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Project-Based Mentoring and K-12 Collaboration for Sustainable Development in Pre-Service Teacher Education

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Abstract

This study combines project-based learning with mentorship. Utilizing a sustainable development project (i.e., SEED Bank Project), this study aims to achieve multiple goals. While it attempts to promote pre-service teacher education by assigning pre-service teachers as mentors to high school students, the study critically examines the impact of a Seed Bank project to its stakeholders. The conceptual framework begins with a description of Project-Based Mentoring (PBM) and the role of Seed Bank project as a Project-Based Learning (PBL) opportunity and then examines the effectiveness of the project through the lens of PBM theory. A phenomenological case study was undertaken with nine pre-service teachers and nine high school students during the 2023–2024 academic year. The context and product evaluation areas of the CIPP (Context, Input, Process, Product) Model, along with the impact and

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process evaluation dimensions of Stake's Responsive Evaluation Model (REM), were selected to analyse the study's findings. The findings of the research highlight the importance of (a) the complementary use of PBL and mentorship to create a win-win context for enriched educational outcomes, (b) the significance of e-mentoring, peer mentoring, and reverse mentoring, and (c) the importance of university & K-12 collaborative projects to advance educational and sustainable development outcomes.

mentoring, reverse mentoring
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Introduction

By designing a win-win experiential learning environment where one party (i.e., pre-service teachers) engaged in mentoring, and the other party (i.e., high school students) engaged in project implementation (i.e., Seed Bank), this multi-stakeholder 'university-society (K-12 school)' cooperation project carried out a multi-folded purpose. First, using the combination of Problem-Based Learning (PBL) and Project-Based Mentoring (PBM), both high school students and pre-service teachers interests in United Nations-Sustainable Development Goals

(UN-SDGs) were aimed to be nurtured. Second, pre-service teacher education was promoted through a well-structured mentoring training. Third, by assigning pre-service teachers to high school students as mentors for the development of the SEED Bank project, a unique PBL opportunity has been provided for high school students. Fourth, through this project, some significant Industry 4.0 skills (both cognitive and non-cognitive) in both pre-service teachers and high-school students were aimed to be promoted. To sum up, while this project aimed to help both high school students and pre-service teachers enhance their knowledge and interest in UN-SDGs with a unique experience (i.e., development of Seed Bank), it also provided pre-service teachers an opportunity to enhance their mentoring competencies and networks. The project intentionally combined PBL in the field of UN-SDG-Target-2.5 [1] with a unique mentoring experience and expands our understanding of how Project-Based Mentorship (PBM) can be utilized to train pre-service teachers, equipping them with essential mentorship skills through hands-on mentor-mentee interactions. By engaging both mentors and mentees in real-world problem-solving, the study not only enhances their pedagogical development but also fosters a sense of social responsibility.

Research Questions

The effectiveness of the project was evaluated through the lens of PBM theory, with research questions addressing four key aspects: the context and product evaluation areas of the CIPP (Context, Input,

[1] UN-SDG-Target-2.5: "End hunger, achieve food security and improved nutrition, and promote sustainable agriculture-Enhancing genetic diversity in food production (UNDP, 2020)

Process, Product) Model, and the impact and process evaluation dimensions of the Responsive Evaluation Model (REM).

1. In what unique ways, the participants' awareness was raised and their skills were developed in the project? (CIPP- Context evaluation)
2. What are the views of participants on the facilitators and the challenges of the process phase of the PBM? (REM- Process evaluation)
3. Through the Seed Bank project, what unique needs of the participants and the community were met? (REM- Impact evaluation).
4. What are the views of the stakeholders on the project outputs? (CIPP- Product evaluation)

Importance of Research

This research is significant for several reasons, particularly in its innovative integration of PBM with the UN-SDGs in the context of pre-service teacher education. While existing studies explore PBL and mentoring in educational settings, most focus on these approaches in isolation (e.g., Almulla, 2020; Du et al., 2024; Hartman et al., 2018). This study, however, uniquely combines both frameworks, creating a multifaceted, experiential learning environment for pre-service teachers and high school students. By embedding the Seed Bank initiative within the UN-SDGs framework, the project provides a hands-on approach to teaching sustainability, environmental responsibility, and community engagement. This distinguishes the study by demonstrating how PBM can serve as a powerful tool not

only for skill development but also for fostering awareness of global challenges such as climate change and biodiversity loss.

Furthermore, this research contributes to the relatively underexplored area of PBM's impact on pre-service teacher development. Traditionally, pre-service teachers receive limited exposure to mentorship roles during training. Research suggests that beginner teachers often enter the profession with misconceptions about the challenges they will face, assuming their university education has fully prepared them (Callahan, 2016; Mokoena & van Tonder, 2024). Hine and Thai (2019) further argue that the practical teaching experiences provided in teacher education programs are insufficient in fully equipping pre-service teachers with the skills necessary for self-directed and effective teaching. This project offers them an opportunity to develop crucial mentoring competencies, which are often overlooked in conventional teacher preparation programs. Additionally, it highlights the value of interdisciplinary, real-world projects that blend academic learning with community-based outcomes.

The study also employs established evaluation frameworks, including Stufflebeam's CIPP (Context, Input, Process, Product) Model and Stake's Responsive Evaluation Model (REM), enabling a comprehensive and systematic assessment of the project's effectiveness. This methodological approach enhances the relevance of the findings, offering new insights into how PBM can effectively address both local educational needs and global sustainability goals.

In sum, this research offers a novel perspective at the intersection of Project-Based Learning (PBL), mentoring, the UN-SDGs, and pre-service teacher education. It contributes valuable insights to the field while presenting a unique model for integrating education with global

development initiatives, demonstrating how PBM can be a powerful tool for both professional growth and civic engagement.

Conceptual Framework

The study intentionally integrates PBL with mentorship (PBM) and examines the effectiveness of PBM using selected dimensions from Stufflebeam's (2003) CIPP Evaluation Model and Stake's (1975) Responsive Evaluation Model (REM) (see Figure 1). The conceptual framework begins with an overview of PBM, followed by an explanation of the Seed Bank Project as a PBL opportunity. It then explores the context and product evaluation areas of the CIPP Model and the impact and process evaluation dimensions of Stake's REM, as these specific dimensions have been chosen to analyse the study's findings.

