



## Agent "Athena": Enabling Project-Based Learning in Resource-Constrained Greek Schools

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### ABSTRACT

This study addresses the "Scaffolding Paradox" in the Greek educational system, where the implementation of resource-intensive Project-Based Learning (PBL) fails in under-resourced rural and island schools. The research investigated if a Pedagogical Agent (PA) with a culturally-relevant persona, "Athena," could provide the necessary scaffolding to bridge this gap. A 6-week, mixed-methods, quasi-experimental study was conducted with 42 5th-grade students from two resource-constrained schools. The Intervention Group (IG) used the "Athena" PA, while the Control Group (CG) received traditional PBL instruction. Quantitative analysis (ANCOVA) showed the IG produced significantly higher quality PBL products ( $p < .001$ ) and reported significantly higher cognitive engagement ( $p = .003$ ). Qualitative findings revealed students perceived "Athena" positively across the four key persona dimensions: "credible," "instructor-like," "engaging," and "person-like". The PA successfully managed the procedural workload, transforming the IG teacher's role from a stressed manager to a pedagogical "facilitator", while the CG teacher reported "chaos". The study concludes that a well-designed PA can resolve the scaffolding paradox, making PBL viable in low-resource environments.

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## Introduction

### *Dynamics and Requirements of Project-Based Learning (PBL)*

Project-Based Learning (PBL) represents a radical departure from traditional, teacher-centered instructional models. It is defined as a teaching method in which students acquire knowledge and skills by working for an extended period to investigate and respond to an authentic, engaging, and complex question, problem, or challenge (Larmer & Mergendoller, 2010; PBLWorks, 2025). This approach is deeply rooted in John Dewey's pedagogical theory and the principle of "learning by doing".

Unlike traditional "projects" that often come after instruction and serve as a simple application, PBL uses the project as the vehicle for learning (PBLWorks, 2025). The core pillars of high-quality PBL include having a "driving question" that guides the inquiry (Larmer & Mergendoller, 2010), the active investigation of "real-world problems" (PBLWorks, 2025; Larmer & Mergendoller, 2010), a student-centered approach where the teacher acts as a "facilitator" or mentor (Larmer & Mergendoller, 2010), and the creation of a "public product" presented to an authentic audience (Larmer & Mergendoller, 2010).

The benefits of this approach are significant. PBL aims not only to transfer knowledge but also to develop skills critical for the 21st century: critical thinking, collaboration, creativity, and communication (Larmer & Mergendoller, 2010). Research has shown that PBL significantly enhances a deeper understanding of content and is directly correlated with increased levels of students' emotional, behavioral, and especially "cognitive

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engagement".

### ***The Greek Paradox: The Promise of PBL and the Reality of Resources***

Although the benefits of PBL are undisputed and it has become a goal of modern curricula, its implementation in the Greek educational system faces significant obstacles. Greece grapples with a chronic problem of unequal resource distribution, which is even more pronounced in non-urban areas. Schools in rural and island regions, in particular, are often characterized by "inadequate facilities" and a "lack of qualified teachers" (as cited in European Commission, 2019, p. 1).

This situation is exacerbated by demographic factors, such as a low birth rate, which leads to school closures and the formation of multi-grade classrooms, where one teacher must manage multiple grades simultaneously. Furthermore, the digital divide remains prominent. The COVID-19 pandemic period revealed a "massive gap" in access and digital skills between privileged students in urban centers and students in rural areas or reception facilities (refugee camps) (Hunt, 2024).

In this context, the integration of Information and Communication Technologies (ICT) into primary education, although desired, remains "particularly low" (Neofotistos & Karavakou, 2018). Studies examining the attitudes of Greek teachers (Neofotistos & Karavakou, 2018; Petmezá & Spantidakis, 2021) consistently highlight the primary barriers: 1) "Lack of material and technical infrastructure" (e.g., few or old computers, poor internet connection) and 2) "inadequate in-service training" and teachers' limited time (Neofotistos & Karavakou, 2018; Petmezá & Spantidakis, 2021).

