

Research Competence and Academic Performance in Senior High School Learners Through an AI Supported Seamless Learning Approach Using Project ARDI

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Abstract

This study explored the adoption of a seamless learning approach through Project ARDI (Automated Research Data Interpreter) in research-based teaching in senior high schools. Based on technology-enhanced, project-based, and seamless learning theories, the study focuses on assessing learners' research skills, performance, and experience in a research-based educational context. A mixed-methods design with a convergent parallel approach was used with 30 senior high school students who took Practical Research 2. Survey, pretest and posttest scores, and academic records were used for quantitative data collection, whereas learner reflection and feedback provided the qualitative data. Techniques for data analysis include descriptive statistics, paired-sample t-test, correlation, and thematic analysis. Before the adoption of Project ARDI, learners had moderate research skills and were progressing toward mastery based on the assessment test and very satisfactory academic performance. After its adoption, higher levels of engagement, benefits, productivity, and attitudes toward research were noted. Differences were evident between the scores obtained on the pretest and posttest, as well as between the performances in the first and second quarter. Nonetheless, due to the action research design used, it would be safe to conclude from these findings the existence of associations rather than causes of the same. In terms of qualitative analysis, an improvement in research confidence, structured support, research involvement, collaboration, and a combination of formal and informal learning was reported. From the findings gathered, it can be concluded that participation in Project ARDI was associated with higher levels of perceived research engagement, research competence, and academic performance. Differences with large effect sizes were found between the pretest and posttest scores and between the performances in the first and second quarter.

Introduction

The fast-paced evolution of the digital era has transformed educational practices and opened up new possibilities for the acquisition and use of knowledge by learners in different settings. Artificial Intelligence (AI), mobile devices, and digital learning environments are some of the ways that allow learning to take place outside the traditional classroom environment, allowing learners to learn in different places and different social environments over periods of time. With the continuous adaptation of educational systems to technological advancements, there is now an increased interest in instruction that supports continuous learning.

Another methodological strategy that has been gaining significant academic attention is that of seamless learning. The concept of seamless learning involves bridging the learning processes from one environment to another through the use of technology. Seamless learning helps in making it possible for learners to transition from in-class learning to learning in an out-of-class setting while still maintaining the same process of knowledge creation and skill formation. According to Wong (2013), seamless learning refers to the learner-centered approach that enhances continuous learning through linking learning from one place to another and through different forms of technologies and social settings.

Milrad et al. (2013) argue that seamless learning extends beyond the classroom walls to enable the learners to engage in realistic activities.

Continuous integration of artificial intelligence in educational institutions has expanded chances of technology-based learning. Artificial intelligence can provide personal help, feedback, scaffolding, and decision making that will allow learners to tackle cognitively complex tasks. In research education, AI can facilitate various stages in the process of research, such as organizing information, analyzing data, interpreting findings, and communicating scholarly work. These skills are of special importance for senior high school students who are expected to obtain necessary research skills that will be required in higher education and in the future professional life. Despite all the opportunities presented by AI in research education, a number of students still experience difficulties with conducting research work, especially with data analysis, interpretation of the findings, research writing, and building research self-confidence.

Competence in research has emerged as an important educational goal in today's education systems because it helps students develop the necessary skills for conducting research, reasoning, problem-solving, and continuous learning. The skills associated with research competence include identifying research questions, collecting information, analyzing data, interpreting evidence, communicating findings, and reflecting on the process of inquiry. Past literature shows that project-based learning and inquiry-based teaching methods help cultivate such competences in students through authentic tasks that require investigation and application of knowledge. In their meta-analysis of 66 experimental and quasi-experimental studies, Zhang and Ma (2023) have reported that project-based learning had positive impacts on academic performance, higher order thinking skills, and affective learning compared to conventional instructional methods. From this finding, it can be said that learner-centered and inquiry-based instructional contexts might offer important avenues for developing research-related competencies (Zhang & Ma, 2023).

The current research is based on the TPACK (Technological Pedagogical Content Knowledge) Framework, which offers the theoretical basis for studying technology integration in teaching. As Mishra and Koehler state, technology integration depends on a dynamic interplay of technological knowledge, pedagogical knowledge, and content knowledge. Technology is not considered an isolated instructional technique; rather, it should be aligned with appropriate pedagogical methods and content to help students obtain meaningful educational experience. With regard to research-based instruction, technological knowledge is the application of AI-assisted tools such as Project ARDI; pedagogical knowledge implies using inquiry-based and project-based instructional approaches; and content knowledge refers to research concepts, methodologies, and data analysis techniques. The interaction of these dimensions allows analyzing technology-mediated learning environment from the perspective of learners' research competency and academic growth (Koehler et al.; Mishra & Koehler).

While a considerable number of studies have been conducted on AI-supported learning, project-based learning, educational technology integration, and seamless learning, there are still important gaps in

existing literature. Existing literature tends to investigate these variables independently and in relation to higher education settings, technology adoption, or artificial intelligence. There is relatively little empirical information available on how AI-assisted learning could be integrated into the seamless learning paradigm to facilitate research competence among senior high school students. There is also relatively little information on how technology-enabled integration of formal and informal learning contexts could influence students' research competence, academic productivity, attitude towards research, and academic achievement in research-based teaching. This knowledge gap becomes especially important in the case of the Philippine senior high school environment since fostering research competence becomes one of the goals of the curriculum.

The concept of seamless learning was defined in this research in terms of incorporating research teaching in the classroom setting with the use of research activities carried out outside class under the umbrella of Project ARDI. Learners are engaged in the process of planning for research, processing of data, interpreting data, and discussion within classroom settings as well as independently outside the classroom.

To address this gap, the present action research examined the implementation of Project ARDI (Automated Research Data Interpreter) within a seamless learning framework. Project ARDI represents an AI-powered tool for research assistance that is embedded in Microsoft Excel. It enables learners to perform tasks like data organization, calculation of descriptive statistics, creation of research tables, and interpretation of quantitative results via step-by-step instructions. With the use of technology enhanced learning, project-based learning approach, and seamless learning experience, the intervention aims at fostering continuous involvement of learners in research activities in both formal and informal learning settings.

In particular, this study looked into the research competence, academic performance, and experiences of senior high school learners who underwent a seamless learning process using the aid of Project ARDI. Using the combination of both quantitative and qualitative data, the study was able to look at the engagement of the learners, the benefits of which, productivity, attitudes towards research, the outcomes of their performance, and the experiences that they have encountered during the said process. The results are anticipated to help enrich the increasing body of literature regarding seamless learning, artificial intelligence, and research competence.