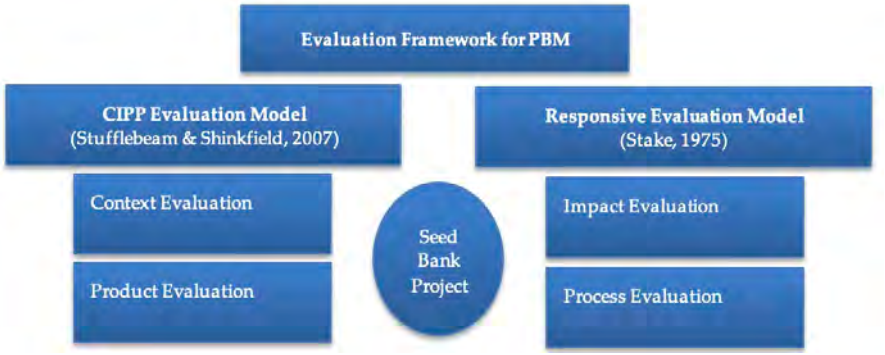


Figure 1. *Evaluation Framework for PBM*

Project Based Mentoring (PBM)

In the 21st century, traditional direct instruction alone is no longer sufficient to equip students with the skills needed for the modern era. Instead, it offers a more effective approach to developing 21st-century

competencies in students, preparing them for the demands of the information age (Bell, 2010; Clark, 2020; Land et al., 2012). Through PBL, learners actively engage in higher-order thinking activities such as planning, researching, analysing information, and creating meaningful products. Additionally, they collaborate and exchange ideas with others, applying their knowledge to real-world contexts (Blumenfeld et al., 1991). The mentorship program in this study was grounded in PBL approach and specifically aligned with the PBM model which was developed and trademarked by Alper (2017). PBM builds upon PBL theories but uniquely incorporates a mentor-mentee dynamic, fostering collaboration on real-world projects (Alper, 2021). While PBM involves knowledge transfer, it differs from traditional educational models. Instead of information flowing from educators, theoreticians, or textbooks, it is passed from a hands-on practitioner to a novice (Alper, 2021). The core philosophy is simple yet impactful: *learning from doers and learning by doing* (Alper, 2021). This approach enhances experiential learning, allowing mentees to gain practical insights and problem-solving skills through direct engagement with mentors in authentic, project-driven environments.

In PBM model, mentees acquire required knowledge and competencies by working for an extended period to address an authentic challenge with guidance from their mentors (Buck Institute for Education, 2019). Mentoring requires regular meetings, continuous engagement, and a significant time commitment from both mentors and mentees (Michailidi & Stavrou, 2021). With the mentor acting as a guide, the mentee can take ownership of a project and experience real-world problems that prepare them for the world (Alper, 2017). During the process, the mentees learn from their shortcomings and failures. In this model, mentors and mentees together share a mutual goal. They

plan the project's framework and decide on a timeline for successful completion together (Alper, 2021). In this model, the student should assume all the responsibility and be the executer of the master plan. By engaging in real-world scenarios and having a mentor by their side, students become more able to deal with real-world obstacles with ease (Alper, 2021). This presents a win/win situation for both parties. Prensky (2014) argued that character-based skills such as persistence, honesty, self-confidence and determination are the most valuable 21st-Century skills and considered as extremely important traits in the labor market. Heckman & Kautz (2014) argued that these traits can best be learned through projects. Moreover, Joplin (1981) argued that learners who participate in mentorship programs benefit from "learning by doing," which has been shown to create a highly effective learning experience for students. As reported by Alper (2021), NFTE (2014) studies showed that learners who are exposed to a mentorship program had better perceptions of the educational program and outperformed their unmentored peers in many aspects, including their comfort level in expressing themselves, ability to access career-related knowledge and skills, and character development.

PBM gives mentors an opportunity to be real educators. During the program, mentors have a good chance to learn how to communicate effectively or manage expectations and disappointments properly. By sharing real-world experiences with their mentees, they learn how to motivate people and keep them engaged when they are about to give up. Cohen (2001) suggests that benefits of mentorship extend far from the original reason of the collaboration. PBM offers great psychological and practical rewards to the mentors. First, it gives mentors an opportunity to share their knowledge and experience by keeping them

engaged in uniquely rich diversity of perspectives in various settings. Second, it gives them a purpose, a schedule, and a value (Alper, 2021).

The Role of Seed Bank Project as a High-Impact Project-Based Learning (HI-PBL) Opportunity

The Seed Bank Project was initiated to support the participants' interests in UN-SDGs. In this study, the Seed Bank project was utilized as a powerful tool— a High Impact Project-Based Learning (HI-PBL) opportunity— to advance one of the most transformative agendas of the UN-SDGs while equipping students with essential Industry 4.0 knowledge and skills. Sustainable development is an increasingly important topic due to the seemingly rapid depletion of natural resources around the world. UN-SDGs were adopted by the United Nations including Turkey in 2015 as a call-to-action for people worldwide to improve the planet and the quality of human life around the world by the year 2030. As part of the 2030 Agenda for Sustainable Development, Turkey included the issue of "awareness-raising activities on environment and nature protection, sustainable production and consumption aimed at increasing the environmental awareness of the society" in the 2019-2023 11th Development Plan as an Article (no: 713.3) (T.C. Cumhurbaşkanlığı Strateji ve Bütçe Başkanlığı, 2019). This alone shows how important this issue is both at the national and international level. Since UN-SDGs are one of the hotly debated issues in recent years, this research aimed to initiate a SEED Bank project in a high school as a part of a K-12 & university collaboration using PBM model.