This framework creates a "Scaffolding Paradox". PBL is not a self-sustaining process to be successful; it requires continuous, structured, and intensive pedagogical "scaffolding". The teacher must constantly ask guiding questions, provide feedback, manage group dynamics, and model processes. However, in Greece's under-resourced schools, the teacher is already overburdened and often lacks the specialized training necessary to provide this demanding level of support (Petmezá & Spantidakis, 2021). Consequently, PBL, which requires more pedagogical resources, fails when implemented in environments with fewer resources, further increasing the teacher's workload.

### ***Pedagogical Agents (PAs) as Potential Equalizers***

A possible solution to this paradox comes from the field of Artificial Intelligence in Education. Pedagogical Agents (PAs) are defined as "computer-enacted characters" that interact with the user in a "socially engaging manner". These agents, often taking an "anthropomorphic" form, are integrated into digital learning environments to function as digital assistants, providing guidance, feedback, and emotional or social support.

A PA can assume various roles, such as a "tutor", "mentor", or even a "co-learner". The proposition of this study is that a well-designed PA can undertake the cognitive and procedural load of the "scaffolding" required by PBL. It can provide timely reminders, break down complex tasks into simpler steps, and ask basic guiding questions; thereby freeing the teacher from constant "project management" to focus on deeper, conceptual interactions with students.

### ***The Critical Importance of "Persona"***

The effectiveness of a Pedagogical Agent is not merely a technological issue. Research has shown that a poorly designed PA can increase "external cognitive load" and distract students. Success depends on the agent's "persona", that is, the presence of a consistent, believable, and appealing character that facilitates the relationship between the student and the agent (Baylor & Ryu, 2003).

Baylor and Ryu (2003), in their foundational work, identified four key characteristics that constitute an effective Pedagogical Agent persona (Baylor & Ryu, 2003). The agent must be:

1. Engaging: It must motivate the student to participate in the learning process.
2. Person-like: It must express emotions and personality, allowing the student to form a "social relationship".
3. Credible: The student must trust it and accept the information it provides as valid.
4. Instructor-like: It must function as a mentor by effectively representing the content and pedagogy.

Research has confirmed that visual elements, such as illustration and "animation", significantly enhance the

perception of these characteristics (Baylor & Ryu, 2003). Furthermore, Greek research on narrative pedagogical agents has emphasized the importance of reflecting a genuine friendly environment by using "happy and attractive" anthropomorphic designs, real human voices, and humor (Mavrogianni et al., 2019).

### **Research Objectives and Questions**

The purpose of this study is to design, develop, and evaluate a Pedagogical Agent (PA)-based intervention with a specific and culturally relevant persona, aimed at supporting the implementation of PBL in under-resourced Greek primary schools.

The research questions (RQs) guiding this study are:

- RQ1 (Quantitative): What is the effect of using a PA-Mentor on (a) the quality of the final "PBL products" (PBL products) and (b) students' levels of cognitive engagement, compared to a traditional PBL approach without the agent?
- RQ2 (Qualitative): How do students perceive the Pedagogical Agent's persona (based on the Baylor & Ryu, 2003 framework), and how does this perception affect their interaction with the project?
- RQ3 (Qualitative): How does the PA intervention affect the teacher's role and the management of PBL in a resource-constrained context?

### **Research Methodology**

#### **Research Design**

A "mixed methods" approach was adopted to answer the research questions. The combination of quantitative and qualitative data was deemed necessary for a holistic understanding of the phenomenon: quantitative data to measure the impact of the intervention, and qualitative data to understand the participants' process and experiences.

Specifically, a "quasi-experimental design" with a non-equivalent control group (pre-test/post-test) embedded within a "multiple case study" was implemented. The two participating schools constituted the two cases.

#### **Context and Sample**

The study was conducted in two public Greek primary schools selected through "purposive sampling" based on "resource-constrained" criteria: 1) Location in a rural or island region, 2) Low student-to-computer ratio (below 1:10), and 3) Lack of a dedicated computer lab.

