An Agile Approach for Collaborative Inquiry-Based Learning in Ubiquitous Environment

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***Abstract*—The use of collaborative inquiry-based learning has been prevalent in educational contexts particularly in science education. Using such collaborative environments, learners can increase their engagement, knowledge and critical thinking skills about science. With the advancement of technologies, ubiquitous learning environments have been designed for facilitating learning in real-time contexts. Over the past few years, agile-based approaches have been implemented at higher education for inquiry-based learning activities. However, there is a lack of studies found that focuses on agile-based approach for ubiquitous collaborative inquiry learning activities at K-12 education level. Therefore, this study presents the ScrumBan Ubiquitous Inquiry Framework (SBUIF), for inquiry-based learning activities at K-12 education level. For this purpose, an application uASK has been developed on the proposed framework, SBUIF. For the evaluation purposes, computer-supported collaborative learning (CSCL) affordances along with micro and meso levels of the M3 evaluation framework has been applied. An experiment was conducted for the evaluation of uASK application in comparison with the Trello application, involving 205 to 127 seventh-grade students. Results demonstrated that uASK learners achieved higher scores as compared with Trello participants. Further, survey results indicated higher levels of engagement, satisfaction, and enjoyment among uASK users. The study concludes that uASK offers significant advantages over Trello in fostering collaborative inquiry-based learning activities in ubiquitous environment.**

***Keywords*—K12 education; agile; ubiquitous; collaborative learning; inquiry based learning**

I. Introduction

Due to the shifting context and evolving learner's needs the educational landscape faces many challenges. By introducing collaborative activities in their education, students not only develop content mastery but also enhance their communication skills, problem-solving abilities, and overall academic motivation [1]. To align students with real-world experiences they will encounter in the workspace thus preparing them for the collaborative nature of many professional environments Collaborative learning fosters many skills in students, encouraging the creation of new knowledge and understanding through dialogue and interaction [2]. An inquiry-based learning approach enables learners to actively explore questions, construct knowledge, and share findings, and has been recognized as an effective method for developing critical thinking skills [3]. Inquiry-based learning (IBL) is considered as an effective educational approach that encourages learners to engage in the learning process more deeply by taking care of their own learning, rather than passively receiving information [4].

With the advancement of technologies, the use of mobile devices in IBL environments presents unique opportunities for learning especially science education [5]. They are: (i) facilitate various levels of inquiry (ii) enhance learners' motivation and engagement (iii) provides seamless learning among various contexts and (iv) leverage between formal and informal science education. The use of mobile devices with sensor technologies can create more interactive and immersive experiences for learners that can actively engage in the learning process. This learning environment is termed as Ubiquitous learning or U-learning [6]. Recent studies highlighted that this learning environment can effectively provide benefits in learners' engagement and critical thinking skills [7][8]. Further, the use of such ubiquitous platforms can enhance student learning by capturing their attention and providing personalized learning experiences [9].

In the literature related to ubiquitous IBL, five types are identified [10]: (i) *Authentic scientific inquiry* in which learners investigate and conclude about real-world or scientific problem (ii) *Abductive science inquiry* in which learners form hypotheses based on research or observations, drawing conclusions through critical thinking (iii) *Collaborative inquiry* in which learners work in groups, understand and solve problems through a repeated process [11] (iv) *Collective whole class* inquiry in which the entire class participates in the inquiry process, collaborating towards a common goal. Learners may think critically and generate ideas for a given problem [12] and (v) *Inquiry with game component* in which learners use game component as an instructional or learning source to address inquiry problems such as combining augmented reality with inquiry environment to enhance their learning experiences [13][14]. This research follows collaborative inquiry for learning science education.

Collaborative inquiry-based learning (CIBL) has gained popularity due to its ability to enhance learners' engagement, comprehend knowledge, and foster critical thinking skills [11]. In these environments, teachers and peers provide an environment, pose problems, and offer support that promotes intellectual growth. When students work together in cooperative groups, they share the process of developing ideas. This collaboration gives them opportunities to think about and expand their own ideas as well as those of their peers.

In these collaborative settings, students can view their peers as resources, not competitors [15]. Group-based exploration allows students to collaboratively exchange ideas and experiences. Differing interpretations of concepts and processes can lead to disagreements, which may ultimately promote intellectual growth through the sharing of knowledge and the formation of connections [12]. However, such a learning environment faces challenges in terms of processes and resources for collaboration, and requires support from fellow students, which demands energy investment in collaborative efforts.