PBL is an engaging, effective, and enjoyable approach to developing the deeper learning skills essential for success in college, careers, and civic life (Buck Institute for Education, 2019). Researchers suggested that PBL cultivates participants' both cognitive (such as knowledge

and skill) and non-cognitive competencies (such as determination and persistence) (Bhuyan et al., 2020; Rijken & Fraser, 2023; Zhao & Wang, 2022). In order to engage learners with a memorable and complete learning experience, this model puts a project at the center of learning (Alper, 2021). The project should focus on realistic problems and must prepare participants for real world outcomes (Sayuti et al., 2020). As a result, participants develop deep content knowledge as well as critical thinking, collaboration, initiation, and communication skills (Buck Institute for Education, 2019). PBL fosters students' curiosity and helps students become responsible citizens by preparing them for 21st century challenges (Krajcik & Czerniak, 2018).

Method

This study employs a phenomenological case study design to explore mentorship roles and social interactions in mentor-mentee practices aimed at supporting the professional development of pre-service teachers. The CIPP Evaluation Model (context and product evaluation areas) and Stake's (1975) Responsive Evaluation Model (impact and process evaluation areas) serve as analytical frameworks to assess both the contextual factors influencing mentorship and the outcomes of these interactions. The case study approach is utilized instrumentally, allowing for a detailed examination of PBM model as a mechanism for fostering professional growth. By treating PBM as an instrumental case, the study provides a structured analysis of mentorship dynamics, instructional strategies, and the broader implications for teacher education programs. Simultaneously, the phenomenological approach is employed to capture participants' lived experiences, particularly their experiential learning throughout the development of the SEED Bank project. This approach enables a deeper understanding of how pre-service teachers perceive and internalize mentorship practices,

emphasizing the subjective meanings they assign to their professional growth. By integrating both instrumental case study and phenomenological inquiry, this study offers a holistic perspective on mentorship in teacher education, bridging structured program evaluation with participants' personal experiences.

REM vs CIPP Evaluation Model

This study integrates different aspects of two evaluation models—Stake's (1975) REM and Stufflebeam's CIPP Evaluation Model—to create a complementary assessment framework. To evaluate the effectiveness of the SEED Bank Project, the context and product evaluation areas of the CIPP Model were combined with the impact and process evaluation dimensions of REM. This approach was selected to prioritize the project's influence on stakeholders and the alignment of its processes with their needs, rather than focusing solely on predefined outcomes. Stufflebeam's CIPP Evaluation Model (2000) provides a comprehensive framework for assessing programs through four key areas: context, input, process, and product evaluation. Context evaluation helps identify and understand the diverse needs of the target population, ensuring the program aligns with those needs (Sankaran & Saad, 2022). Input evaluation examines the allocation of resources and assists in planning decisions and strategy development to achieve project objectives. Process evaluation focuses on whether the program is being implemented as intended, asking, "Are we doing it correctly?" or "Did we do what we said we would?" (Haji et al., 2013). Finally, product evaluation measures, interprets, and assesses the program's outcomes.

Stake's Responsive Evaluation Model (REM) (1975), in contrast, prioritizes the needs and perspectives of participants over the original intentions of the program. In this model, stakeholders play a central

role in defining the outcomes they consider meaningful. Special attention is given to individuals who are typically excluded from knowledge creation and project implementation (Van Heijster et al., 2021). REM begins by addressing the concerns of various stakeholders to assess the quality and value of a program. Rooted in the naturalistic paradigm, it emphasizes evaluating the educational process rather than predefined outcomes. By conducting an evaluation that directly responds to stakeholders' needs, the findings become more relevant (impact evaluation) and more likely to be used for program improvement (process evaluation) (Curran et al., 2003). REM aims to refine interventions during implementation, ensuring they remain aligned with practical realities while incorporating stakeholder input.

The choice of an evaluation model depends on the program's objectives. The CIPP model is designed to equip decision-makers with actionable insights, distinguishing itself through its emphasis on context in evaluating teaching, learning, and development (Stufflebeam & Shinkfield, 2007). It serves as a tool to adapt programs to better meet organizational needs. In contrast, REM focuses on assessing the impact and process of an intervention rather than solely measuring results, ensuring that evaluation remains responsive to stakeholder experiences and concerns.

Procedure

This study received ethics approval from both the Institutional Review Board at the university where the lead researcher is employed, and the Research Initiative Committee of the partner K-12 school system before data collection began. Two groups of students were selected for participation: pre-service teachers from the university, who served as mentors, and high school students from the partner K-12 school, who were mentees. Participation was entirely voluntary, with no penalties

for refusal and no incentives provided. Each participant received an informed consent form, which outlined the study's purpose and methodology and requested permission to record interviews. The study followed a structured timeline that incorporated both mentorship training and experiential learning through the SEED Bank project.

Mentor Training Programme

The mentor training program was adapted from the NSF-funded *Entering Mentoring* curriculum (Greenberg, 2018) and designed to equip pre-service teachers (mentors) with essential mentoring skills before engaging with high school students. The training covered the following key areas (see Figure 2).

Getting Started. In the first session, pre-service teachers' perceptions of mentoring were explored, and the significance of PBM was discussed.

Establishing Expectations. Participants were oriented to the process and the expectations of PBM.

High-Quality Communication. The importance of building and maintaining effective mentoring relationships with mentees was discussed.

Assessing Understanding. Strategies for enhancing and assessing mentees' understanding were discussed.

Mentoring Ethically. Ethical considerations in mentor-mentee relationships, along with mentors' roles and responsibilities in addressing these issues, were discussed.

Developing a Mentoring Philosophy. In the final session, mentors were asked to share their mentoring philosophies with their peers.

