



Peer Collaboration and Generative AI Interaction: Assessing Student Agency in Project-Based Programming

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Abstract

Generative artificial intelligence (GenAI) and large language models are increasingly integrated into project development processes; however, limited empirical evidence explains how students preserve agency when working concurrently with peers and AI systems. This qualitative study examined how associate degree students positioned GenAI during a project-based programming course and how individual and collective agency emerged in this context. The study group consisted of 42 students enrolled in a Computer Programming Program at a vocational school in Türkiye in 2026. The students developed software projects in 14 collaborative groups over a 14-week Professional Project course. The data were collected through an open-ended questionnaire addressing students' experiences of AI use, decision-making, cognitive support, and collaboration. The data were analyzed through directed content analysis, informed by the concepts of human-AI co-agency, student agency, cognitive scaffolding, and collaborative learning. The findings indicated that students predominantly positioned GenAI as a teammate or mentor rather than as a merely technical tool. They associated AI support mainly with scaffolding, reflective dialogue, and cognitive load reduction. Although AI was used extensively, the students reported that final decisions were generally made through group discussion, critical questioning, verification, and independent judgment. Most participants preferred a hybrid collaboration model that combined AI support with peer interaction. These findings suggest that, when embedded in a pedagogically structured project-based learning environment, GenAI can support problem-solving / project-based programming / project-based learning and collaborative work without necessarily diminishing students' agency. The study offers implications for designing human-centered AI-supported learning environments that maintain learners' responsibility, critical engagement, and collective decision-making.

Keywords: *Generative AI; Project-Based Learning; Student Agency; Collective Agency; Programming Education; Human-AI Co-agency*

1. Introduction

The rapid development of Generative AI (GenAI) and Large Language Models (LLMs) has fundamentally transformed the nature of student-technology interaction in educational settings [1]. These systems are no longer used merely as passive repositories of information; rather, they increasingly function as conversational resources and adaptive control subsystems that actively intervene in the learning process. Shifting from a static tool-user relationship toward a dynamic cognitive partnership [2], [3], AI agents now support complex tasks such as ideation, code testing, debugging, and the refinement of project outputs.

This transformation is particularly relevant for Project-Based Learning (PBL), where students are expected to engage in authentic problems, negotiate ideas with peers, and construct solutions through iterative inquiry and production. When integrated into these environments, AI agents move beyond static utility. They serve as capable peers providing cognitive scaffolding [4], [5], act as teachable models [6], [7], and function as metacognitive regulators that promote socially shared regulation of learning [8], [9].

In AI-supported PBL environments, a central educational issue is not simply whether GenAI can produce technically accurate responses, but whether students remain active agents in the learning process. Student agencies refer to learners' capacity to take initiative, make informed decisions, evaluate information critically, and assume responsibility for learning outcomes. Previous studies suggest that AI can provide cognitive scaffolding, reduce procedural burdens, lower the fear of failure, and promote reflection in collaborative contexts [10], [4], [5]. However, this introduces a significant tension: over-reliance on AI



systems may weaken critical engagement, cause "production blocking" through over-mediation, and shift epistemic authority from learners to automated outputs [11], [2], [12]. Thus, the educational value of GenAI depends substantially on how learners position and regulate it within their learning activities.

This issue becomes more complex in collaborative PBL settings, where agency is distributed across individual learners, peers, tools, and shared routines. Depending on whether students perceive GenAI as a tool, a mentor, or a teammate, their patterns of collaboration, evaluation, and decision-making differ. This aligns with the "cognitive co-agent" model, which emphasizes human-AI co-agency; knowledge construction must emerge through interaction, interpretation, and selective integration rather than through passive acceptance of AI-generated content [13], [14]. Students are required to navigate "epistemic entanglement" [15], treating AI outputs as dialogic material to be interrogated [16]. However, working autonomously with AI risks eroding shared ownership and peer solidarity central to PBL, necessitating that teachers design pedagogical structures where AI enriches rather than replaces peer collaboration [17].

Despite the explanatory power of traditional constructivist frameworks, they struggle to account for systems that actively shape arguments in real time [18]. Furthermore, empirical evidence remains limited regarding how students negotiate this delicate balance of agency and collaboration in programming projects. Accordingly, this study investigated students' experiences of GenAI use in a project-based programming course. Employing a qualitative approach to analyze student interactions and responses, the study addressed three research questions: (a) How do students position GenAI during project development? (b) What forms of cognitive support do students attribute to GenAI? (c) How does student agency manifest during decision-making and collaboration with peers and AI?

2. Method

2.1 Research Design

This study employed qualitative research design. Directed content analysis was used because the analysis was guided by existing theoretical constructs related to human-AI co-agency, student agency, cognitive scaffolding, and collaborative learning [7]. This approach enabled the use of conceptually informed initial codes while allowing additional meanings to emerge from students' written responses.