Literature Review

Seamless Learning in Technology-Enhanced Education

The growing prevalence of digital technologies has shifted learning from being a process that takes place within the confines of a classroom to one that is continuous and occurs in different contexts. In such a context, seamless learning has become a teaching methodology that integrates both formal and informal learning contexts in order for learners to relate their learning experiences in terms of context,

time, technologies, and social interaction. As defined by Wong (2013), seamless learning can be described as a technology-based form of continuous learning outside classroom boundaries that integrates learning activities and contexts in a purposeful manner. Milrad et al. (2013) pointed out that seamless learning creates continuity between school and real-life learning experiences.

Studies have shown that there is a possibility of seamless learning environments creating conditions for learner autonomy, engagement, self-regulated learning, and knowledge transfer. According to Looi and Wong (2013), seamless learning design can lead to situations whereby students will be able to blend their classroom learning with actual experiences which happen beyond classroom or formal educational settings. This process is bound to enhance their level of understanding while facilitating the application of knowledge gained. In today's world where learners need to be prepared for real-life situations, this becomes imperative.

Seamless learning can be especially significant in research education because research practices go beyond classroom teaching. It involves gathering information, analyzing data, working with other students, and reflecting on findings in different settings. This means that the application of seamless learning in research education could give opportunities to learners to undertake authentic investigation and develop their research skills.

Technological Pedagogical Content Knowledge (TPACK) Framework

The current study adopts the Technological Pedagogical Content Knowledge (TPACK) Framework, as this framework elaborates on the integration of technology within the process of teaching and learning. Mishra and Koehler (2006) argued that successful integration of technology would involve the convergence of three types of knowledge: technological knowledge, pedagogical knowledge, and content knowledge. Instead of focusing on technology as an additional part of the instruction process, TPACK focuses on the integration of technology with suitable pedagogical approaches and content.

Koehler et al. (2014) have pointed out that successful technological integration takes place when teachers have a clear idea of how technology can be used to meet certain learning goals and methodologies. In terms of research-based instruction, technological knowledge refers to using artificial intelligence-based technology, for example, Project ARDI, pedagogical knowledge refers to inquiry-based learning and project-based learning, while content knowledge refers to research methodology and scholarly communication. Interaction between the three knowledge fields provides an environment where active learning and research skills development is possible.

TPACK model is ideal for analyzing how Project ARDI supports research instructions with technology by blending research knowledge with learner-centered teaching approaches and AI-based technology support systems.

Project-Based Learning and Research Competence Development

Project-Based Learning (PBL) is an approach to instruction which is learner-centered and supports authentic inquiry, collaboration, critical thinking, and problem solving through working on meaningful projects. Unlike traditional instruction approaches where content delivery is emphasized, PBL invites learners to ask real world questions, develop solutions, and create outputs that showcase their learning.

Project-based learning (PBL) has been effectively proven in educational research as an approach to learning. According to Zhang & Ma (2023), a meta-analysis of 66 experimental/quasi-experimental studies demonstrated that PBL results in better academic performance, affects, and higher-order thinking skills of students as opposed to traditional methods of instruction. Additionally, according to the authors, PBL has proven to be highly efficient in fostering inquiry processes, critical thinking, and engagement of secondary school learners.

Project-based learning is highly appropriate for research education, where students are expected to explore real issues, gather and analyze data, present information, and reflect on their research process. Through active engagement in the research process, project-based learning can help develop research skills as well as increase confidence and motivation to conduct research.

Technology-Supported Inquiry Learning

The inquiry-based approach stresses the knowledge acquisition process through questioning, investigating, evaluating, and reflecting. In inquiry-based learning, learners do not merely acquire knowledge but are engaged in the processes of asking questions, collecting information, analyzing information, and constructing an explanation. Inquiry learning with the help of technology enhances these processes in that it enables learners to have access to information, collaborate, analyze data, and construct knowledge using technology. Studies have shown that technology-assisted inquiry-based learning can deepen understanding of concepts and enhance scientific reasoning and engagement among learners (Lazonder & Harmsen, 2016; Pedaste et al., 2015).

Educational technologies serve as cognitive scaffolds that help learners in the course of the inquiry. Educational technologies may be of help to learners in organizing information, representing information, assessing performance, and reporting results, hence alleviating cognitive overload associated with difficult investigations. As Lazonder & Harmsen (2016) state, guidance and scaffolding provided by educational technology within the inquiry environment play an important role in determining learners' inquiry performance and concept understanding. In turn, Pedaste et al. (2015) have highlighted that inquiry learning with the use of technology helps to pass through the stages of inquiry – orientation, conceptualization, investigation, conclusion, and discussion.

In research-based learning, AI technology provides additional possibilities in order to enrich the process of inquiry through the support in terms of data structuring, analyzing, and interpreting. Technology can help students deal with the technical side of research work while allowing them to concentrate on the

process of critical thinking and reasoning. Therefore, such technology-based inquiry environments can become an effective way of developing research skills.

Learner Engagement, Research Competence, and Academic Outcomes

Research competence is not only about the mastery of research skills but also involves other aspects such as the learners' confidence, research self-efficacy, critical thinking, problem-solving skills, attitudes toward inquiry and the capability of independent learning. With the current educational trends that emphasize evidence-based reasoning and lifelong learning, the development of research competence is seen as one of the essential educational goals, particularly for the senior high school students getting ready for further studies and career life. It has been found that research self-efficacy plays an important role in determining the success of learners in conducting research activities. Tiyyuri et al. (2018) stated that learners who had higher levels of research self-efficacy would perform better academically and be more engaged in the research process.

There has been a connection between technology-based learning environments and positive effects on engagement, motivation, self-efficacy, and knowledge transfer in learners. In a review study of blended learning environments, Howard et al. (2022) showed that self-efficacy, relevant learning experiences, and the chance for application in real-world situations are the major determinants of learner engagement. The results from their research reveal that technology-enhanced instructional environments provide an atmosphere that encourages engagement, effort, and positive learning outcomes. Likewise, Bond et al. (2020) indicated that educational technologies are able to encourage behavioral, cognitive, and affective aspects of learner engagement.

In addition to this, inquiry experiences which incorporate use of technology, collaboration, and reflection have been found to facilitate the development of research competency. These environments provide learners with the ability to develop their research competencies through application in meaningful situations while at the same time promoting positive attitudes towards inquiry and construction of knowledge. Learners who engage in technology-mediated research processes acquire both procedural skills and research self-efficacy, which could enhance their academic productivity and performance. Therefore, learning interventions that combine technology-mediated learning, inquiry, and authentic research experiences may offer meaningful ways to develop research competencies among senior high school learners.

Research Gap

While much research has explored seamless learning, project-based learning, technology-assisted inquiry learning, and educational technology integration, such areas have often been researched independently of one another. Previous research in these areas has generally focused on technology usage, learners' perceptions of artificial intelligence, and the impact of education in general, whereas few

studies have examined AI-assisted seamless learning in research-based education in senior high schools.