These interactive sessions were conducted in an informal, conversational format, allowing mentors to discuss their expectations and challenges. Mentors had one month to complete the training and respond to a short-answer question: *"Provide a short description of what you plan to do as a mentor."*

Getting Started	Exploring perceptions of mentors about mentoring and PBM
Establishing Expectations	Introduction to PBM Process & Orientation
High-Quality Communication	Relationship building and maintaining
Assessing Understanding	Discussion of strategies for enhancing and assessing mentees' understanding
Mentoring Ethically	Discussing of ethical issues and responsibilities
Developing a Mentoring Philosophy	Sharing mentoring philosophy

Note. Adapted from *Entering Mentoring* curriculum (Greenberg, 2018)

Figure 2. *Implementation of Mentor Training Programme*

To maximize the effectiveness of mentorship, the study employed three complementary mentoring approaches: e-Mentoring, Peer Mentoring, and Reverse Mentoring. E-Mentoring provided virtual support and knowledge exchange, allowing pre-service teachers and high school students to engage in flexible online mentoring sessions beyond scheduled in-person meetings. These interactions facilitated discussions on UN Sustainable Development Goals (UN-SDGs), mentorship principles, sustainable agriculture, and project logistics. This approach ensured accessibility and continuity, enabling mentees

to seek guidance outside of formal sessions while also fostering digital collaboration skills essential for modern educational environments. Peer Mentoring focused on collaborative learning and shared experiences, with pre-service teachers engaging in reflective discussions and problem-solving within their university cohort. This allowed them to refine their mentoring strategies before working directly with high school students, reinforcing their confidence and pedagogical skills. Additionally, Reverse Mentoring introduced a student-led learning dynamic, where high school students shared their perspectives and expertise on youth engagement strategies and sustainability projects. By recognizing the knowledge of younger mentees in specific domains, this approach challenged traditional power structures in mentoring. It empowered mentees by validating their contributions, fostering an interactive and reciprocal learning environment, and equipping pre-service teachers with insights into student-centered teaching approaches. By integrating these mentorship types, the program promoted inclusive, dynamic, and transformative mentorship experiences.

Implementation of Seed Bank Project

The SEED Bank Project was implemented as a High Impact Project-Based Learning (HI-PBL) experience, following the Gold Standard PBL framework (Larmer et al., 2015a, 2015b) (see Figure 3). This approach provided a structured yet flexible learning environment that emphasized real-world problem-solving, inquiry-driven exploration, and meaningful student engagement. The project was structured around the following core elements.

Learning Goals (Key Knowledge, Understanding, and Success Skills)

- Mentors and mentees developed a deep understanding of sustainable agriculture and BM-SDGs.
- They engaged in active problem-solving, developing practical solutions for agricultural sustainability.

Real-Life Problem

- The project addressed an authentic issue: the need to preserve and distribute seeds to promote biodiversity.
- Learners explored practical applications of their knowledge, ensuring real-world impact.

Sustained Inquiry

- Participants continuously questioned and refined their approaches.
- Mentors guided mentees through research-based problem-solving, promoting critical thinking.

Learner Voice and Choice

- Mentees were encouraged to express their ideas, make decisions, and modify project elements.
- They played an active role in shaping the Seed Bank's design and implementation.

Reflection

- Both mentors and mentees engaged in ongoing self-assessment, discussing challenges and progress.

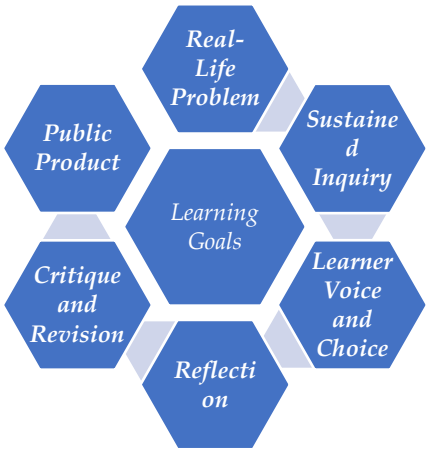
- Structured reflection sessions helped participants internalize their learning experiences.

Critique and Revision

- Participants received peer and expert feedback on their project designs.
- Mentors helped mentees revise and improve their strategies before implementation.

Public Product

- The project culminated in a final presentation, where mentees shared their work with school administrators, community members, and agricultural professionals.
- This phase validated mentees' contributions, highlighting the broader relevance of their work.



Note. Adapted from the Gold Standard PBL framework (Larmer et al., 2015a, 2015b).

Figure 3. *Project Design Elements*

SEED Bank Project Implementation & The Phases of Mentorship

The mentorship and SEED Bank project followed a structured, phased approach to ensure effective mentor-mentee engagement and successful project implementation. This process was divided into four key phases, each designed to build foundational knowledge, foster collaboration, and support hands-on learning experiences (see Figure 4).

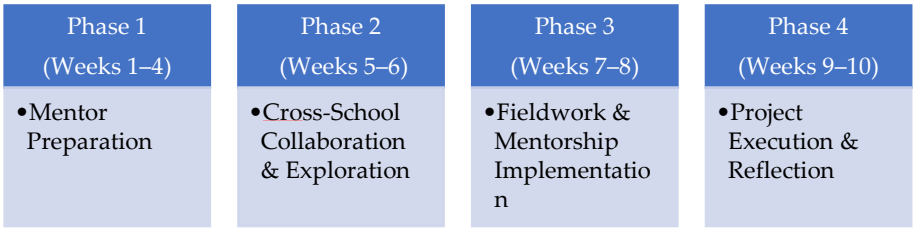


Figure 4. *Phases of Mentorship & SEED Bank Project Implementation*

Phase 1: Mentor Preparation (Weeks 1–4)

- Pre-service teachers received training on mentorship principles and UN-SDGs, with a specific focus on Target 2.5 (maintaining genetic diversity in agriculture).
- They engaged with e-mentoring discussions and peer mentoring within their cohort.
- They conducted independent investigations and presented findings under faculty supervision.

Phase 2: Cross-School Collaboration & Exploration (Weeks 5–6)

- Pre-service teachers partnered with high school mentees, engaging in exploratory activities at the K-12 school.

- Reverse mentoring emerged as mentees shared their prior knowledge on agriculture, sustainability, and local environmental initiatives.
- Researchers and professionals in sustainable agriculture provided additional guidance.

Phase 3: Fieldwork & Mentorship Implementation (Weeks 7–8)

- Pre-service teachers visited the partner school, where they initiated the mentoring process and explored potential sites for the SEED Bank project.
- They assessed school resources, worked collaboratively with mentees, and designed project implementation strategies.