2.2 Participants and Context

The participants were 42 associate degree students enrolled in the Computer Programming Program at Yüksek İhtisas University Vocational School in Türkiye in 2026. The study was conducted within a 14-week Professional Project course structured according to PBL principles. The students worked in 14 project groups and used GenAI tools during software development. Criterion sampling was used to include students who actively participated in group work, used GenAI during project development, and volunteered to share their reflections.

2.3 Data Collection and Analysis

Data were collected through an open-ended questionnaire developed by the researchers. The first section included demographic items related to gender, programming experience, prior PBL experience, and prior AI-use experience. The second section consisted of seven open-ended questions focusing on students' perceptions of AI, decision-making processes, collaboration experiences, and agency. The responses were transferred to MAXQDA 24 and coded under four thematic areas: role-oriented positioning, functional cognitive support, agency indicators, and collaboration preferences. Code definitions were reviewed collaboratively, disagreements were resolved through discussion, and interpretations were supported by participant statements. Direct participant quotations were included to enhance the reliability of the findings, and the participants were coded as P1, P2, P3... P42.

3. Findings

The findings are presented under five areas: participant characteristics, students' positioning of GenAI, cognitive support attributed to GenAI, agency indicators, and collaboration preferences.



Table 1. Demographic Characteristics of Participants

Variable	n	%
Female	11	26.2
Male	31	73.8
Programming experience: 0-6 months	8	19.0
Programming experience: 6-12 months	3	7.1
Programming experience: 1-2 years	26	61.9
Programming experience: 2 years or more	5	11.9
Previous PBL experience: Yes	17	40.5
Previous PBL experience: No	25	59.5
Previous AI-use experience: Yes	38	90.5
Previous AI-use experience: No	4	9.5

Table 2. Students' Positioning of Generative AI

Code	f
Teammate	24
Mentor	21
Tool	3

As shown in Table 2, students most frequently described artificial intelligence as a teammate (f=24) and a mentor (f=21); very few considered it merely a tool (f=3). This indicates that students view AI not as a passive technology, but as an active participant contributing to the project development process.

Participant statements further support this finding. P15 highlighted AI's contribution to in-group collaboration by stating, "We asked our question and reached a joint decision by exchanging ideas among ourselves." Similarly, P16 noted that AI's suggestions were not accepted outright but were instead evaluated and refined by group members, stating, "We add our own interpretations to the AI's suggestions."

Students also defined AI as a mentor that guides the learning process. P37 stated, "It helped us understand and overcome the obstacles we faced as we advanced our process," while P40 noted, "It guided us, and we reached a solution with my friends."

Overall, the findings demonstrate that students position generative AI not simply as a technical tool that provides information, but as a collaborative learning partner offering guidance throughout the project development process. Student responses indicated that AI-generated suggestions were typically discussed, interpreted, and revised within the group before being incorporated into project decisions.

Table 3. Cognitive Support Attributed to Generative AI

Code	f
Scaffolding	37
Reflective dialogue	20
Cognitive load reduction	15

As indicated in Table 3, the students most frequently associated artificial intelligence with the scaffolding function (f=37). Furthermore, the functions of AI in fostering reflective dialogue (f=20) and reducing cognitive load (f=15) were also frequently emphasized by the students. This indicates that artificial intelligence provides various forms of cognitive support during students' learning and problem-solving processes.

Participant statements reveal that artificial intelligence assumes a guiding role, particularly in problem-solving. P32 highlighted the mentoring function of AI, stating, "It both provided hints and showed the way, and enabled us to notice some of our mistakes." Similarly, P41 noted that AI supported their progress, expressing, "By helping me at points where I got stuck while developing my project on my own, it accelerated my transition to the next stage."

Regarding AI's function of supporting reflective thinking, P41 stated, "By noticing the logic or syntax errors in the code I wrote and alerting me, it took on an interrogative role that enabled me to solve the problems on my own." This view demonstrates that artificial intelligence not only offers solutions but also actively supports students' thinking processes.



The students viewed artificial intelligence not as a source of ready-made information, but as a supportive element that helped them develop their own ideas. P36 summarized this perspective by stating: "Artificial intelligence is not a source from which I consume ready-made information; rather, I blend the technical infrastructure it provides with my own logic and interpretation to prepare the solution step by step."

Overall, the findings demonstrate that generative artificial intelligence is evaluated by students not merely as an information-providing tool in their learning processes, but as a multidimensional cognitive support element that offers guidance, points out errors, encourages thinking, and facilitates the problem-solving process. Students emphasized that GenAI helped them identify errors, receive hints, and proceed to subsequent stages of design and development. Reflective dialogue was also evident, as the students reported using AI to reconsider their logic, syntax, and solution strategies rather than merely to obtain ready-made code.