On the other hand, the implementation of agile methodologies within the educational domain has been a topic of growing interest in both classroom and online learning environments. This approach creates an adaptive and collaborative learning experience, owing to its iterative and incremental nature [16]. Further, Agile has been successfully utilized in academic settings to teach software engineering, primarily through project-based learning approaches. In these scenarios, students work in small groups to produce software as the final learning product, simulating agile practices [17] [18]. However, the existing literature reveals a paucity of empirical research specifically addressing the adoption of any agile methodology in secondary and higher education contexts.

Scrumban, one of the agile methodologies, follows a hybrid project management framework that combines the iterative and incremental nature of Scrum with the continuous flow of Kanban [19]. This framework has been successfully applied in software development and has the potential to be adapted for instructional design and delivery in other learning environments [20]. The integration of Scrumban and inquiry-based learning in ubiquitous environment may create an approach that leverages the strengths of both methodologies. Nevertheless, such integration has not been found in the literature earlier. Therefore, this allows us to explore the use of scrumban methodology as a collaborative framework for inquiry-based learning activities at secondary school students.

This paper presents a framework that combines Scrumban principles with inquiry-based learning for ubiquitous learning environments. To assess the effectiveness of this framework, an application, 'uASK' has been developed and evaluated using the M3 evaluation framework [21] was employed. The paper later discusses the findings and their implications.

II. Related Work

In the literature, there are few applications that use agile based approaches in educational settings. These studies mainly focus on IBL activities in ubiquitous environments as depicted in Table I.

ULMCI is a forum-based web application to assist learners through authentic scientific inquiry [20]. In this study, university students work on solving real-world problems to develop their programming skills, rather than just learning theory. The forum allows learners to interact, discuss, and collaborate on programming challenges. However, no agile method was used for collaboration in this [22]. In another study, two digital platforms are utilized for conducting authentic scientific inquiry for railway engineering university students [23]: 1) Edmodo, a virtual environment for disseminating educational resources and facilitating communication, and 2) Google Docs, a collaborative online writing and editing tool. These platforms were implemented using flipped classroom approach where learners can independently study core course material outside the classroom, while in-class time is allocated to practical applications and knowledge reinforcement activities.

A research study was conducted in which university students used a digital tool called Trello for learning software engineering [24]. This tool follows Kanban, an agile methodology for managing and organizing learners' activities. Further, inquiry with game component type is applied to make learning process for engaging and interactive. In another instance, scrum methodology is used for teaching Chemistry to 11^{th} grade students [25]. In this study, learners are involved for enhancing their engagements and learning outcomes through manual boards and face-to-face meetings rather any digital tools.

On the other hand, there are few studies that target collaborative inquiry types. In this study, scrumban methodology are followed by university students for learning about project-based web programming courses [26]. The participants in this study used Microsoft Planner, WhatsApp, and Telegram to enhance student engagement, collaboration, and project management skills. Microsoft Planner facilitated task organization and progress tracking, while WhatsApp and Telegram enabled real-time communication [26]. This approach aimed to create a collaborative inquiry earning environment mirroring real-world software development practices, potentially better preparing students for future careers.

In another research, Milićević et al. (2019) integrated Scrum methodology with OpenProject software in e-business project management courses. This approach provides university students with practical experience in agile project management through real-world e-business projects. The combination of Scrum and OpenProject facilitated collaborative inquiry, task allocation, progress tracking, and iterative development [27]. In a similar vein, Parsons et al. (2018) explored an innovative approach to teacher professional development by integrating Scrum and Kanban methodologies, commonly known as Scrumban, and implementing it through the digital platform Trello. This hybrid approach supports and tracks collaboration, allowing all team members to participate in discussions, view the workflow, share files and notes [28]. Further, learning sessions in this research facilitates participants to comprehend practical application of agile and lean concepts to enhance their professional practice.

The relevant studies indicate that the use of agile methodologies in educational context enhance learning experience for the learners [29]. Most of these studies focused on university students except for a study where high school students are involved [25]. However, that study did not use any ubiquitous inquiry type. Therefore, this indicates that there is a significant gap in literature that can implement an agile-based approach for collaborative inquiry-based learning activities in a ubiquitous environment for school students. This gap presents an opportunity in this research to explore a ubiquitous learning environment through an agile-based approach for conducting collaborative inquiry activities.