Phase 4: Project Execution & Reflection (Weeks 9–10)

- Pre-service teachers developed and delivered a 15–20-minute mentorship presentation on the Seed Bank project, where they introduced themselves, shared their interests, and outlined their plans for the project. This presentation helped facilitate mentor-mentee pairing by ensuring better alignment based on shared goals, interests, and expertise, ultimately enhancing the effectiveness of the mentorship experience.
- A discussion session followed, where mentors and mentees were paired based on shared interests and project goals (see Table 1 for mentor-mentee pairings).
- The project concluded with a reflective evaluation, where mentors and mentees discussed their experiences throughout the project.

Table 1.

Mentor-mentee pairings

Pair	Pseudonym (for mentor)	Gender and Grade Level (for mentor)	Pseudonym (for mentee)	Gender and grade level (for mentee)
1	Huma	Female / Junior	Sami	Male / Grade 11
2	Hakan	Male / Senior	Rıfat	Male / Grade 10
3	Lale	Female / Senior	Rana	Female / Grade 12
4	Itır	Female / Junior	Meltem	Female / Grade 11
5	Nihan	Female / Senior	Sena	Female / Grade 10
6	Pino	Male / Junior	Ebru	Female / Grade 12
7	Figen	Female / Senior	Simay	Male / Grade 11
8	Tufan	Male / Junior	Sinem	Female / Grade11
9	Ipek	Female / Junior	Cihan	Male / Grade 11

Participants

Pre-service teachers (mentors) met four inclusion criteria. They must have

- enrolled in an undergraduate program with a major in the Faculty of Education during 2023-2024 Academic Year.
- agreed to attend a five-hour mentoring training, and
- agreed to commit a minimum of five hours per month for on-site project activities and to fulfill face-to-face mentorship requirements.
- agreed to commit a minimum of five hours per month to fulfill e-mentorship requirements.

The ages of pre-service teachers ranged from 20 to 27 years old (M = 22.88). Three university mentors were male, and six were female.

High school students (mentees) met four inclusion criteria. They must have

- agreed to commit a minimum of four hours per month for on-site project activities
- agreed to commit a minimum of four hours per month to benefit from e-mentorship service.

The ages of high school students (mentees) ranged from 16 to 18 years old (M =16.77). Three mentees were male, and six were female.

Data Collection

The study was conducted during the 2023–2024 academic year and utilized a diverse range of data sources, including interview and focus group transcripts, reflection papers, and observation reports. To monitor the mentor-mentee relationship, bi-monthly interviews were conducted, beginning in October. A semi-structured interview approach was employed to explore key aspects of the program, focusing on:

(a) The most valued outcomes of the program from the stakeholders' perspectives.

(b)The practical implementation of mentoring.

(c) The opportunities and challenges associated with Project-Based Mentorship (PBM).

(d) The products of the program.

This multi-faceted data collection approach provided comprehensive insights into the effectiveness of PBM and its impact on participants.

The interviewers used probes and follow-up questions to gain a deeper insight into each participant's experiences. They made a concerted effort to foster open-ended discussions and ensure that participants felt their input was valued and significant. Sonix.ai was utilized to transcribe the audio recordings. Additionally, the first author reviewed each transcript while replaying the corresponding audio recording. After the author's review, the transcripts were also shared with participants to verify their accuracy. Once the transcripts were confirmed as accurate, the first author conducted an initial multi-step thematic analysis (Patton, 2002; Yin, 2009).

Data Analysis

The analysis of qualitative data employed the content analysis method. Content analysis involves systematically classifying data through coding to identify key categories. When there is prior knowledge of the topic, it helps in formulating ideas about the expected categories and codes that might emerge. By using pre-established theoretical categories related to existing theories, content analysis can process large volumes of qualitative data and distill it into a summarized form by identifying and coding these pre-existing (and potentially new) categories.

All authors thoroughly reviewed the interviews to identify common themes and patterns and to achieve a shared understanding (Patton, 2002). The first author led the development of codes through a repetitive process involving literature review and evaluation of interview data. Codes were designed to address the issues and align with concepts from the conceptual framework. Using MAXQDA Pro software, relevant text and words were identified to answer the research question. Once no new codes were found, the coded data were exported to Microsoft Excel for analysis of similarities and

overlaps. The data were then reduced and consolidated, and final codes were organized into major thematic categories. The authors reached consensus on the findings after reviewing additional documentation related to the PBM program, including training materials, program expectations, timelines, mentor-mentee meeting agendas, and observation forms. For triangulation, the mentoring processes and experiences reported by mentees and mentors were verified by the program facilitators (researchers).

Findings

The findings were grouped under four pre-determined main dimensions (context, process, impact and product) (see. Table 2).

Table 2.
Summary of Findings

Pre-determined Dimension	Emerging Themes
CIPP-Context Dimension	Internalization of UN-SDGs **Mentorship as a Transformative Experience for Pre-Service Teachers** **Career Aspirations: Affirmation and Reevaluation**
REM-Process Dimension	Facilitators (e-mentoring, peer and reverse mentoring) Challenges and Setbacks: Navigating Through Them
REM-Impact Dimension	Networking Developing character-based skills
CIPP-Product Dimension	The Seed Bank **Mentor Training Programme**

CIPP- Context Dimension

Regarding the first research question, "*In what unique ways were the participants' awareness raised and their skills developed in the project?*", the analysis yielded three key findings. First, the Seed Bank initiative played a crucial role in *the internalization of UN-SDGs*, as both mentors and mentees moved beyond theoretical knowledge to actively engage in sustainability efforts, deepening their understanding of environmental responsibility. Second, the mentorship program proved to be *a transformative experience for pre-service teachers*, enhancing their professional competencies by providing firsthand insights into student behavior, communication, and instructional strategies. This experience not only strengthened their mentoring skills but also increased their confidence and preparedness for the teaching profession. Finally, the project had a significant impact on participants' *career aspirations, leading to both affirmation and reevaluation*. While some pre-service teachers found their passion for teaching reaffirmed, others realized that the profession was not the right fit for them, demonstrating the value of experiential learning in shaping career trajectories.