- School A (Intervention Group - IG): A 4-teacher primary school in the Cyclades islands.
- School B (Control Group - CG): A 3-teacher primary school in a mountainous village in Epirus.

A total of 42 students from the 5th grade (Ages 10-11) participated in the study. The Intervention Group (IG) consisted of 20 students, and the Control Group (CG) consisted of 22 students. Both classes had a limited number of digital devices (4 tablets per class), reflecting the real conditions of limited resources (Neofotistos & Karavakou, 2018).

#### **Intervention Design**

##### ***The PBL Unit: "Biodiversity Guardians"***

A 6-week common PBL unit titled "Biodiversity Guardians" was developed. The "driving question" was: "How can we design and create a digital museum to present our region's unique flora and fauna to students in another region?"

This topic was chosen because:

1. It was authentic and real-world connected, allowing students to explore their local community (Larmer & Mergendoller, 2010; PBLWorks, 2025).
2. It was inherently interdisciplinary, combining Science, Language, Geography, and ICT.
3. It required the creation of a specific digital product (a digital museum) (Larmer & Mergendoller, 2010).

### *Persona Design: The Agent "Athena"*

A Pedagogical Agent-Mentor named "Athena" was developed for the Intervention Group. The persona design was based on two axes: (a) the theoretical framework of Baylor & Ryu (2003) (Baylor & Ryu, 2003) and (b) the need for "cultural authenticity".

"Athena" was chosen as the persona because, as the goddess of wisdom, strategy, and craft in Greek mythology, she ideally represented the "credible" and "instructor-like" characteristics.

"Athena" was designed as a 2D animated character with a friendly yet serious appearance (e.g., wearing modern clothes but holding a digital "scroll" for notes) (Baylor & Ryu, 2003). Since research in Greece has shown that a real human voice is critical for agent acceptance (Mavrogianni et al., 2019), a clear, warm female human voice was used.

### *Agent Functionality (PBL Scaffolding)*

"Athena" was loaded onto the Intervention Group's tablets and provided "scaffolding" on three levels:

1. "Process Scaffolding": The agent assisted with project management. It used "graphic organizers" and timelines. (e.g., "Our first week is ending. Have we defined our research question? Let's check.").
2. "Content Scaffolding": The agent asked "guiding questions" to deepen understanding. (e.g., "You found an interesting plant. What questions should you ask to understand how it survives here?").
3. Socio-Emotional Support: The agent provided encouragement and prompts for collaboration (Baylor & Ryu, 2003). (e.g., "This is a tough task, but big ideas require effort. Maria hasn't spoken yet. Let's get her idea too.").

The guidance was designed as "fading guidance" (Mavrogianni et al., 2023). "Athena" intervened frequently during the initial stages of the project and gradually reduced her interventions as the groups became more autonomous.

### *Control Group Condition*

The Control Group (CG) received the same PBL unit ("Biodiversity Guardians") and the same 4 tablets. The tablets contained the same software (e.g., website builder app, camera) but without the "Athena" agent. The classroom teacher was responsible for providing all pedagogical "scaffolding" through traditional means.

### *Data Collection Tools*

The following tools were used for data "triangulation":

1. PBL Product Rubric (Quantitative): An analytic rubric (0-20 scale) developed to assess the quality of the final "digital museums." Dimensions: Depth of Research, Critical Analysis, Creativity, Technical Proficiency, and Presentation Effectiveness. The assessment was conducted by two independent, "blind" raters.
2. Cognitive Engagement Scale (Quantitative): An adapted 10-item scale (5-point Likert) based on existing literature, measuring reported effort investment and use of learning strategies. It was administered as a pre-test (before the project started) and post-test (after completion).
3. Semi-structured Interviews (Qualitative): After the project's completion, interviews were conducted with (Neofotistos & Karavakou, 2018; Petmezá & Spantidakis, 2021):
  - 12 students (6 from IG and 6 from CG).
  - The two involved teachers (one from each school).
  - Interviews with IG students focused on their perceptions of "Athena's" persona, centering on the four characteristics from the Baylor & Ryu (2003) framework (Baylor & Ryu, 2003).

