participants. Common strengths were observed across all groups, most notably the adept use of open-ended dialogue to extract compelling and comprehensive information from interviewees. For instance, Group 1's proficient script was attributed to their well-researched topic and relevant choice of subject matter for their target audience, focusing on the impacts of social media on girls and girls in STEM. One of the student hosts from Group 1 shared research with the guest, which demonstrated a keen understanding of their audience's interests and concerns, contributing to the effectiveness of their script:

> An article about the effects of social media on teenagers shows that kids and teenagers who use social media the most have a negative effect on their grades. Once, in 15 minutes or 30 minutes, they look at their phones, it has a negative impact on their grades.

The assessment criteria encompassed various elements, including script segmentation, the presence of segment notes, and the overall coherence and flow of the script. While most groups met these criteria satisfactorily, some were noted for lacking focus or having trouble maintaining a smooth narrative flow. For example, Group 5's script occasionally framed questions about gender and equity in the STEM workplace. The interviewers from Group 5 asked questions such as, "Have you ever wanted to give up? If so, what happened? Did someone help you along the way?" and "Your job is in the STEM field, which is unfortunately dominated by men. Because of this, what struggles have you had to deal with?" Although multiple questions were in a row, resulting in a choppy flow, the students could ask meaningful and relevant questions.

Despite these minor shortcomings, the overarching proficiency in open-ended dialogue was a noteworthy highlight across all scripts. Such an approach indicates a fundamental understanding of effective communication techniques and an ability to engage interviewees in meaningful conversation, contributing to the overall quality of the podcasts produced by the student groups.

3.4 Recording

Recording quality varied significantly across the groups, with Groups 3 and 4 achieving exemplary scores, Groups 1 and 5 demonstrating developing proficiency, and Group 2 falling short with an incomplete score. The variability between groups indicates differences in learners' ability to produce recordings that adhere to specified guidelines and maintain audience engagement. For example, Group 4 consistently delivered a conversational podcast characterized by solid and relevant questions, as well as thoughtful follow-up inquiries, highlighting the *compelling communication* aspect of the rubric:

Student Host:	So, we just wanted to ask you, how you got into [the] STEM [field] in the first place?
Guest:	Yeah, that's an interesting story. I didn't have a lot of female role models who [went] into technology. So, I didn't have anyone telling me that I could go into that field. I did internships with different companies
Student Host:	That's amazing. Now, if you don't mind me asking you a question, what [were] those internships?

This example illustrates that the co-hosts actively listened to their guest, fostering an engaging and dynamic dialogue that captivated the audience's attention. Further, group 4's podcast recording exemplifies excellence in several aspects. The podcast is recorded in a quiet environment without background noise and distractions, ensuring a high-quality listening experience for the audience. Additionally, the podcast length is well-managed, keeping the audience interested and engaged. Moreover, the communication between the hosts and the guests is influential, as demonstrated by the conversational flow and the thoughtful follow-up inquiries. Their recording style contributes to an engaging, dynamic dialogue that captivates the audience's attention.

In contrast, Group 2's recording suffered several shortcomings, including muffled audio and persistent background noise throughout the podcast. These technical issues detracted from the overall quality of the recording and hindered the audience's ability to engage with the content thoroughly. Additionally, Group 2 failed to meet the prescribed minimum time of 10 min, further impacting their score and limiting the effectiveness of their podcast (see Table 5 for podcast lengths).

The inconsistency in recording quality highlights the importance of providing learners with adequate resources and support to ensure the production of high-quality podcasts. Educators may consider offering training sessions on recording techniques and equipment usage and providing guidelines for maintaining audio clarity and adhering to time constraints. Furthermore, ongoing feedback and monitoring of recording practices can help students identify areas for improvement and refine their skills in future podcast projects.