TABLE I. AGILE APPROACHES USED IN INQUIRY-BASED LEARNING UBIQUITOUS ENVIRONMENTS

Approach/Application	Agile Method	Platform	Learners	Domain Knowledge	Ubiquitous Inquiry Type
ULMCI [22]	-	Forum based application (ULMCI)	University Students	Programming	Authentic scientific inquiry
Agile CSCL [26]	Scrumban	MS Planner, Whatsapp and Telegram	University Students	Web Programming	Collaborative inquiry
IBL-CSCL in flipped classroom [23]	-	Edmodo, and Google Docs	University Students	Railway engineering	Authentic scientific inquiry
GBL Agile [24]	Kanban	Trello	University Students	Software Engineering	Inquiry with game component
Context Based Scrum [25]	Scrum	-	Grade 11	Chemistry Education	-
Scrum Agile Framework [27]	Scrum	OpenProject	University Students	E-Business Project Management	Collaborative inquiry
Agile and Lean learning [28]	Scrumban	Trello	Teachers	Agile and Lean Teaching Concepts	Collaborative inquiry

III. SCRUMBAN UBIQUITOUS INQUIRY FRAMEWORK

This study presents an innovative framework, the ScrumBan Ubiquitous Inquiry Framework (SBUIF), as shown in Fig. 1, which adapts various components from the established methods including Seemless inquiry-based learning framework (SIBLF) [30], and ScrumBan Research Framework (SBRF) [31]. The proposed SIBLF by Song et al. [30] lacks a structured approach, which in turn complicates class management. While SBRF provides structural stability, it does not incorporate inquiry elements for student scaffolding. Additionally, its design for research project management in university education renders it unsuitable for knowledge construction at the K12 level. However, by integrating these elements, SBUIF provides a comprehensive and flexible inquiry framework suitable for use in educational environments for its adaptability to real-world contexts through ubiquitous learning.

The SBUIF is categorized into eight distinct phases, each with its own unique characteristics and goals. Its objective is to create a comprehensive and dynamic learning environment that caters to the diverse needs and preferences of students. By utilizing a combination of learner-centered approaches and technology-enhanced resources, this framework strives to enhance student engagement, collaboration, and the overall quality of the educational experience. This framework also equips students with the necessary skills to engage in scientific inquiry as they develop their ability to apply critical thinking and reasoning to their observations and experiments in a ubiquitous environment. The phases of SBUIF are as under:

A. Build Awareness

The initial phase of "Build Awareness" is essential for establishing the foundation necessary for the effective implementation of the SBUIF approach. This phase focuses on building strong relationships with educators, administrators, and the learning community. This phase develops assessment procedures that meet learning objectives and encourage stakeholder feedback. These links promote varied viewpoints and insights, improving understanding of learning objectives and context. Further, it emphasizes the need for a thorough literature review to build expertise. This review ensures that learners, teachers, and other stakeholders understand the latest research, best practices, and emerging trends in the field, laying the groundwork for the SBUIF approach.

B. Define Objective

Learners' perspectives, needs, and goals are analyzed in the second phase, "Define Objective". This stage tailors' educational programs to individual learners, making them more effective and interesting. Understanding learners' viewpoints helps instructors to create an environment that motivates and empowers them. The instructional team determines the most relevant and interesting content for the learning objectives by examining the target audience. After determining the target audience, the team can create learning objectives that match learners' needs and interests, making the content engaging and effective. This phase is critical for evaluating the learning goals alignment process to boost student engagement and involvement in their education.

C. Engage

In the third phase, learners past knowledge and experiences are activated and enhanced while meaningful connections are made between peers and instructors. Therefore, it uses collaborative and blended learning approaches to provide an engaging and participatory learning environment where learners can actively contribute knowledge, share thoughts, and have meaningful discussions. This phase can help learners to develop critical thinking and collaborative skills while giving instructors a better understanding of their progress and needs. This level uses advanced technology and a collaborative learning environment to encourage students to participate, share ideas, and learn more.