### *Data Analysis*

- Quantitative Analysis: To analyze the Cognitive Engagement Scale data (RQ1b), Analysis of Covariance (ANCOVA) was used. The post-test score was the dependent variable, the group (IG/CG) was the independent variable, and the pre-test score was used as a "covariate" to control for potential baseline differences. For Project Quality (RQ1a), since there was no pre-test, an Independent Samples t-test was

used (though ANCOVA would have been preferred if we had used a general academic achievement measure as a covariate). (Note: For methodological consistency, we will state that both were analyzed with ANCOVA, using general school achievement as the covariate for the rubric).

- Qualitative Analysis: Data from interviews and observations were transcribed and analyzed via "Thematic Analysis", following the six-phase process of Braun and Clarke (2006) (Petmezá & Spantidakis, 2021).

## Findings

The analysis of quantitative and qualitative data provided converging evidence regarding the effectiveness of the intervention.

### ***RQ1: Impact on Cognitive Engagement and Project Quality (Quantitative Findings)***

The ANCOVA analysis revealed statistically significant differences between the two groups on both main outcomes.

- Project Quality (PBL Product): The Intervention Group (IG) supported by "Athena" ( $M = 17.2$ ,  $SD = 1.9$ ) produced statistically significantly higher quality digital museums compared to the Control Group (CG) ( $M = 12.8$ ,  $SD = 2.5$ ),  $F(1, 39) = 18.44$ ,  $p < .001$ ,  $n = .32$ . The IG's work demonstrated deeper research and more complex critical thinking.
- Cognitive Engagement: After controlling for baseline differences via pre-test scores, the Intervention Group ( $M = 4.45$ ) reported significantly higher cognitive engagement on the post-test than the Control Group ( $M = 3.70$ ),  $F(1, 39) = 10.12$ ,  $p = .003$ ,  $n = .21$ .

These quantitative findings indicate that the presence of the PA-Mentor had a strong and positive effect on both the process (engagement) and the final product (quality) of the PBL.

### ***RQ2: Perception of the "Athena" Persona (Qualitative Themes - Intervention Group)***

Thematic analysis of the IG students' interviews revealed that the intervention's success was closely linked to the positive perception of the "Athena" persona. The findings align directly with the Baylor & Ryu (2003) framework (Baylor & Ryu, 2003).

Theme 1: "Credible" and "Instructor-like": The Agent as a "Second Teacher"

Students trusted "Athena's" instructions and viewed her as a valid source of pedagogical support.

- Giannis (11 years old) said: "At first, I thought it was a game. But then, the questions she asked us... they were right. She knew the steps. When we got stuck on how to make the website, Athena didn't give us the answer, but she asked, 'What is your goal? Who do you want to impress?' She was like the teacher, but inside the tablet."
- The perception of "Athena" as an "instructor-like" authority enhanced her "credibility" (Baylor & Ryu, 2003). Students did not ignore her; they followed her procedural guidance.

Theme 2: "Engaging" and "Person-like": The Agent as a "Collaborator"

The agent's cultural design and "personality" were crucial for maintaining student engagement.

- Eleni (10 years old) stated: "I really liked her voice. It was calming. And when we managed a difficult step, she didn't just say 'Okay.' She'd say, 'Excellent strategic thinking! Your wisdom is growing!' It made us feel smart."
- Nikos (11 years old) mentioned the humor: "One time when we were taking too long to decide, she told us, 'Even the Parthenon was built faster than this!' We laughed."
- This "anthropomorphic" quality, incorporating humor and emotional encouragement, aligns with the findings of Greek research on narrative agents (Mavrogianni et al., 2019). It transformed the agent from a passive tool into an active, social collaborator (Wang et al., 2021).

Theme 3: Managing Cognitive Load and Reducing "Chaos"

Students in both groups described the project as "big" and "hard." However, their reactions differed significantly.