3.5 Editing

Editing proficiency was predominantly categorized as developing among the student groups, with most failing to address issues such as background noises, interjecting co-hosts, and abrupt transitions between topics. There is a clear need for improvement in post-production processes to ensure a smoother and more polished listening experience for the audience. For example, in Group 5's podcast, there were instances where the co-hosts asked multiple interview questions consecutively without allowing sufficient time for the guest to respond. For example, they asked, "What is it like being an operations analyst? And how does it feel gender-wise? What advice would you give young women who want a STEM career?" The group's choice to use a rapid-fire questioning style may have hindered the flow of the conversation and made it challenging for the guest to provide thoughtful and comprehensive responses.

Moreover, one of the questions ("What motivated you to choose your job?"), had already been answered by the guest, highlighting a lack of attention to detail in the editing process. Additional editing to rework the students' questions and the guest's answers would have improved the flow of the discussion. These shortcomings detracted from the overall coherence and flow of the podcast, diminishing its effectiveness in conveying the intended message.

The limited proficiency in editing across the student groups suggests a need for additional time and resources to refine post-production techniques and address common issues encountered during the editing process. By dedicating more time to editing and incorporating feedback from peers and instructors, students can enhance the quality of their podcasts and deliver a more seamless listening experience to their audience.

The challenges observed in editing underscore the importance of investing sufficient time and effort into post-production processes to ensure the production of high-quality podcasts. Educators may consider providing students with comprehensive training on editing software and techniques and opportunities for peer review and constructive feedback. Additionally, allocating sufficient time for post-production activities in the podcasting timeline can help students address issues and refine their podcasts before final submission.

4 Discussion

Our investigation into the experiences of middle school girls in a week-long, technology-based PBL STEM camp reveals crucial insights into the intersection of PBL and informal STEM education. We argue that PBL not only transcends traditional educational frameworks but also serves as a vital platform for developing technology skills, especially in podcast production. Moreover, this model encourages gender equity in STEM by actively engaging diverse learners in an inclusive, technology-rich environment.

Table 5 Length of Podcasts

Group	Podcast Length
1	14 Minutes 17 Seconds
2	8 Minutes 53 Seconds
3	15 Minutes 49 Seconds
4	13 Minutes 14 Seconds
5	10 Minutes

4.1 Empowerment through PBL

Our findings confirm that immersive PBL environments are essential for promoting STEM learning, as they empower participants to take control of their educational journeys. This empowerment aligns with previous research emphasizing the importance of collaborative learning environments in fostering teamwork skills [22, 30, 35]. However, what emerged unexpectedly in our study was the profound impact of role negotiation and flexible leadership within the project groups. While we anticipated that collaboration would enhance the quality of work, we were surprised by the significant influence that role assignment and negotiation of accountability had on the final project outcomes. For instance, Group 1's ability to quickly assign roles and adapt when a member was absent illustrated how unexpected leadership flexibility directly influenced the quality of the podcast. These insights underscore the need for practical group interaction evaluations when assessing PBL outcomes, as traditional measures of collaboration may overlook these more nuanced dynamics.

Our study builds upon existing research by illustrating how PBL benefits a diverse cohort of learners. Contrary to prior assumptions that PBL primarily benefits a homogeneous group, our data demonstrate that PBL can broaden participation and inspire learners from varied backgrounds to explore STEM fields [34].

4.2 Gender equity in STEM

PBL's effectiveness in promoting critical thinking and problem-solving skills is well-documented [30], and our research extends this by introducing a focus on gender equity in STEM. Our findings reinforce existing literature, which emphasizes the need for gender-inclusive practices [20]. Unexpectedly, our results revealed that the girls not only became more confident in navigating technical challenges but also developed a stronger sense of solidarity as they tackled issues related to gender dynamics in STEM careers. Contrary to our expectations that gender-inclusive practices would foster individual empowerment, we found that group solidarity emerged as a key mechanism through which the girls supported each other in exploring STEM fields. This unexpected dimension highlights how PBL can actively cultivate not just individual confidence, but collective empowerment, preparing young women to overcome challenges in academia and industry [25].