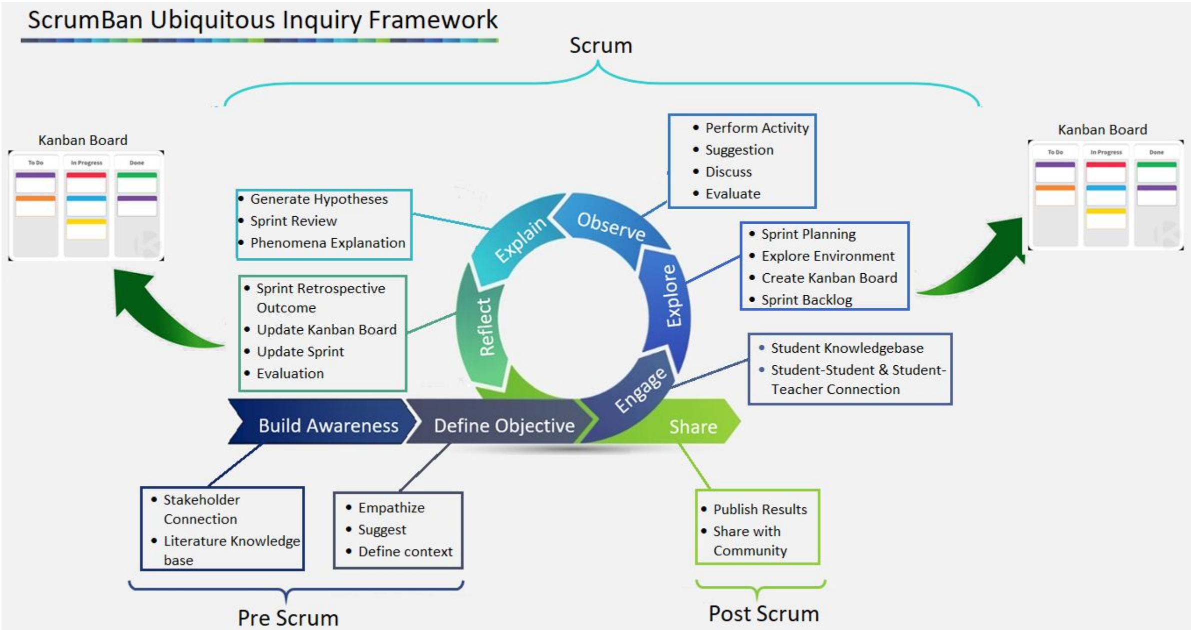

Fig. 1. Proposed ScrumBan ubiquitous inquiry framework adapted from study [30] [32].

D. Explore

Lesson design is systematic and iterative in the fourth phase, "Explore". The instructor and learners plan learning sprints during sprint planning. The sprint planning process helps instructors and learners grasp learning sprint objectives, goals, and expectations, improving learning outcomes. To ensure effective and efficient learning outcomes, educators must carefully develop and define learning sprint objectives, goals, and expectations. Instructors and students evaluate resources, technologies, and learning barriers in the Explore phase. The exploration phase includes creating a Kanban board and sprint backlog to organize and visualize learning. The Kanban board may show the status of each work, helping the team communicate progress and identify areas for improvement. Kanban boards and sprint backlogs boost teamwork and learning. This phase allows instructors to discover and correct student misconceptions and gaps in comprehension, which may be addressed with targeted interventions and additional support to improve learning.

E. Observe

In this phase, the instructor monitors student performance and provides real-time feedback and advice to improve learning and fulfill various requirements. To facilitate learning and meet various needs, the instructor analyzes learners' involvement and performance during learning activities and provides real-time feedback and advice. This phase promotes ongoing improvement through detailed discussions and activity evaluations. This allows the instructor to constantly enhance and alter the teaching method, creating a more inclusive and effective learning environment that boosts learners' engagement and educational quality.

F. Explain

During the "Explain" phase, learners are instructed to develop hypotheses, assess the advancements achieved throughout the sprint, and obtain detailed explanations of the foundational concepts and principles. This phase is essential for facilitating learners' connections between observed phenomena and underlying theories, thereby enhancing their understanding of the subject matter. This phase offers opportunities for learners to refine hypotheses, challenge assumptions, and enhance insights through interactive discussions and constructive feedback from instructors and peers. Engaging in meaningful exchanges allows learners to explore alternative perspectives, identify new connections, and enhance their critical thinking skills. This collaborative process facilitates a nuanced and comprehensive understanding of the subject matter, thereby enhancing the ability to draw informed conclusions and address complex problems.