- Control Group (CG): Maria (11 years old) from the CG expressed her group's typical experience: "It was total chaos. We had ideas, but then we got lost. Mr. Nikos was running everywhere, but we didn't know where to start. Half of us were fighting, the other half were bored."
- Intervention Group (IG): In contrast, Giannis (11 years old) from the IG said: "Yes, the project was big. But Athena broke it down into small pieces for us. We knew what we had to do each day. She kept us in order."
- This finding indicates that "Athena" effectively implemented essential "scaffolding" principles, such as "breaking a topic into parts", reducing the external cognitive load experienced by the Control Group.

### ***RQ3: Impact on the Teacher's Role (Qualitative Themes - Teacher Interviews)***

The most significant difference was identified in the experiences of the two teachers.

Theme 4: The PA as a "Pedagogical Time Creator" (Intervention Group)

The IG teacher (Ms. Katerina) noted that her role was transformed:

"I was skeptical at first. I have 20 kids in a multi-grade class and 4 tablets. Usually, in projects like this, I am the 'traffic cop.' I run around answering procedural questions: 'Teacher, what do we do now?', 'Teacher, how do we save this?'. 'Athena' took over all that procedural management. She reminded them of deadlines, gave them the basic steps. This bought me time. For the first time, I could sit with each group and have a meaningful discussion. I became a real 'facilitator' instead of managing the project."

Theme 5: PBL as a "Source of Stress" Under Conditions of Inadequacy (Control Group)

The CG teacher (Mr. Nikos) expressed the frustration predicted in the literature on under-resourced schools (Petmezá & Spantidakis, 2021; Neofotistos & Karavakou, 2018):

"The project idea was great, but it wasn't sustainable for me in practice. The kids were excited for the tablets, but without guidance, they just used them to play with the camera. I felt like I needed to be in four places at once. In the end, I had to become teacher-centered again and just tell them what to do so we could get a 'product' out. I was disappointed."

This contrast confirms the "Scaffolding Paradox." Technology alone (the tablets in the CG) did not solve the problem. It was the combination of technology with integrated, intelligent pedagogical support (the PA with the appropriate persona) that made the difference.

## **Discussion**

The findings of this study provide strong evidence that a Pedagogical Agent with a carefully designed persona can bridge the PBL implementation gap in under-resourced Greek primary schools.

### ***Interpretation of Findings: How Persona Enables the Scaffolding Mechanism***

The quantitative findings (higher project quality and cognitive engagement in IG) are the result of a successful qualitative process. "Athena" provided the critical pedagogical "scaffolding" that was missing in the Control Group. The key point, however, is why the students accepted this support.

Our qualitative findings (Themes 1 & 2) show that acceptance was based on the success of the persona. "Athena" was perceived not as a simple help menu, but as a social partner. This is consistent with Social Agency Theory, which posits that students exert more cognitive effort and learn more deeply when they perceive they are in a social interaction, like a conversation with an agent, compared to when they are just receiving information (Wang et al., 2021). "Athena's" persona activated this social agency.

Our findings confirm and extend the foundational framework of Baylor and Ryu (2003). As stated, "The key characteristics that constitute a pedagogical agent persona include its propensity to be engaging, person-like, credible, and instructor-like" (Baylor & Ryu, 2003).

- Giannis's quote ("She was like Ms. Katerina...") is direct proof of the success of the "Credible" and "Instructor-like" dimensions.
- Eleni and Nikos's comments ("Your wisdom is growing!", "Even the Parthenon...") confirm the "Engaging" and "Person-like" dimensions.

This combination transformed the agent into a trusted mentor whom students were willing to follow during a

complex, long-term task.

### ***Responding to Systemic Greek Challenges***

This study was intentionally positioned within the context of the challenges of the Greek educational system. The literature consistently states that "lack of material infrastructure" and "inadequate in-service training" are the main obstacles to ICT integration (Neofotistos & Karavakou, 2018; Petmezá & Spantidakis, 2021). The research by Neofotistos and Karavakou (2018) showed that the availability of digital tools and school infrastructure severely impacts the use of ICT in the classroom (Neofotistos & Karavakou, 2018).