4.3 Technological integration in PBL

One of the unique contributions of our study is exploring the intersection of PBL and technological integration in informal learning environments, addressing a critical gap in the existing literature [33]. While previous studies [2, 14] have examined technology's role in enhancing student engagement, we were surprised to find that emerging technologies empowered students to take creative risks in ways we had not anticipated. For example, several participants exceeded the basic podcasting requirements by experimenting with complex editing software and sound effects. This form of technological integration not only made learning interactive but also promoted unexpected levels of self-regulated learning and creativity, essential for students preparing for modern communication and media fields [6, 41].

Our data suggest that integrating technology into PBL is not merely advantageous—it is essential for equipping students with skills relevant to the evolving communication landscape. The use of technology as a tool for collaboration, critical thinking, and creativity supports a multifaceted learning environment, enhancing the impact of PBL [3, 6, 30]. These findings contribute to the broader discourse on technology's role in education, underscoring how emerging technologies can catalyze transformative learning experiences [29].

5 Limitations and implications

While our study provides insights into the positive impact of PBL and technological integration on UUREM middle-grade girls' STEM learning, several limitations must be acknowledged. The specific context of the week-long technology-based PBL at a STEM camp, where UUREM girls constituted the majority, may limit the generalizability of our findings. The program's short duration could affect skill acquisition and long-term knowledge retention. Additionally, the self-selection bias of participants attending a STEM camp may limit generalizability to a broader UUREM middle school population. The absence of a control group hinders establishing a causal relationship between the intervention and outcomes. Lastly, the specific technologies and their accessibility may impact reproducibility and scalability across diverse educational settings. Acknowledging these limitations provides valuable insights for future research in this domain.

The implications drawn from our study hold significant promise for various stakeholders involved in STEM education, offering actionable insights that can shape the design and implementation of future initiatives. Our findings may substantially contribute to the development of STEM curricula that are not only culturally responsive but also profoundly resonant with the interests and experiences of UUREM girls. This alignment has the potential to foster greater engagement, ensuring that educational content is both relevant and relatable, thereby enhancing the overall effectiveness of STEM learning experiences for UUREM girls. Educators stand to benefit from a deeper understanding of effective strategies to facilitate informal STEM learning that caters specifically to UUREM girls, thereby promoting more inclusive teaching practices. By leveraging the insights gleaned from the role of technology in informal STEM learning, strategies for integrating emerging technologies can be effectively developed, ensuring equitable access to tools that enhance the overall learning experience for UUREM girls.

Moreover, our study sheds light on anticipated challenges that UUREM girls may encounter in informal STEM learning settings, including issues related to collaboration among girls and navigating discussions on racial and gender-related topics within the STEM workplace. These insights are valuable for informal STEM facilitators, allowing them to proactively address challenges and create supportive environments that foster collaboration and dialogue. Notably, the camp's success in facilitating interactions between UUREM girls and professionals across various STEM fields emerged as a distinct advantage. This exposure provided UUREM girls with the opportunity to learn, interview, and reflect on the experiences of being UUREM individuals and women in STEM careers. Witnessing real-world challenges faced by these professionals and understanding how they navigated and overcame them served as a powerful learning tool.

In conclusion, our study's implications extend beyond the academic realm, offering a roadmap for researchers and informal educators to collaboratively work towards fostering a more inclusive and supportive environment for UUREM girls in STEM education. By addressing the identified challenges and leveraging the success stories of professionals, we can collectively contribute to dismantling barriers and promoting an equitable and empowering STEM education experience for UUREM girls.

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Author contributions The authors confirm contribution to the paper as follows: study conception and design: MTS, SLM, and CW; data collection: MTS and SLM; analysis and interpretation of results: MTS, SLM, and CW; draft manuscript preparation: MTS, SLM, and CW. All authors reviewed the results and approved the final version of the manuscript.

Data availability The datasets generated during and/or analyzed during the current study are not publicly available to protect the participants identities but are available from the corresponding authors on reasonable request.

Declarations

Ethics approval and consent to participate The studies involving humans were approved by Southern Methodist University's Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s), and minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article.

Competing interests The authors have no competing interests to declare that are relevant to the content of this article.