There is a lack of empirical information on the use of AI-enhanced instruction as an integrated seamless learning process that would contribute to developing research competence, academic productivity, research attitude, and academic performance of senior high school students. In the context of the Philippines' education system, the issue is relevant to this particular country since research competence is one of the key aspects of senior high school curriculum.

To address this gap, this study examines the integration of Project ARDI (Automated Research Data Interpreter) into a seamless learning context and its relationship with students' research ability, academic output, research attitudes, and academic achievement.

Theoretical Framework and Conceptual Framework

The present research is based on the Technological Pedagogical Content Knowledge (TPACK) framework, which provides insight into the role technology plays within the teaching-learning process through the intersection of technological knowledge, pedagogical knowledge, and content knowledge. According to Mishra and Koehler (2006), this framework suggests that technology integration does not depend on technology itself; rather, it depends on the alignment between technological tools and pedagogical practices and content knowledge. The framework recognizes the fact that meaningful learning takes place when teachers know how to interrelate technology, teaching methods, and the field of knowledge.

According to Koehler et al. (2014), TPACK entails more than mere technical skills, pointing out the capability of educators to choose and utilize technology in order to achieve particular learning goals. In terms of research-informed instruction, technological knowledge would be the use of AI technologies like Project ARDI; pedagogical knowledge would be the application of inquiry-based, project-based, and seamless learning; and content knowledge would be the knowledge of research-related concepts, methods, and statistics. Combining these areas of knowledge contributes to learning settings where there is inquiry and competence development.

This research would benefit from using the TPACK theory especially since Project ARDI was designed to be used as a tool for instructional assistance that uses AI. Unlike being only a technological tool, the project was used alongside pedagogical practices that incorporate inquiry, collaboration, and project-based teaching in relation to the content standards of Practical Research 2. Hence, the TPACK theory can be considered useful in explaining how the integration of technology, pedagogy, and research content may be associated with learner outcomes, research skills, productivity, and academic performance of the learners.

Seamless learning principles, alongside TPACK, will be followed in the study, since it emphasizes continuity of learning in formal and informal settings. Seamless learning suggests that learning

processes are not confined in classrooms only but may take place at various locations, through various devices and interactions (Wong, 2013; Milrad et al., 2013). Learners participating in Project ARDI have been able to engage in research processes inside and outside the classroom setting.

In summary, the concepts of TPACK and seamless learning form the theoretical framework of the study. Specifically, TPACK explains how technology, pedagogy, and content knowledge are integrated, whereas seamless learning is concerned with how these three integrate to ensure continuous learning both formally and informally. These two theories, therefore, help design and implement Project ARDI.

Conceptual Framework

According to the theoretical framework of this research, the combination of the TPCK through Project ARDI facilitates seamless learning which can be associated with the improved performance of learners. Based on the TPCK model, Project ARDI is a technology component that serves as the foundation of inquiry-based and project-based teaching in research education. The creation of seamless learning through linking classroom instructions and independent inquiry allows learners to perform research.

The integration of technology, pedagogy, and research content through Project ARDI is proposed to support seamless learning experiences that may be associated with research competence, academic productivity, academic performance, and positive attitudes toward research.

It should be noted that TPACK was not directly measured as a study variable. Rather, it served as the theoretical lens guiding the design and implementation of Project ARDI and the seamless learning approach employed in the study.

Research Questions

This study examined the implementation of Project ARDI within a seamless learning framework and explored its association with learners' research competence, academic performance, and research experiences.

Specifically, it sought to answer the following questions:

1. What is the level of senior high school learners' research competence before and after participation in the seamless learning approach through Project ARDI in terms of:
 - 1.1. engagement;
 - 1.2. perceived benefits;
 - 1.3. academic productivity; and
 - 1.4. attitudes towards research?

2. What is the level of learners' pretest and posttest performance in research-based instruction?
3. What is the level of learners' academic performance before and after participation in the seamless learning approach through Project ARDI?
4. Is there a significant difference between learners' pretest and posttest performance?
5. Is there a significant difference between learners' first quarter and second quarter academic performance?
6. Is there a statistically significant relationship between learners' posttest performance and second quarter academic performance following participation in Project ARDI?
7. How do senior high school learners describe their experiences and perceptions of research activities following participation in the seamless learning approach through Project ARDI?

Methodology

Participants

The subjects of this action research include thirty (30) Senior High School students from the General Academic Strand (GAS) who were taking up Practical Research 2 for the 2025-2026 school year at Sta. Catalina Integrated National High School. The said subjects were chosen because they were directly exposed to research-based learning and have been participating in Project ARDI as part of their research classes.

Purposive sampling was used to select participants based on specific criteria for the current study. The use of purposive sampling is suitable when the researcher is purposely choosing participants that have relevant characteristics concerning the aims of the research and can offer rich information regarding the phenomenon under study (Creswell & Poth, 2023; Patton, 2015). In this study, the inclusion criteria for participation were the following: (a) being registered in Practical Research 2 course at the time of implementation, (b) being part of the seamless learning intervention through Project ARDI, and (c) completing all the research tasks.

These individuals were also the major source of both quantitative and qualitative data. The quantitative data was obtained using research competence surveys, pre-test and post-test measures, as well as academic performance data. The qualitative data, on the other hand, was collected through learners' reflections and focus group discussion looking at their experience and engagement in Project ARDI in the seamless learning environment.

As the research was conducted through the method of classroom-based action research, participant selection was based on direct involvement in the intervention and not in statistical representativeness.

This implies that the results need to be understood in light of the particular educational setting in which the research was conducted.

Research Design

This research used a convergent parallel mixed methods design within a classroom-based action research context to examine the implementation of Project ARDI and its association with learner outcomes. Data were gathered simultaneously using quantitative and qualitative approaches and then analyzed individually before synthesis.

Quantitative data analysis involved the use of descriptive statistics, paired samples t-tests to analyze pre and post-test scores, and Pearson's correlation to determine relationships between academic achievement, post test scores, and self-perceived competence. Thematic analysis was applied to the qualitative data, which were coded and categorized based on the experiences of the learners.

Operationalization of Seamless Learning

Seamless learning in the present study has been defined in terms of the incorporation of classroom-based research lessons alongside learner-driven research tasks that were undertaken beyond the confines of the conventional classroom setting. This approach has been used with the objective of ensuring consistency in learning, whereby learners would be able to perform research tasks in class as well as out of class.

In a structured learning environment, the students participated in discussions, research sessions, collaborative work, and classroom-based research using the Project ARDI. Outside the classroom, the learners continued to conduct research activities either independently or collaboratively, concentrating on data analysis, data interpretation, research output production, and reflective learning, through the same instructional assistance system.