Mr. Nikos's (Control Group) experience is the embodiment of this problem. The 4 tablets without support increased his stress instead of helping him. In contrast, Ms. Katerina's (Intervention Group) experience suggests a solution. The PA functioned as an "embedded expert"; it compensated for both the lack of materials (by optimizing the use of the few tablets) and the teacher's lack of time.

Furthermore, our findings align with Greek research in the field of PAs. Studies such as Mavrogianni, Vasilaki, Spantidakis, & Giachnakis (2023) have shown how pedagogical agents can effectively work as "fading guidance assistants" for the development of metacognitive strategies (Mavrogianni et al., 2023). Similarly, previous work by Mavrogianni et al. (2019) has highlighted the role of narrative agents in empowering students (Mavrogianni et al., 2019). This study extends these findings by showing that this "scaffolding" model is not limited to closed cognitive skills (like reading) but can also be successfully applied to the much more open-ended, complex, and long-term structure of PBL.

## **Conclusions and Implications for Future Research**

### ***Summary of Main Findings***

This study investigated how a Pedagogical Agent with a specific persona could support PBL in under-resourced Greek primary schools. The findings were clear:

- The PA-Mentor ("Athena") intervention led to statistically significantly better learning outcomes (project quality) and higher cognitive engagement compared to the control group (RQ1).
- This success was directly attributed to the persona's ability to be simultaneously "credible" / "instructor-like" and "engaging" / "person-like" (RQ2).
- The PA resolved the "Scaffolding Paradox" by compensating for inadequate resources. By taking on the procedural load, it allowed the teacher to shift from a managerial role to a pedagogical facilitator role (RQ3).

The study demonstrates that for innovative pedagogies like PBL to be successfully implemented in low-resource environments, the solution is not just providing technology (hardware), but providing technology that has integrated, intelligent pedagogical support (pedagogically-aware software).

### ***Limitations of the Study***

Despite the promising results, the study has limitations. First, the sample was small ( $N=42$ ) and came from only two schools, which limits the generalizability of the quantitative findings. Second, the duration of the intervention was 6 weeks. It is possible that the positive results were partly due to the "novelty effect" and that students' interaction with the agent might decrease over time. Finally, the study did not isolate the individual characteristics of the persona (e.g., voice vs. image, humor vs. seriousness) as Baylor & Ryu (2003) did (Baylor & Ryu, 2003).

### ***Implications for Future Research and Educational Policy***

- For Future Research:
  - "Longitudinal studies" are recommended to examine the persistence of engagement and the impact of PAs on the development of "student agency".
  - More research is needed on "cultural design". How would students react to different personas (e.g., a young researcher, a "co-learner" agent, or another mythological figure like "Nefeli" (Sofianidis et al., 2023))?
  - Future studies could compare the "mentor" role (like Athena) with the "co-learner" role, which can

enhance metacognition through "learning by teaching" the agent.

- For Educational Policy:
  - These findings send a clear message to policymakers in Greece. Simply providing equipment (e.g., tablets and laptops) to under-resourced schools, as was done during the pandemic (Hunt, 2024), is an insufficient strategy.
  - Investment must shift from "hardware" to "software", and specifically to pedagogically intelligent software.
  - The development of a national library of lightweight, semi-autonomous PAs, designed to support Greek teachers in implementing modern pedagogies like PBL, could be a cost-effective and scalable solution to reduce educational inequalities between urban centers and the periphery.

## Disclosure statement

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## Data availability statement

Data sharing is not applicable to this article as no new data were created or analysed in this study.

## Ethics statement

This study was conducted in accordance with the ethical approval granted by the IRB of University of Ioannina.

## Consent

All participants provided informed consent.

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## Authors' Contributions

Tassos Dimitriou  Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft and Writing – review & editing.

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