Appendix A

Connection of PBL Elements and Learning Outcomes (Fig. 4).

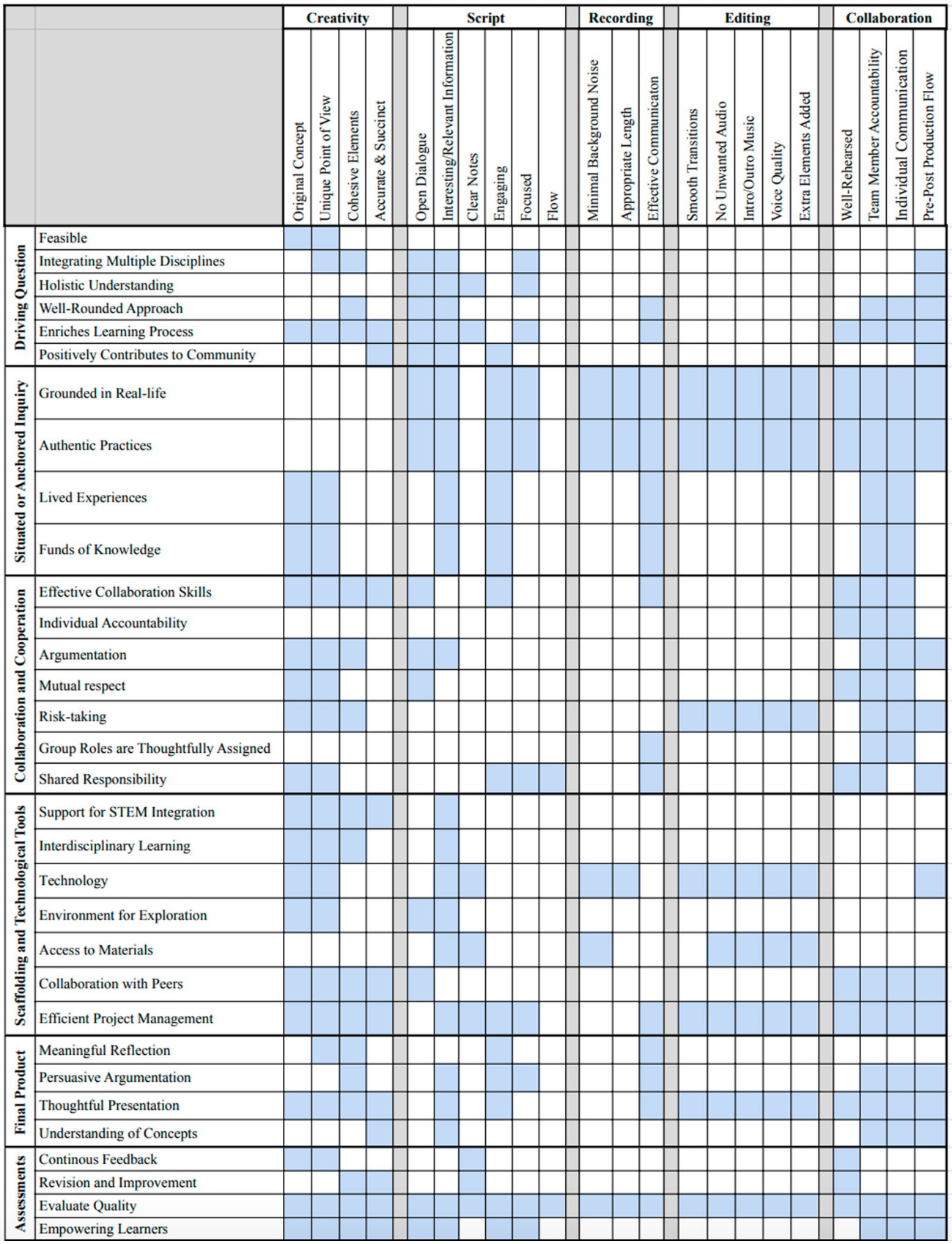

Fig. 4 Connection of PBL Elements and Learning Outcomes

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