The role of Project ARDI was that of being the technological medium linking all these learning environments through providing structured guidance in carrying out research activities regardless of time and space. As such, learners were involved in continuous research learning without limiting learning to classroom settings alone. In line with the tenets of seamless learning, learning activities took place in various settings yet continuity in research learning knowledge and skill development was maintained.

Description of Project ARDI

Project ARDI (Automated Research Data Interpreter), which is an AI-supported educational instrument that was created using Microsoft Excel, is used to help students organize, analyze, and interpret quantitative research data. It is created with the aim of providing guidance to students during the process of data analysis and helping those who have challenges in performing statistical analyses and interpreting research results.

Project ARDI combines automatic computation features, template features, processing features, and interpretation prompts in order to assist learners in generating descriptive statistical information and organizing the research findings. The project simplifies procedures by automating certain computations while at the same time providing interpretations that help learners understand the research and statistical concepts.

Project ARDI can be described as a tool for scaffolding that is based on the principles of inquiry- and project-based learning methods. Instead of replacing students' engagement in research, this tool helps the learner navigate through the research process and encourages active involvement in data analysis, reflection, and decision-making. Project ARDI aims at increasing learners' confidence, competence in research, and engagement in the research process.

Instruments

Data collection was done using the Research Competence Questionnaire, which was developed by the researcher, Pretest-Posttest Achievement Test, Research Output Assessment Rubrics, Classroom Observation Checklist, and FGD Guide. These data collection tools have been used to collect both qualitative and quantitative data related to research competencies, academic productivity, attitudes towards research, participation, academic performance, and Project ARDI experience of learners.

The Research Competence Questionnaire consisted of questions based on the Likert scale that measured four aspects of research competence, namely: learner engagement; perceived benefits of research; academic productivity; and attitudes towards research. These items have been created based on the objectives of the study and relevant literature on learner engagement and research competence.

Content validity was established by having the instruments examined by a panel of three experts, including an educational researcher, an English teacher, and a statistician. Content validity was tested for relevance, clarity in language used, appropriateness of item construction, consistency with the research purpose, and congruence with the competencies required by Practical Research 2. It is well known that expert review is an important step in establishing content validity of the research instrument (Polit & Beck, 2006; Zamanzadeh et al., 2015).

Pilot testing was done prior to the actual data collection process in July 2025 on fifteen (15) senior high school students who were not part of the actual sample participants. The objective of this pilot testing was to determine whether the instruments for the study are clear, understandable, feasible, and how the instruments will be administered.

Pretest-Posttest Achievement Test was developed based on the learning competencies provided by the Practical Research 2 syllabus. It tested the learners' understanding of research concepts focusing mainly on data analysis and interpretation of results among other aspects of research process. In order to make sure that there is consistency between the desired learning objectives and test, Table of Specifications was developed.

The research outputs developed by the learners as part of the implementation process were analyzed using Research Output Assessment Rubrics based on project-based learning. The assessment criteria for these research outputs included accuracy, completeness, organization, interpretation of data, and overall quality of the research output. On the other hand, classroom participation was measured with a checklist of indicators, while the perceptions about Project ARDI were analyzed using a focus group discussion guide.

Reliability of Research Competence Questionnaire was tested using Cronbach's alpha technique, which yielded a reliability coefficient of $\alpha = .86$. According to Taber (2018), any Cronbach's alpha value above .80 indicates acceptable internal consistency reliability, meaning that the items measure constructs that are similar to each other in education research settings.

Even though expert review and reliability tests have validated the appropriateness of the research instruments for the current study, further psychometric measures like I-CVI, S-CVI, EFA, CFA, and item discrimination test were not conducted owing to the sample size of the study. This being an action research project in a classroom setting, it was necessary to keep it within manageable limits of time and resources. Therefore, conclusions drawn from the tests have to be considered in context, and future researchers can further validate through psychometric tests.

Limitations

Because this study employed a one-group pretest-posttest action research design without a control group, the observed improvements cannot be attributed exclusively to Project ARDI. Other educational, contextual, or learner-related factors may have contributed to the outcomes. Consequently, findings should be interpreted as indicative of associations observed during the implementation period rather than definitive evidence of causality.

The qualitative component relied on thematic analysis conducted by a single researcher. Although several trustworthiness procedures were employed, including audit trail maintenance and the use of participant quotations, formal intercoder agreement was not established. Future studies may benefit from involving multiple coders to further strengthen analytical credibility.

Data Collection

The data was collected between July and December of 2025 when implementing the ARDI Project in Practical Research 2 courses. The mixed methods design for this research was convergent parallel and therefore both quantitative and qualitative data were collected at the same time to get an all-inclusive view of the learners' experience.

Prior to the study, approvals were sought from the school principal, and the participants were briefed on the purpose of the study, its methods and the ethical issues involved. The participants provided their consent to participate in the study while their parents/guardians signed consent on their behalf.

For the quantitative analysis, a pretest was also performed at the first quarter as a means of obtaining learners' baseline levels of knowledge and understanding of research. The Research Competence Questionnaire was similarly administered before Project ARDI was introduced to obtain learners' baseline levels of engagement, perceptions of gains, academic productivity, and attitude towards research. Post-tests for the two instruments were also performed after the implementation phase during the second quarter.

Information on academic performance was collected using the students' official grades for the Practical Research 2 during the first and second grading periods. Information on academic performance was analyzed to determine whether there was any change in performance during the period of implementation. Information on research output was also gathered based on the research rubrics.

In the qualitative part, learner reflections and Focus Group Discussions (FGDs) were carried out after implementing Project ARDI. The focus group discussion involved five participants purposively selected from the intervention group based on their availability and willingness to share detailed experiences regarding Project ARDI. Semi-structured questions were used to assess the learners' perceptions of the effectiveness of Project ARDI in helping conduct research, how the project contributed to their participation and attitude towards research.

In addition to that, classroom observations were carried out in order to record learners' participation, collaboration, engagement, and interactions during research-related tasks. Notes taken from the observations were used as additional data for interpreting the results gathered both quantitatively and qualitatively.

The research used a multi-method approach involving pre-test post-test, academic performance, reflection on learning, classroom observations and focus group discussions to produce corroborative evidence. This helped in achieving a more thorough analysis of the implementation of Project ARDI in the Seamless Learning Environment.

Data Analysis

A mixed method approach was adopted for the analysis of the implementation of Project ARDI in the context of seamless learning. The use of both quantitative and qualitative data enabled an all-inclusive view of the research abilities, academic achievements, involvement, output, attitude towards research, and experience of the learners with the program.

Quantitative Data Analysis

Statistical analysis of the quantitative data gathered from the Research Competence Questionnaire, the Pretest-Posttest Achievement Test, and learners' grades was done using both descriptive and inferential statistics. Descriptive statistics, which included frequency, percentage, weighted mean, standard deviation, and rank order, were used to describe the research competence of the learners.