Internalization of UN-SDGs

Findings under this theme revealed that both mentors and mentees significantly enhanced their knowledge of the UN-SDGs and developed essential skills to actively contribute to environmental sustainability. The project provided a transformative learning experience, moving beyond theoretical knowledge to practical engagement. As Huma, a pre-service teacher, observed, participants who had previously only read about environmental sustainability became deeply involved in hands-on activities. She described the experience vividly: *"Lining with carefully labeled jars of seeds on shelves,*

each one representing a species crucial to the region's ecosystem and learning about seed preservation techniques".

This direct immersion in conservation efforts not only deepened participants' understanding of sustainability but also reinforced their commitment to environmental stewardship. The experience extended beyond theoretical discussions, requiring mentees to navigate real-world challenges—from negotiating with school administrators for compost bins to establishing connections with local farmers who shared their expertise.

Both mentors and mentees developed a profound understanding of the Seed Bank's purpose and expressed their dedication to continuing sustainability efforts. This sense of internalization was evident in their reflections. As Rifat, one of the mentees, emphasized: *"With our Seed Bank project, we learned the importance of preserving our agricultural heritage to ensure a bountiful harvest for generations to come. Sustainable development isn't just a fancy term; it's about safeguarding what we have today for tomorrow".*

Similarly, Rana shared how the experience reshaped her perspective: *"I never realized how important it is to protect our local biodiversity".* She went on to state her newfound aspiration to study agriculture and contribute to similar initiatives.

For Meltem, the project transformed sustainability from an abstract concept into an actionable mission: *"I used to think sustainable development was just a lofty goal. Now, I see it as something we can actively work towards, one project at a time. The Seed Bank initiative showed me how we can fight hunger by saving and sharing seeds. It's empowering to know that we are able to make a difference".*

Through these experiences, mentees internalized the significance of sustainability and saw themselves as active participants in addressing global challenges, demonstrating the transformative power of Project-Based Mentorship (PBM) in fostering long-term commitment to environmental and social responsibility.

Mentorship as a Transformative Experience for Pre-Service Teachers

The second research finding regarding the first research question revealed that mentoring experience had a profound impact on pre-service teachers, shaping their awareness of their profession, expectations about student behavior, and overall readiness for teaching. Through direct engagement with mentees, they gained practical insights into mentorship, student psychology, and the diverse needs of learners, all of which contributed to their professional development and preparedness for the teaching profession.

Hakan, one of the pre-service teachers, reflected on how mentoring younger students broadened his understanding of children's diverse abilities and helped him develop a more reflective and adaptive approach to teaching. He described the sense of fulfillment in witnessing his mentees' progress, stating that *"It was a rewarding experience to watch my students grow and succeed with my guidance"*.

Similarly, Lale shared how mentoring enhanced her communication skills and deepened her understanding of student psychology. The experience boosted her confidence in teaching and reaffirmed her passion for education. She remarked on the power of even small efforts, saying, *"It's amazing to see how even the smallest efforts can lead to significant improvements in a student's learning journey"*.

For Itır, mentorship brought a sense of fulfillment and personal growth, allowing her to build meaningful connections with her

mentees. She explained, *"Trying to bring out the best in my mentee added more meaning to my life, expanded my mind, and enriched my ability to bond with others".*

Career Aspirations: Affirmation and Reevaluation

The mentorship experience also played a pivotal role in shaping career aspirations, helping pre-service teachers clarify their professional goals. While some found their passion for teaching reaffirmed, others realized that teaching was not the right fit for them.

Nihan expressed how mentoring strengthened her decision to become a teacher, reinforcing her belief in education's transformative power. Conversely, Pino discovered that teaching was not for him, acknowledging the emotional demands and constant responsibilities of the profession. He appreciated the clarity the experience provided, stating, *"Although I enjoyed certain aspects of mentoring, it became clear that teaching demands a level of commitment and passion that I do not possess."*

Echoing this sentiment, Figen shared how mentoring younger students made her reevaluate her enthusiasm for teaching. She emphasized the value of the experience in making an informed career decision, stating, *"Interacting with younger students in a mentoring role made me understand that my enthusiasm for teaching isn't as strong as I thought. Yet, it was an essential experience that helped me make an informed career decision."*

These findings highlight the dual impact of mentorship—while it enhanced professional development for those committed to teaching, it also provided critical self-awareness for those reconsidering their career paths. The structured mentorship process allowed pre-service teachers to experience the realities of teaching firsthand, leading to greater confidence, improved skills, and a clearer sense of professional direction.

REM- Process Dimension

The 'process' dimension of the project revealed both facilitators and challenges that shaped the progression of PBM. As Sami (one of the mentees) highlighted, every success and setback were a learning opportunity, discussed and analyzed with mentors and peers.

Facilitators (e-mentoring, peer and reverse mentoring)

E-mentoring played a pivotal role in the project, offering mentees more regular, flexible, and convenient meetings, which greatly enhanced experience-sharing. Sena noted that e-mentoring allowed consistent support, when in-person meetings were not feasible, a sentiment also echoed by Ebru, who valued the sustained mentorship it provided.

Though peer and reverse mentoring were not formally structured in the program, they emerged organically and became integral to the mentoring process. Rana stressed that peer support was crucial, as encouragement from fellow mentees extended beyond the mentor-mentee dyad. Simay reflected on how peer mentoring helped her recognize the unique strengths and perspectives each participant brought, enhancing collective problem-solving. Similarly, Tufan, who engaged in reverse mentoring, noted that it challenged his assumptions and broadened his understanding of new technologies introduced by younger students. Sami emphasized that the integration of peer and reverse mentoring created a dynamic learning environment where everyone contributed to mutual growth. Huma further highlighted that the project's success was deeply tied to fostering a culture where learning and teaching were shared responsibilities.