Table 4. Student Agency Indicators in AI Interaction

Code	f
Group initiative	30
Group decision-making	29
Independent decision-making	22
Generating own ideas	19
Questioning	18
AI dependence	18
Verification	14
Alternative solution generation	11

As indicated in Table 4, students exhibited behaviors such as taking initiative, decision-making, questioning, verification, and independent thinking in their interactions with artificial intelligence. Group-level decision-making and initiative-taking were particularly prominent, demonstrating that students assumed active roles during the project development process. Additionally, independent decision-making, generating original ideas, and questioning artificial intelligence outputs emerged as notable findings. These results reveal that students did not completely surrender their cognitive responsibility to artificial intelligence.

Participant statements indicate that students utilized artificial intelligence not as a decision-making authority, but as a tool to support their thinking processes. P42 highlighted this approach, stating, "It made us more independent. Instead of taking ideas directly from artificial intelligence, we generated our own ideas and asked the AI for detailed feedback on the nature of our idea and how we could improve it." This perspective demonstrates that students sought to develop their own ideas rather than accepting ready-made solutions. It was also observed that students critically evaluated the information provided by artificial intelligence. P2 indicated that they cross-referenced AI outputs with different sources, stating, "I did not use the responses directly; I compared them with other artificial intelligence tools to synthesize a single set of data." Similarly, P21 emphasized that the final decisions rested with the students, expressing, "Even though we received help from artificial intelligence, we proceeded according to our own thoughts on certain issues. We questioned the provided answers and selected the most appropriate one."

The findings indicated that agency was most visible through group initiative and group decision-making. The students also reported independent decision-making, idea generation, questioning, verification, and the development of alternative solutions. Although AI dependence appeared in 18 coded instances, it did not dominate the overall pattern. The findings indicate a form of hybrid agency in which AI support was used actively, while final responsibility remained largely with students and groups.

Table 5. Collaboration Preferences

Code	f
AI and group members together	36
Only AI	5
Only group members	2

Table 5 demonstrates that the vast majority of students prefer a collaborative working model that incorporates both artificial intelligence and group members. In contrast, the number of students who prefer to work exclusively with artificial intelligence or solely with group members is lower. This finding demonstrates that students prefer to utilize both the technical support provided by artificial intelligence and group interaction during the project development process.



Participant statements reveal that working alongside both artificial intelligence and group members offers distinct advantages. P14 highlighted the contribution of this joint effort, stating, "Gathering information to evaluate it with my group mate, and accelerating the process by considering what we can add to that information and how much we can improve it."

Similarly, P26 indicated that artificial intelligence and group members complement each other, expressing, "Artificial intelligence alone is not highly efficient and may not yield the exact results we desire; however, alongside both artificial intelligence and my friends, we reached a more effective outcome." P37 expressed AI's contribution to faster and easier problem resolution, stating, "With the support of artificial intelligence for errors we could not understand, we solved the problem in a much shorter time than usual."

Overall, most students preferred a hybrid collaboration model that included both AI and group members. Students valued AI for rapid technical support and troubleshooting, while peers contributed interpretation, negotiation, contextual judgment, and shared responsibility. Thus, AI did not appear to replace peer interaction; rather, it was generally positioned as a complementary element within group work.

4. Discussion and Conclusion

The findings show that the students in a project-based programming environment tended to position GenAI as a teammate or mentor rather than as an inanimate software tool. This result is consistent with human-AI co-agency perspectives, which conceptualize knowledge construction as an interactive process involving human interpretation, dialogue, and selective integration of AI-generated outputs [13], [14]. In this study, AI suggestions were not simply accepted; they were brought into group discussions and evaluated collectively. The study also demonstrates the role of GenAI as a cognitive support mechanism. By providing scaffolding and reducing cognitive load, AI enabled the students to address technical difficulties and focus on higher-level problem-solving / problem-based learning processes [10], [4], [5]. This contribution is especially relevant in programming education, where minor syntax or logic errors may interrupt students' progress. However, the findings suggest that AI support functioned primarily as a facilitating mechanism rather than as a substitute for students' own reasoning.

A central contribution of the study is its finding that extensive AI use does not necessarily diminish student agency. The participants reported generating original ideas, questioning AI outputs, verifying information, and retaining control over final decisions [2], [15]. Nevertheless, the occurrence of AI dependence indicates that AI use requires deliberate pedagogical structuring. Learning tasks should require students to justify how they evaluated AI suggestions, why they accepted or rejected them, and how group members contributed to final project decisions.

The findings also address concerns that AI use may isolate learners or weaken peer collaboration. Students' strong preference for a hybrid model suggests that they recognized the distinct contributions of AI and peers. In the observed context, AI supported collective agency by contributing to technical efficiency and reflective problem solving, while peer interaction sustained negotiation, accountability, and shared ownership.

This study is limited to 42 students from a single vocational school and relies on self-reported written reflections. Therefore, the findings should be interpreted as context-specific rather than generalizable to all programming or PBL environments. Future studies should triangulate open-ended responses with AI interaction logs, classroom observations, and project performance indicators. In conclusion, GenAI can support project-based programming education when it is embedded in learning designs that protect students' critical judgment, collaborative responsibility, and agency.

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