In order to determine if there were significant differences in the scores in pretest and posttest as well as between the first and the second quarter performances, paired-samples t-tests were conducted. A paired-samples t-test can be used to determine the difference between two measurements taken from the same participants (Field, 2018).

In order to obtain a complete understanding of the statistical analysis results, effect sizes were used along with the significance tests. In particular, Cohen's d was used as a measure of observed effect sizes, and η^2 was used to measure the amount of variation that can be attributed to the observed changes. Also, 95% CIs were provided as an indication of how precisely the observed differences between means can be measured. It is suggested that both effect sizes and significance tests should be reported in educational research in order to interpret results meaningfully (Lakens, 2013).

Correlation analysis was performed using Pearson's product moment correlation coefficient (r) in order to evaluate the relationship between research competence variables and academic performance. The degree of relationship has been determined according to traditional interpretation of correlations (Field, 2018).

Qualitative Data Analysis

Thematic analysis was conducted using the six-step process explained by Braun and Clarke (2006) for analyzing qualitative data obtained from learner reflections and Focus Group Discussions (FGDs). The technique of thematic analysis was selected based on its rigorous yet flexible nature of analyzing qualitative data.

The analysis followed the following stages:

1. Familiarization with data. Reflection journals and focus group discussion transcripts were carefully examined for gaining familiarity with data and identifying initial patterns.
2. Initial coding of data. Important statements related to learners' experience, perception, and engagement in Project ARDI were recognized and coded initially.
3. Development of categories. Codes that had similar meanings were put together in conceptual categories.
4. Development of themes. Categories were synthesized together into themes that reflect common patterns of participants' experiences.
5. Review of themes. Themes were reviewed against the original data for ensuring coherence, consistency, and representativeness of learners' experiences.
6. Definition and reporting of themes. Final themes were defined, named, and supported by participants' quotations representing meaning of each theme.

Trustworthiness of Qualitative Findings

Strategies were implemented in order to increase the validity of the qualitative analysis. First, following Lincoln & Guba (1985), the credibility of the analysis was increased by including direct quotes from participants as supporting information on each theme. The dependability of the analysis was ensured by keeping an audit trail, which included all the decisions made during the coding process, category development, and analysis in general. The confirmability of the analysis was increased by constantly checking the themes against the data sources in order to make sure that what the participants said is reflected in the results.

Researcher Reflexivity

Since the study was conducted in the same classroom in which the researcher worked, there was always reflexivity in the entire research process. Reflexivity helped the researcher constantly think about possible biases and assumptions and try to reduce subjectivity in interpretations through grounding them in participants’ responses and evidence. It meant that decisions made during analysis were based on the data collected rather than any expectations related to the results of Project ARDI.

Intercoder Agreement

The coding process was done by one researcher owing to the nature of classroom action research and the limitations of the research resources. Therefore, there was no calculation of any intercoder agreement statistics. This limitation is recognized and needs to be taken into consideration when analyzing the qualitative results. Further research can improve the rigors of analysis by including multiple coders and intercoder reliability.

Findings

This section presents the quantitative and qualitative findings related to learners' research competence, academic performance, and research experiences during the implementation of Project ARDI within a seamless learning environment. Quantitative data will be supported by qualitative observations to provide a thorough analysis of the observed improvements.

Table 1 *Research Competence and Learner Engagement*

<i>Indicators</i>	<i>Before</i>			<i>After</i>		
	<i>M</i>	<i>SD</i>	<i>VI</i>	<i>M</i>	<i>SD</i>	<i>VI</i>
Engagement Levels	2.93	0.77	SWC	4.34	0.56	HC
Perceived Benefits	2.95	0.77	SWC	4.43	0.59	HC
Academic Productivity	2.70	0.84	SWC	4.19	0.65	C
Attitudes Towards Research	3.19	0.87	SWC	4.51	0.53	HC

Legend: 1.00-1.80 (NC-Not Competent); 1.81-2.60 (SC-Slightly Competent); 2.61-3.40 (SWC-Somewhat Competent) 3.41-4.20 (C-Competent); 4.21-5.00 (HC-Highly Competent)

As shown in Table 1, learners demonstrated higher post-implementation scores across all dimensions of research competence. Engagement increased from $M = 2.93$ ($SD = 0.77$) to $M = 4.34$ ($SD = 0.56$). Perceived benefits increased from $M = 2.95$ ($SD = 0.77$) to $M = 4.43$ ($SD = 0.59$). Academic productivity increased from $M = 2.70$ ($SD = 0.84$) to $M = 4.19$ ($SD = 0.65$), while attitudes toward research increased from $M = 3.19$ ($SD = 0.87$) to $M = 4.51$ ($SD = 0.53$).

Table 2 *Achievement Test Performance and Academic Outcomes*

Measure	M_{Q1}	M_{Q2}	Mean Difference	$t(29)$	p	Cohen's d	η^2	95% CI
Achievement Test Score	26.80	39.63	12.83	16.62	<.001	3.03	.91	[11.5, 14.41]
Academic Performance	86.17	90.23	4.06	15.63	<.001	2.85	.89	[3.53, 4.59]

Note. M = mean; CI = confidence interval; η^2 = eta-squared. Cohen's d represents the magnitude of the observed difference between pretest and posttest scores.

Achievement test performance increased from a mean score of 26.80 to 39.63. Academic performance increased from a first-quarter mean of 86.17 to a second-quarter mean of 90.23. Large effect sizes were observed for both outcomes.

Table 3 *Significant Relationship Between the Academic Performance and the Posttest Performance of the Senior High School Learners After the Implementation of Seamless Learning Approach Through Project ARDI in Research-Based Instruction*

		<i>r-value</i>	<i>p-value</i>	<i>Degree of Significance</i>	<i>Analysis</i>	<i>Decision</i>
2 nd Quarter's Academic Performance	Posttest Performance	-0.023	0.451	Not Significant	Very Weak Negative Correlation	Null Hypothesis is Accepted

$p < 0.05$

Pearson correlation analysis indicated a very weak negative correlation between second-quarter academic performance and posttest achievement scores ($r = -.023$, $p = .451$). The relationship was not statistically significant.

Coding Framework for Theme Development

Analysis of learner reflections and focus group discussions revealed several recurring themes describing participants' experiences with Project ARDI and the seamless learning approach. The themes suggest perceived improvements in research understanding, confidence, engagement, collaboration, and learning continuity across formal and informal environments. Together, these themes provide qualitative insights that complement the quantitative findings and help explain learners' experiences during implementation.