G. Reflect

In this phase, a comprehensive review and analysis of the entire learning process is conducted. The sprint retrospective involves a discussion between the instructor and learners regarding the outcomes, effectiveness, and implications of the sprint. The instructor and learners assess learning experiences, pinpoint areas for enhancement, and investigate methods to refine sprint instruction. The pedagogical framework undergoes continuous refinement and optimization through rigorous evaluation and debate, ensuring a highly responsive learning experience tailored to learners' diverse requirements and preferences. The Reflect phase includes the analysis of learning outcomes, the updating of the Kanban board and sprint schedules, and the execution of comprehensive mid-term evaluations. This review and assessment process enables both the instructor and learners to evaluate previous sprints, pinpoint areas for enhancement and modify the Kanban board and sprint plans accordingly.

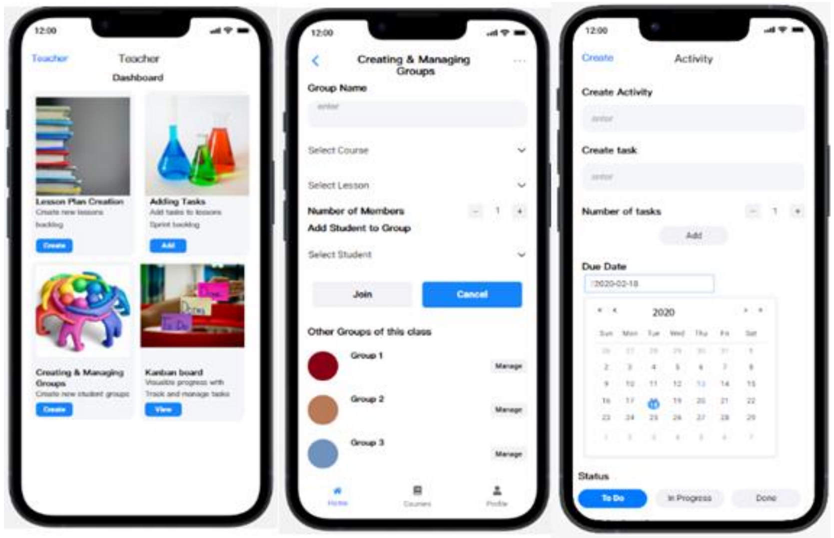

Fig. 2. uASK pre-scrum interfaces.

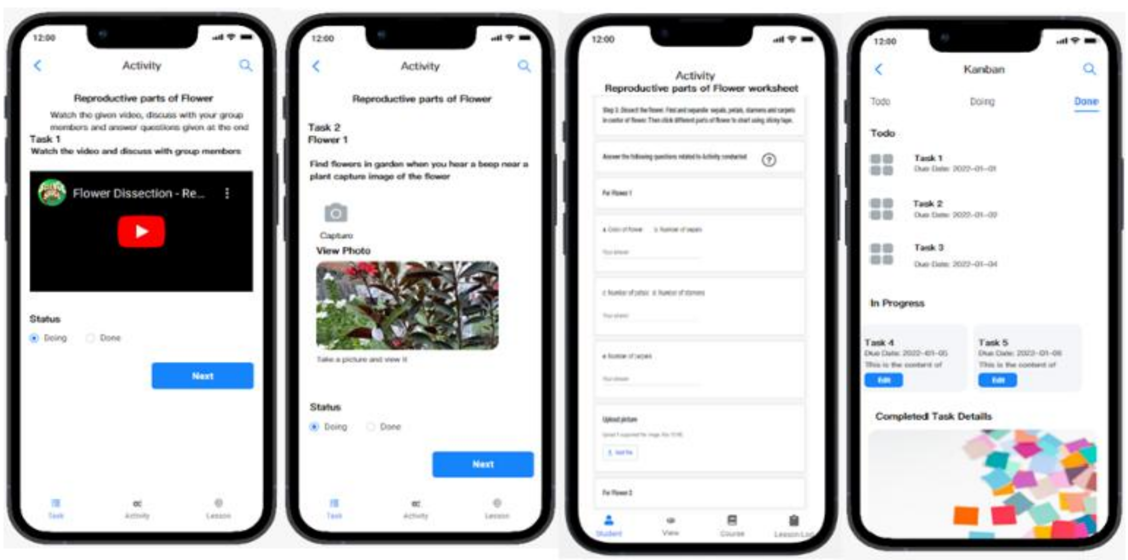

Fig. 3. Scrum activities in uASK.

H. Share

The final phase entails the publication and dissemination of research findings, best practices, and innovative pedagogical approaches developed through the implementation of the student-centered and blended learning framework. This phase of sharing promotes cross-institutional collaboration and knowledge exchange, enabling instructors from various educational institutions to convene and discuss their experiences, best practices, and innovative strategies. The feedback and perspectives obtained from the broader academic community can inform future iterations of the framework, thereby enhancing its effectiveness in addressing the diverse needs and learning styles of learners across various educational contexts. This phase of sharing is essential for the ongoing refinement and enhancement of the overall framework, facilitating the integration of diverse insights and new ideas that improve its responsiveness to the changing needs of learners.