These findings demonstrated that the integration of e-mentoring, peer mentoring, and reverse mentoring, combined with a structured PBL

approach, significantly enhanced the mentoring experience. E-mentoring ensured continuous access to mentorship beyond structured sessions, allowing for flexibility and sustained support. Peer mentoring played a crucial role in strengthening mentors' pedagogical confidence and preparedness, as mentees learned from one another through shared experiences. Additionally, reverse mentoring fostered a collaborative and reciprocal learning environment, challenging traditional power dynamics by encouraging mentors to learn from their mentees' perspectives and expertise. Finally, the PBL framework reinforced experiential learning, ensuring that participants engaged in real-world, hands-on problem-solving that made their learning more meaningful and applicable.

Challenges and Setbacks: Navigating Through Them

Despite its successes, the project faced several challenges, as revealed by the findings. Establishing trust and effective communication within mentor-mentee relationships was a gradual process that required consistent check-ins and ongoing dialogue. A key takeaway from the findings was that mutual understanding of expectations is crucial for success, as misalignments often lead to frustration. Hakan highlighted the importance of regular reflection and clear communication of expectations to avoid misunderstandings and disappointment. The findings also emphasized that effective mentoring involves four main components: regular interpersonal interactions, building a strong rapport between mentor and mentee, effective communication, and managing expectations while handling disappointments. Furthermore, logistical constraints, such as coordinating schedules between university and high school students, posed another challenge. However, the findings showed that participants were able to mitigate these difficulties through flexible meeting arrangements and the use of

digital communication tools. Finally, resource limitations, particularly in accessing sustainable farming materials, emerged as another challenge. This was addressed through community partnerships and external funding, which provided the necessary support to overcome these obstacles.

REM- Impact Dimension

Under the 'impact evaluation' dimension, the analysis yielded two main findings highlighting the impact of PBM in developing networks and character-based skills such as persistence, honesty, self-confidence and determination.

Networking

Both pre-service teachers and high-school students developed valuable networks during the process. High school students valued their interactions with their mentors who helped them understand how to navigate obstacles encountered during the project. Likewise, pre-service teachers valued their interactions with their mentees who have given them an opportunity to be real educators. Moreover, as put forward by Rifat (one of the mentors) this project opened a whole new network for all participants involved, connecting students with professionals and peers they wouldn't have met otherwise.

The Seed Bank initiative also fostered partnerships with local farmers, agricultural experts, and environmental organizations, enhancing community engagement and collaboration. Ilayda, as a mentee, delightfully noted that she has gained access to her mentor's extensive network and built relationships with academics, industry experts and peers.

Developing character-based skills

Developing character-based skills such as persistence, resilience, self-confidence and determination are the most valuable 21st-Century skills and considered as extremely important traits in the labor market (Prensky, 2014). Findings revealed that both mentor and mentees invested extremely in those traits. Ipek (one of the pre-service teachers) proudly said their mentees tackled each hurdle with unwavering determination. She explained how they discovered the power of collaboration, and the resilience required to achieve their goals along the way. Sinem (one of the mentees) noted "*Through the Seed Bank project, we all have gained valuable skills in teamwork, problem-solving, and sustainable practices that will benefit us throughout our lives*".

Lale, one of the pre-service teachers, highlighted how mentoring significantly enhanced her self-confidence throughout the process. Cihan (one of the mentees) said that "*Through mentoring, I learned that persistence is key to overcoming challenges. My mentor's guidance and support helped me stay focused and determined, even when things got tough*". Similarly, Rana echoed Cihan's sentiment and noted that "*Having a mentor who consistently pushed me to step out of my comfort zone helped me build resilience. I learned bouncing back stronger from setbacks and not to be discouraged by them*". Moreover, most of the participants (both from mentees and mentors) stated that the Seed Bank initiative has fostered a sense of responsibility and stewardship in themselves towards the community and the environment.

CIPP- Product Dimension

Under the 'product evaluation' dimension, the analysis yielded that there were two main products in the project.

The Seed Bank

The Seed Bank, established in a high school, served as a tangible and sustainable project outcome designed to promote biodiversity conservation and agricultural sustainability. As a key product of the initiative, the Seed Bank functioned as a repository for locally significant seeds, ensuring their preservation and availability for future use.

The project involved systematic collection, categorization, and storage of diverse seed varieties, with a focus on maintaining genetic diversity and supporting sustainable farming practices. Proper storage methods were implemented to ensure seed viability over time, while a structured management system was developed to track seed distribution and replenishment.

Beyond its immediate function, the Seed Bank acted as an educational tool, encouraging students to engage with real-world agricultural and environmental issues. By integrating knowledge from sustainable agriculture and biodiversity conservation, the project provided a long-term resource for both the school and the wider community. The Seed Bank not only addressed local environmental challenges but also reinforced the importance of self-sufficiency and ecological stewardship through hands-on learning and community involvement.

The impact of the project became even more evident when it was shared with a larger audience. Reflecting on this experience, Sena expressed her feelings, stating, *"When we presented our project to people who found it useful, it really hit home how much our efforts could contribute to the community. Seeing our agricultural project being valued by others made all the hard work worthwhile and showed how it could be applied beyond just our own group"*. Her words highlight the broader significance of the

Seed Bank, not only as a local initiative but as a model for sustainable agricultural practices that can inspire and benefit others beyond the school environment.

Mentor Training Programme

In addition to the Seed Bank, another significant product of the project was the adaptation of the NSF-funded *Entering Mentoring* curriculum (Greenberg, 2018) into Turkish for the Mentor Training Program. This adaptation proved invaluable in providing a culturally relevant framework for mentorship, ensuring that pre-service teachers were equipped with essential skills and knowledge tailored to the local context. By integrating this structured approach, the training program enhanced the effectiveness of mentorship efforts, fostering meaningful mentor-mentee relationships and improving the overall impact of the initiative.