Learners' Experiences with Project ARDI

The qualitative themes suggest that learners viewed Project ARDI as a supportive instructional resource. Participants described improved research understanding, structured guidance, ease of use, increased confidence, and stronger engagement with research activities. The themes also highlighted continuity between classroom-based and independent learning, reflecting core principles of seamless learning.

These findings support previous research indicating that technology-supported inquiry environments can help learners navigate complex tasks through structured guidance and scaffolding while maintaining opportunities for active inquiry and problem-solving (Pedaste et al., 2015; Lazonder & Harmsen, 2016).

Table 4 *Development of Themes from Learner Reflections and Focus Group Discussions Transformation in Research Competence*

Initial Codes	Categories	Emergent Themes
Better understanding of research concepts; improved interpretation of research findings; increased ability to analyze data	Research understanding and skill acquisition	Transformation in Research Competence
Step-by-step research guidance; structured support; easier completion of tasks	Guided learning and instructional support	Empowerment Through Structured Guidance
Easy to use; user-friendly interface; accessible support for research tasks	Usability and accessibility	User-Friendly Research Experience
Increased confidence; motivation to conduct research; reduced anxiety toward research activities	Research confidence and self-efficacy	Enhanced Research Confidence and Engagement
Collaboration with peers; sharing of ideas; support from classmates	Collaborative learning experiences	Strengthened Collaborative Learning
Use of technology beyond classroom hours; learning at home; continued engagement with research activities	Formal and informal learning integration	Seamless Learning Across Contexts

The qualitative findings were derived from learner reflections and focus group discussions conducted following the implementation of Project ARDI. Analysis followed the thematic analysis procedures proposed by Braun and Clarke (2006). Initial coding resulted in several recurring ideas related to learners' experiences during the intervention. Similar codes were subsequently grouped into categories and synthesized into broader themes representing shared patterns across participant responses.

Table 4 presents the themes and representative codes that emerged from the analysis. The themes reflect learners' perceptions of Project ARDI as a tool that supported research understanding, structured guidance, usability, confidence development, and engagement with research activities. These themes were selected because they appeared consistently across multiple participant responses and directly addressed the study's qualitative research question regarding learners' experiences and perspectives following participation in the seamless learning approach.

Theme 1: Transformation in Research Competence

The learners described the ARDI project as an aid which helped them improve their understanding of research concepts and increased their confidence in carrying out research processes. Many of the participants observed that some concepts which were difficult to understand were made easier through this tool, and that it also made analyzing data simpler. These findings indicate that the use of structured technological aids can be used to develop research competence among learners by simplifying the process and facilitating understanding of concepts. This is in agreement with previous studies indicating that inquiry-based learning using technology aids along with proper scaffolding increases learners' inquiry abilities, conceptual understanding, and confidence in doing research tasks (Lazonder & Harmsen, 2016; Pedaste et al., 2015).

P1: "I now understand the procedures better."

P5: "It helped me understand research concepts which were difficult before."

P2: "I was taught how to analyze data."

P4: "I am now able to interpret the findings more confidently."

Theme 2: Empowerment Through Structured Guidance

The learners appreciated the usefulness of the scaffolded guidance provided by Project ARDI. The learners claimed that the tool helped them in managing their research data, following a systematic approach, and understanding the significance of research results. This suggests that the structured guidance helped the learners to navigate through complicated research processes. There is evidence from previous studies suggesting that guided inquiry-based learning environments promote learning by providing appropriate support while still leaving space for critical thinking (Lazonder & Harmsen, 2016).

The instrument gave a lot of help, especially in organizing data in the form of tables and in interpreting the findings. (Participant 1)

Project ARDI made it possible to move from data collection to analysis stage. (Participant 3)

It helped in making sense out of data rather than just putting some numbers in the form of a table. (Participant 2)

There was no confusion because the data analysis procedure was quite clear. (Participant 4)

Theme 3: User-Friendly Research Experience

The participants found Project ARDI easy to use, friendly for beginners, and user-friendly. Participants stated that the software helped alleviate the stress usually associated with research assignments and helped them focus on understanding the process of conducting research. The usability of educational technology is an important factor influencing learner engagement and participation, particularly when learning new skills (Howard et al., 2022).

According to participant feedback, Project ARDI was user friendly and did not cause confusion among novices (Participant 1). It is perceived to be user friendly and fit for senior high school students (Participant 5). The structure of the research allowed for a step-by-step process for researching the parts of the project (Participant 2). The instructions were clear (Participant 3). Generally, the interface helped reduce stress when researching (Participant 4).

Theme 4: Enhanced Research Confidence and Engagement

The participants felt more confident, motivated, and autonomous while conducting research tasks. It was seen that the participants were more willing to do research tasks and had more willingness to

discuss research findings. This suggests that technology-enabled research experiences may help in fostering research self-efficacy. As per previous literature, students with higher research self-efficacy are more likely to be engaged in their academic work and persist in their research work (Tiyuri et al., 2018).

"I gained confidence in carrying out my own research." (Participant 1)

"I felt motivated to carry out my research due to better understanding of the processes." (Participant 2)

"This helped me overcome any fears and made data analysis easy." (Participant 3)

"I found myself becoming more involved in research tasks due to the improved clarity of the process." (Participant 4)

"Now I feel more confident in explaining our research results." (Participant 5)

Theme 5: Perceived Value of Project ARDI in Supporting Research Skills

The learners viewed the intervention as a valuable learning experience that helped them to understand the process of research and complete research-based tasks. Also, they made some recommendations, which showed that they were thinking about their own learning experience. This result is consistent with the previous literature (Bond et al., 2020; Howard et al., 2022).

The project proves its efficiency in improving research skills. (Participant 1)

The project was very helpful in solving issues with data analysis that usually pose difficulties. (Participant 4)

The program is useful but may become more useful if supplemented with more examples. (Participant 2)

The usage of the Project ARDI in research studies seems to be justified. (Participant 3)

The program looks appropriate for beginners working with research topics. (Participant 5)

This quotation reflects the learner's perception and should not be interpreted as evidence of intervention effectiveness.

The five themes together suggest that the learners viewed the project as a tool that provided support in terms of research knowledge, guided approach, user-friendliness, increased confidence, and increased engagement in research tasks. If analyzed from the perspective of the TPACK and Seamless Learning models, the results suggest that the incorporation of technology along with research pedagogy can create a conducive environment for participation and engagement in research tasks. However, in consideration of the use of an action research approach to the study, the above results should be treated as perceptions of learners.

Discussion

Research Competence and Learner Engagement

These results reveal an increased level of perception of research competence following the engagement of the participants in Project ARDI, with improvements in learner engagement, perceived usefulness, academic productivity, and attitudes towards research. In essence, this means that the participants felt more competent and more involved in the research process during the implementation period.