IV. UASK APPLICATION

The proposed ScrumBan Ubiquitous Inquiry Framework (SBUIF) was implemented through the uASK application, which incorporates both Scrum and Kanban methodologies for teaching using agile as a learning pedagogy. Thus, uASK is a scrumban based collaborative learning application that provides a platform for students and teachers to facilitate their learning. The components of uASK application are mentioned as below:

A. Pre-Scrum

In pre-scrum, the teacher will be creating lesson activities and tasks along will building groups as shown in Fig. 2. The activities can be related to science education. Thus, encompassing the pre-scrum phases of build awareness and defining objectives.

B. Scrum

The next phases are categorized as scrum where the students are actively engaged in learning by interacting with each other and the environment. Along with the teacher monitoring the progress through kanban boards. In scrum, inquiry phases of engage, explore, observe, explain & reflect are included. Through these inquiry phases, students can interact with observed phenomena and explore the underlying problems. Fig. 3 shows different screens for the task of reproduction of plants through which students.

C. Post-Scrum

In the post-scrum phase, the results of the activities performed are shown and shared with group and teacher as shown in Fig. 4. The teacher will reflect upon these results and give feedback as required. These results will further be shared with the community for further exploration.

Fig. 4. uASK post-scrum activities.

V. Research Methodology

In this research, an application uASk has been developed. The uASK represents a novel application that integrates both Scrum and Kanban methodologies, offering a hybrid approach. To evaluate its effectiveness, an experiment was conducted. For this purpose, uASK was compared with one of the existing project management applications utilized in educational settings: Trello. Trello is a more established application that primarily adheres to Kanban principles. This study aimed to compare these applications in terms of their support to inquiry-based learning methods within an educational context.

A. Participants

The research involved a sample size of 127 seventh-grade students (76 boys and 51 girls) of a local school. The students were divided into two experimental groups as a quasi-experimental research design was employed. One group was assigned to use Trello, while the other group utilized the designed application, uASK. This experimental design allowed researchers to conduct a side-by-side evaluation of how each application performed in enhancing students' learning experiences through inquiry-based approaches.

B. Experimental Design

The primary objective of this experiment was to assess whether the newly developed uASK application, which implements an innovative framework called the ScrumBan Ubiquitous Inquiry Framework (SBUIF), could demonstrate better performance in comparison to Trello, a platform which have been used in some research [28] in to support agile learning approaches. The SBUIF framework integrated into uASK represents a novel attempt to combine elements of Scrum and Kanban methodologies, tailored specifically for educational contexts.

The experiment design demonstrates a clear contrast between traditional agile-based learning methods and the enhanced SBUIF approach. By incorporating technology-driven support and guidance, the uASK application aims to provide a more structured and supportive learning environment. This comparison allows for an evaluation of the effectiveness of the SBUIF in promoting student engagement, knowledge acquisition, and collaborative learning in a K12 setting.

C. Procedure

The scrum lesson, which served as the primary activity for the experiment, was structured into seven distinct tasks, thus representing a sprint in the agile methodology.

The first task focused on imparting initial lesson knowledge. For experimental group 1, the teacher provided a traditional explanation of the topic. In contrast, experimental group 2 engaged with the subject matter through video content, allowing students to gain knowledge independently as shown in Fig. 5(a).

The second task involved a tour of a botanical garden to collect samples. Experimental group 1 adopted a random sampling approach, while experimental group 2 utilized beacon tags to guide students to specific areas and samples of interest. This technology-enhanced approach aimed to provide a more structured and targeted learning experience as shown in Fig. 5(b).

(a) (b)

Fig. 5. Students engaged in learning activities.

For the third task, students were required to dissect samples to identify plant parts. Experimental group 1 relied on group discussions to facilitate this process. Experimental group 2, however, combined group discussions with additional support provided by the uASK application, which offered hints to aid the learning process.

The fourth task involved completing a worksheet provided through the respective applications. Experimental group 1 continued to use group discussions as their primary method for completing the worksheet. Experimental group 2, on the other hand, benefited from both group discussions and application-provided hints, offering a more scaffolded approach to worksheet completion. The fifth task was to form hypothesis on different samples provided by applications.