Discussion

This study examined the mentor-mentee relationships, and the competencies acquired through the development of the Seed Bank project, demonstrating how university-K-12 collaborations can simultaneously advance educational and sustainable development goals. Findings revealed that participation in the project deepened students' understanding of local plants, biodiversity preservation, and sustainable farming practices, reinforcing key UN-SDGs. Beyond environmental education, the initiative fostered essential 21st-century and Industry 4.0 skills, equipping students with problem-solving abilities, collaboration, and resilience—critical attributes for future professional environments. Aligning with Alper (2021), the study confirmed that PBM creates an active learning environment where students engage in hands-on project management while also learning

to navigate challenges and setbacks. The mentorship component further contributed to leadership development, enabling mentees to take ownership of their projects under the guidance of their mentors. Participants reported gaining confidence, a stronger sense of community appreciation, and valuable transferable skills applicable to their future careers.

The findings underscore the importance of structured mentoring experiences within university-K-12 collaborations. While K-12 students benefit from hands-on leadership opportunities, pre-service teachers gain professional exposure and firsthand insights into real-world teaching environments. This aligns with Ehrich (2022), who highlights how mentorship can evolve beyond hierarchical models into reciprocal learning relationships. The Seed Bank project demonstrated that mentorship is not merely a one-directional transfer of knowledge but a dynamic exchange, fostering environments that encourage open dialogue and innovation. Consistent with the work of Hayes and Mahfouz (2020) and Malka et al. (2022), this study challenges traditional power structures in mentoring by emphasizing collaborative learning rather than rigid top-down instruction. Additionally, the findings support Hozien's (2023) argument that mentorship models rooted in cooperation and shared responsibility dismantle hierarchical barriers, enhancing both personal and professional growth for all participants. A key aspect of this collaborative approach was the integration of e-mentoring, peer mentoring, and reverse mentoring, which played distinct yet complementary roles in shaping the mentoring experience. E-mentoring allowed for continuous guidance beyond scheduled sessions, ensuring that mentees had flexible access to support. This proved particularly valuable in overcoming logistical constraints and

fostering a sense of consistency in learning. Peer mentoring, which emerged organically, reinforced the idea that learning is a shared responsibility. By exchanging experiences and solutions, mentees strengthened their problem-solving skills while pre-service teachers developed greater pedagogical confidence. Reverse mentoring further disrupted traditional hierarchies by encouraging younger mentees to introduce new perspectives, particularly regarding technology and contemporary approaches to sustainability. This reciprocal exchange broadened mentors' understanding of evolving educational needs and empowered mentees to take on more active roles in the learning process. By fostering an egalitarian approach to mentoring, the project encouraged mentees to voice their ideas, take initiative, and engage more meaningfully in their learning journey, thereby reducing superiority bias (Haidusek-Niazy et al., 2023). These insights have broader implications for both educational and corporate settings, illustrating how participatory mentorship models—particularly those integrating digital tools, peer collaboration, and reverse mentoring—can enhance leadership development and innovation.

This study highlights the potential of PBM in preparing students for modern, technology-driven workplaces. By integrating real-world problem-solving, collaboration, and mentorship, PBM equips students with future-ready skills necessary for navigating complex global challenges. The interdisciplinary nature of the Seed Bank project cultivated competencies essential for Industry 4.0, including systems thinking, digital literacy, and an entrepreneurial mindset. Students learned to approach sustainability challenges with a holistic perspective, apply digital tools for communication and decision-making, and develop leadership and resource-management skills crucial for professional growth. These findings reinforce the

significance of embedding PBM into educational frameworks to enhance students' adaptability and readiness for global workforce demands.

Policy and Practical Implications

The study offers several practical insights for education policymakers, teacher training programs, and institutional leaders. First, the Seed Bank project serves as a model for integrating sustainability initiatives into K-12 and higher education curricula. Policymakers should consider embedding similar mentorship-driven sustainability programs within national education frameworks to promote experiential, UN-SDG-aligned learning. Second, universities should incorporate PBM methodologies into teacher training programs to ensure that pre-service teachers engage in sustainability-focused mentorship experiences. Third, given its effectiveness, the PBM framework should be adapted across diverse educational settings, including both rural and urban schools, to maximize its impact. Finally, educational institutions should collaborate with local communities, businesses, and environmental organizations to strengthen PBM initiatives and provide students with authentic, hands-on learning experiences.

Conclusion

This study highlights the transformative potential of PBM in fostering meaningful mentor-mentee relationships, enhancing education, and advancing sustainability goals. The Seed Bank project demonstrated that structured mentorship programs can effectively integrate UN-SDGs-focused learning into both K-12 and higher education contexts. By expanding such models, educational institutions can nurture future

leaders who are environmentally conscious, adaptable, and equipped to meet the evolving demands of the 21st-century workforce. Moreover, these models can facilitate the establishment of sustainable partnerships with other schools, universities, and community organizations, further strengthening the impact of mentorship in education.

Limitations & Recommendations for Future Research

While this study provides valuable insights, it has certain limitations that must be acknowledged. As a case study, its findings may not be universally generalizable, as the scalability of the Seed Bank project and the PBM framework depends on factors such as institutional support, resource availability, and stakeholder engagement. To enhance adaptability across diverse educational and cultural contexts, future research should examine PBM in a wider range of settings, exploring how project themes can be customized based on local environmental and social challenges to ensure greater relevance and engagement. Additionally, further studies could investigate the long-term impact of PBM on the career trajectories of both mentors and mentees, offering a deeper understanding of its influence on professional development. Another promising avenue for research involves examining the role of digital tools in enhancing mentorship experiences, particularly in facilitating communication, collaboration, and accessibility in remote or resource-limited environments. Although peer and reverse mentoring emerged organically in this study, future programs should integrate them more intentionally to foster inclusive, reciprocal learning. Structured peer mentoring can enhance collaboration and problem-solving, while reverse mentoring allows mentees to share fresh insights, promoting adaptability and innovation.

Another limitation concerns the sample size, as a relatively small participant pool may constrain the generalizability of the findings. Expanding the study across multiple institutions and diverse geographical locations would provide a more comprehensive assessment of PBM's effectiveness. Furthermore, while peer and reverse mentoring emerged organically in this study, future research should explore structured implementations of these approaches to assess their systematic impact on learning outcomes. By addressing these areas, future studies can contribute to refining PBM as a scalable, adaptable, and impactful educational model capable of shaping future-ready learners and professionals.

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