The qualitative findings provide further support for this interpretation, as participants indicated increased understanding of research concepts, increased self-confidence, and increased likelihood to participate in research activities. These findings support previous research that indicates positive relationships between technology-enabled learning, engagement of the learner, and research skills (Bond et al., 2020; Howard et al., 2022).

From the perspective of the TPACK model, the trends observed may be due to the interaction between technological knowledge through Project ARDI, pedagogical knowledge using inquiry-based and project-based learning, and the knowledge related to research content. Moreover, the trends observed conform to seamless learning, showing continuity in classroom learning and independent research.

Achievement Test Performance and Academic Outcomes

Differences were statistically significant in regard to achievement test results and academic performances, which implies that the subjects displayed better performance in the intervention phase.

Nevertheless, due to the significant effect sizes, caution should be exercised in interpreting these results. Considering the design of the experiment, the changes in scores can be attributed to a combination of factors such as instructional, contextual, motivational, and developmental (Lakens, 2013; Shek & Zhu, 2018).

The results of the qualitative analysis can help to explain the observed findings. It was found that participants felt more aware of how the research process is conducted, improved their data analysis skills, and felt more confident doing research activities.

Also, the academic grades should be viewed as contextual indicators of the learners' performance. Considering that the academic performance is affected by several educational aspects, the differences in the grades cannot be attributed only to Project ARDI.

Learners' Experiences with Project ARDI

Qualitative results indicate that participants viewed Project ARDI as a source of help in the process of research learning. Participants mentioned the aspects such as structure, user-friendliness, confidence building, teamwork, and continuity of learning.

These results corroborate previous studies showing that technology-based inquiry learning environments support learning through scaffolding and simplification of the process (Lazonder & Harmsen, 2016; Pedaste et al., 2015). Participants frequently mentioned that Project ARDI helped them to structure information and understand the research process better.

It is important to state that the theme of Seamless Learning Across Contexts is significant as it emphasizes the ability of learners to conduct research activities outside the formal classroom environment. The above fact is evidence to the theory of seamless learning.

Integration of Quantitative and Qualitative Findings

Combining the findings from both quantitative and qualitative analyses provides a better insight into the experiences of learners using Project ARDI in a seamless learning environment. Quantitatively, learners demonstrated better levels of perception about research skills, engagement, productivity, attitudes towards research, scores on achievement tests, and academic performance during the implementation period. Qualitatively, learners demonstrated experiences characterized by better comprehension about research skills, guidance, confidence, collaboration, and continuity of learning.

The qualitative themes reveal the patterns that have been established from the quantitative findings. For example, the higher engagement, perceived advantages, and positive attitudes towards research that have been found in the survey results have been proven through the learners' perceptions of increased motivation, greater self-confidence, and easier participation in research tasks. Similarly, the variations seen in the achievement scores and performance levels are supported by the perceptions of improved understanding of the research concepts, better research processes, and greater confidence in analyzing and interpreting the data.

The theme of Empowerment Through Structured Guidance provides additional background on the findings relating to productivity and research competence from a quantitative perspective. The participants invariably noted that the structured guidance provided by the Project ARDI assisted in organizing the data, understanding the process of research, and completing research activities more efficiently. Likewise, the themes of Transformation in Research Competence and Enhanced Research Confidence and Engagement provide an explanation as to why the participants felt more competent and positive about the process of research.

It is worth noting that the theme of Seamless Learning Across Contexts is fundamental to the conceptual base of the study. The participants found that the Project ARDI allowed them to continuously engage in research activities outside of class. This result confirms the theory of seamless learning, which states that learning should be continuous regardless of context and instruction mode.

In general, the synthesis of the findings shows that the quantitative changes that happened during the period of implementation were accompanied by positive learner experiences regarding guidance, self-efficacy, engagement, collaboration, and learning continuity. Despite the inability of the one-group

pretest-posttest action research design to infer causality, the integration of the quantitative and qualitative data allows us to gain a more complete picture of the experiences of the learners under the Project ARDI.

The convergence of quantitative and qualitative evidence strengthens confidence in the overall interpretation of the findings. Improvements observed in research competence, engagement, attitudes toward research, and achievement measures were supported by learners' descriptions of enhanced confidence, structured guidance, improved research understanding, and continuity of learning across contexts. Although causal conclusions cannot be drawn, the consistency between quantitative and qualitative findings provides a more comprehensive understanding of how learners experienced Project ARDI within a seamless learning environment.

Implications

The findings of this study suggest that participation in a seamless learning approach supported by Project ARDI was associated with higher levels of perceived research competence, learner engagement, academic productivity, and positive attitudes toward research among participating senior high school learners. Although causal conclusions cannot be drawn from the present action research design, the observed improvements indicate the potential value of integrating AI-assisted instructional tools within research-based instruction. These findings suggest that technology-supported, collaborative, and project-based learning environments may provide meaningful opportunities for learners to engage more actively in research-related tasks and inquiry processes.

From a practical perspective, the findings highlight the potential of Project ARDI as a supplementary instructional support tool for teachers implementing research-based instruction. By providing structured guidance for data organization, analysis, and interpretation, the tool may help learners navigate complex research tasks while encouraging engagement both within and beyond the classroom. Such support may be particularly valuable in contexts where learners experience difficulties in conducting research independently.

The study also provides implications for curriculum developers and school leaders seeking to strengthen research education through meaningful technology integration. The findings support the idea that connecting formal classroom instruction with authentic learning experiences outside the classroom may create opportunities for more continuous and learner-centered research engagement. Consequently, seamless learning strategies supported by appropriate technological tools may be considered when designing learning experiences intended to foster inquiry, collaboration, and research competence.

From a theoretical perspective, the findings provide support for the relevance of the Technological Pedagogical Content Knowledge (TPACK) framework and seamless learning principles within research-based instruction. The study illustrates how the integration of technology, pedagogy, and research can create learning experiences that support learner participation and engagement across multiple learning contexts. While further research is needed to establish causal relationships, the findings contribute to

the growing body of literature exploring the role of AI-supported learning environments in developing research-related competencies among secondary school learners.

Finally, future studies employing larger samples, comparative research designs, and multiple educational settings are recommended to further examine the extent to which AI-assisted seamless learning approaches are associated with research competence development and academic outcomes. Such investigations may provide a stronger basis for understanding the role of technology-supported research instruction in diverse educational contexts.

Conclusion

This research examined the implementation of Project ARDI within a seamless learning approach and the relationship between the implementation of the project and research competence, academic achievement, and research experience of senior high school students. Findings revealed higher perceived research competence of the respondents after engaging in the intervention especially in terms of learner engagement, perceived value of research, academic productivity, and attitude towards research. Likewise, statistical significance was established in the comparison of pretest-posttest and first-second quarter academic achievement.