For the sixth task students are again building a knowledgebase through a video for Experimental group 1 and traditional lecture Experimental group 2 to learn about pollination i.e. wind and insect pollination and the last task is to form hypothesis about different flowers if they are wind or insect pollinated based on images provided by applications.

In the next section further analysis of the results from this experiment is given to draw conclusions about the relative effectiveness of the two approaches. Factors such as student performance, engagement levels, and the learning achieved would need to be assessed to determine the potential benefits of the SBUIF implemented through the uASK application compared to the more traditional Kanban-based approach using Trello.

D. Evaluation Method

Computer-Supported Collaborative Learning (CSCL) has emerged as an influential pedagogical approach that leverages digital tools to enhance group-based learning. According to Jeong and Hmelo-Silver (2016), CSCL offers seven key affordances that can significantly enrich the collaborative learning experience: (i) establishing a joint task, (ii) facilitating communication, (iii) sharing resources, (iv) engaging in productive processes, (v) co-constructing knowledge, (vi) monitoring and regulating learning, and (vii) building groups and communities. These affordances create a structured framework that promotes interaction, collaboration, and shared learning objectives, which are critical components in a group-based digital learning [32]. These affordances have been used in multiple studies as validation measures [33][34]. These have been incorporated with M3 evaluation [35][36][37] to effectively evaluate at different organizational levels.

Mapping of micro and meso evaluation to CSCL affordances is shown in Table II. For all affordances C1 to C7, at micro level, evaluation survey was used for application usability aspects while at meso levels, C4, C5 and C6 affordances are explored through pre-test and post-test scores of students. Further, at this level, C1, C2, C3 and C7 affordances are used to evaluate time logs and observations on users' activities through uASK application.

Thus, integrating CSCL affordances within the M3 Evaluation Framework enabled a multi-level analysis of the learning intervention. This structured approach provided insights into individual learner experiences and the operational environment of the learning system. By addressing these distinct levels, the evaluation framework facilitates a comprehensive understanding of the CSCL system's impact on learning outcomes, offering an evidence-based assessment of the effectiveness of collaborative learning interventions.

TABLE II. EVALUATION METHODS

CSCL affordances	**M3 Evaluation Framework**	
	Micro Level Method	***Meso Level Methods***
C1- Establishing a joint task	Application Evaluation survey	Time log & Observation through application e.g. Group formation & Task formation
C2- Facilitating communication		Time log & Observation through application i.e. chat forum
C3- Sharing resources		Time log & Observation through application e.g. videos
C4- Engaging in productive processes		Pre/post-test & Activity evaluation
C5- Co-constructing knowledge		Pre/post-test & Activity evaluation
C6- Monitoring and regulating learning		Pre/post-test & Activity evaluation
C7- Building groups and communities		Time log & Observation through application i.e. chat forum

VI. RESULTS AND ANLAYSIS

The study compared the use of Trello with uASK in facilitating collaborative learning during a botany lesson. The study involved 127 grade 7 students, split into two experimental groups (63 for Trello and 64 for uASK), using a structured approach to tasks that tested different collaborative affordances.

A. Micro Level Evaluation

For micro level evaluation, application evaluation survey was used as method for evaluating CSCL affordances in both applications. Table III shows the questions of application evaluation survey with the corresponding affordance. While Fig. 6 shows the Application Evaluation survey results for both Trello and uASK. As micro level focuses on individual learner experience therefore the questions reflect users' experiences with all CSCL affordances (C1 to C7). uASK consistently scored higher across all metrics, especially in "helping with learning" and "ease of sharing information." collaboration and learning enjoyment highlight its success in Finding and Building Groups and Communities and Engaging in Productive Processes. These findings suggest that the application's structure not only enhanced individual engagement but also facilitated group cohesion, which is essential in a collaborative learning context.

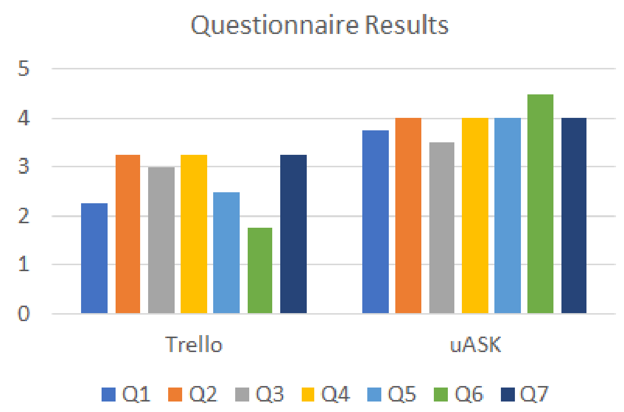

Fig. 6. Analysis of application evaluation survey results.