Qualitative data supported the results with an explanation of the participants' experiences with Project ARDI. Learners indicated improved understanding of research, increased availability of structured guidance, increased self-confidence in performing research tasks, higher level of involvement in research activities, and improved connections between formal and informal learning experiences. The combination of these findings suggests that learners perceived Project ARDI as a useful instructional support tool within research-based instruction.

In light of the TPACK and seamless learning approach, the results reflect on the potential of integrating technology, pedagogy, and research content to support research learning experiences in various environments. This paper also discusses the application of AI-assisted instructional systems as a potentially valuable means of supporting scaffolding, learner engagement, and continuity of learning across contexts.

However, interpretations of the results need to take into consideration the study's weaknesses. The employment of the one-group pretest-posttest action research design without a comparison group makes it impossible to ascribe all observed changes to the effects of Project ARDI. Moreover, a small sample size and a single school setting limit the scope of the findings' generalizability. Thus, the results obtained should be seen as evidence of correlations established throughout the project implementation stage but not of its effectiveness for itself.

Although faced with these challenges, the present study adds to an increasing body of knowledge on seamless learning, AI-assisted education, and fostering research competence in secondary schools. The combination of quantitative and qualitative findings suggests that there could be some potential for

technology-mediated research learning environments in terms of boosting learners' involvement in research and their confidence in it. Future research is encouraged to use bigger samples, different settings, and compare groups.

Declarations

Funding Details

This action research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data Availability Statement

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Clinical Trial Number

Not applicable.

Conflict of Interest

The corresponding author declares that there are no financial or non-financial conflicts of interest related to this study.

Ethical Approval

This study was reviewed and approved by the Sta. Catalina Integrated National High School Research Ethics Committee and was conducted in accordance with institutional ethical guidelines and principles governing educational research involving human participants.

Disclosure statement

The author confirms that there is no conflict of interest or any financial nor non-financial interest arising from the direct application of this study.

Consent to Participate

Informed consent was obtained from all participants involved in the study. Informed consent was obtained from all participants prior to their participation in the study. For participants below 18 years of age, informed consent was secured from their parents or legal guardians before data collection commenced.

Consent to Publish

The author consents to the publication of this manuscript and all accompanying materials. Participants were informed that anonymized data may be used for scholarly publication and dissemination purposes.

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Declaration of Generative AI in Scientific Writing

In the preparation of this research article, the author used Copilot solely for refinement and language editing. All generated text were carefully revised, verified, and reviewed by the author, who takes full responsibility for integrity, accuracy, and final form of the article.

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Figures

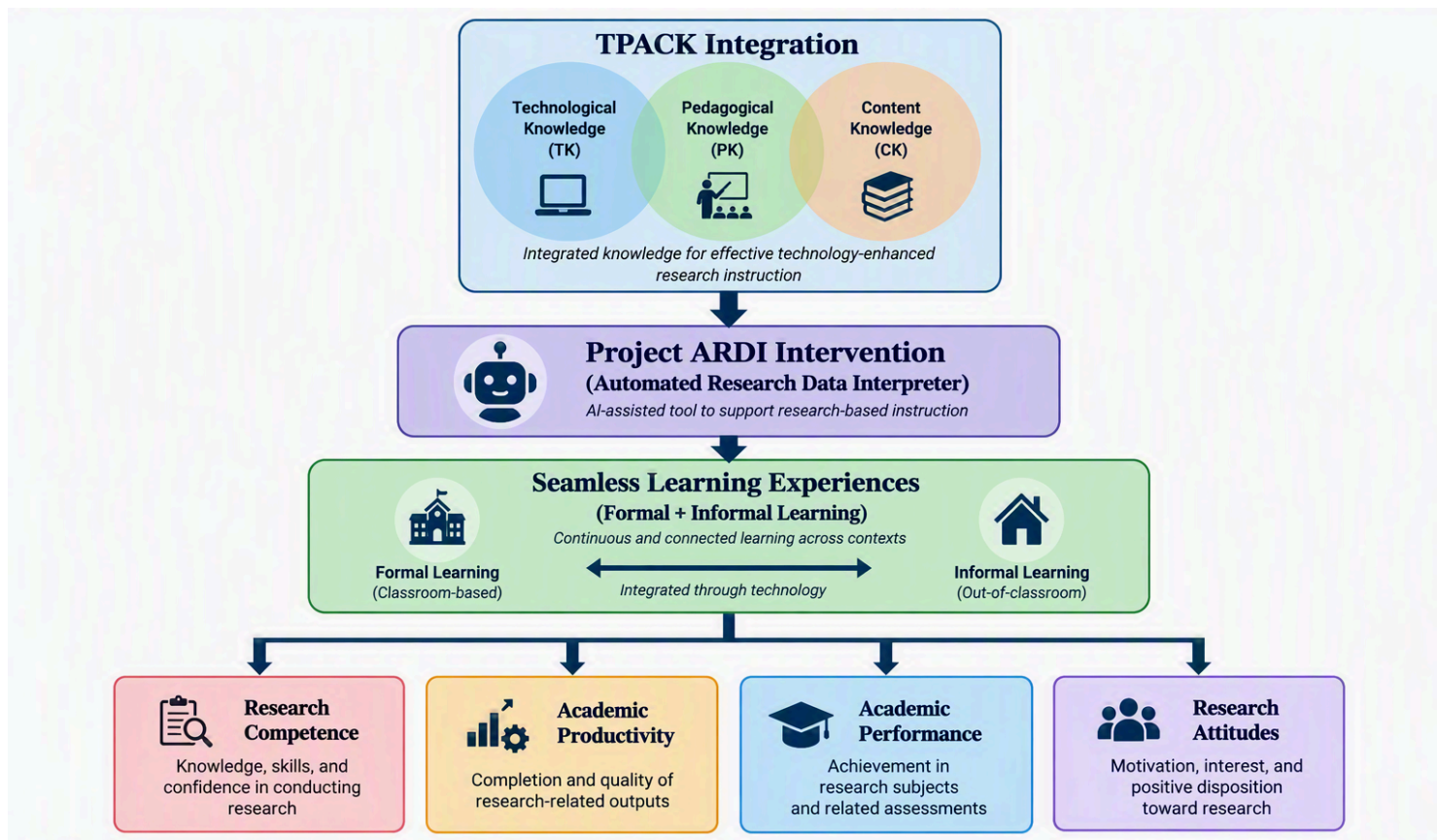


Figure 1

Conceptual Framework of the Study

Note. TPACK = Technological Pedagogical Content Knowledge; Project ARDI = Automated Research Data Interpreter. The framework illustrates the proposed associations among TPACK integration, Project ARDI implementation, seamless learning experiences, and learner outcomes. The model is conceptual and does not imply causal relationships.