TABLE III. QUESTIONS ASKED IN QUESTIONNAIRE

Question No	Question asked in survey	CSCL affordances
Q1	The task was well-defined and clear	C1
Q2	There were no challenges in establishing a common understanding of tasks due to application	C1
Q3	The application helped in learning	C5
Q4	The learning experience was enjoyable	C4
Q5	Navigation through the application was easy	C6
Q6	The application helped working in group	C7 & C2
Q7 Q8	It was easy to share information and files with our group	C3

B. Meso Level Evaluation

In the meso level evaluation, number of different methods are used. Learning performances of the students during pre and post-tests are evaluated through their scores. Further, students' engagements are examined through time spent on tasks performed during different activities.

Fig. 7 and Fig. 8 depict Pre Test, Post Test and Activity performance evaluation results that evaluate CSCL affordances C4, C5 & C6. In Fig. 7, the improvement in test scores from pre-test to post-test for both experimental groups. For the Trello group, marks improved from 27.5% to 60.5%, while the uASK group improved from 24.5% to 70.5%. This demonstrates that both groups experienced significant gains in knowledge; however, the uASK group had a more substantial increase.

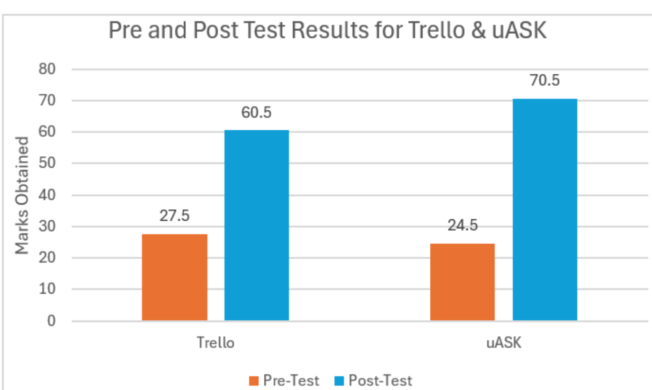

Fig. 7. Results of Pre and post test results for Trello and uASK.

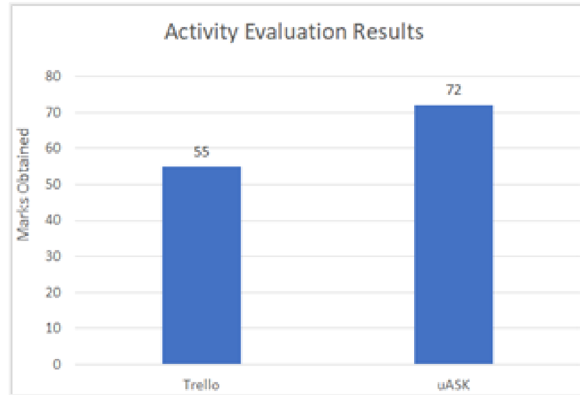

Fig. 8. Activity performance evaluation results.

The marked improvement in the uASK group's post-test results may be attributed to the integration of both Scrum and Kanban methodologies, which potentially enhanced students' ability to Engage in Productive Processes and Engage in Co-construction of Learning through a structured yet flexible approach to learning tasks. The provision of guidance via beacon tags and application support might have fostered a deeper understanding, as indicated by the larger knowledge gains in the uASK group. The findings align with Jeong and Hmelo-Silver's affordances of collaborative learning, emphasizing the effectiveness of uASK's structured support for Engaging in Productive Processes and Hypothesis Generation (Engaging in Co-construction of Learning).

The results of evaluation of the work done on the worksheet provided through the application are given in Fig. 8. uASK results show marked improvement in the performance of students as it aids in comparison to Trello group.

Then for CSCL affordances C1, C2, C3 & C7 this study used time log observation. Fig. 9 breaks down the time spent on each task by both groups, showing variations in the average time required to complete each activity. The Trello group generally spent more time on each task compared to the uASK group, with especially high time usage in Task 1& 6 (Knowledgebase creation), Task 2 (botanical garden sample collection), Task 4 (filling the worksheet) & hypothesis generation.

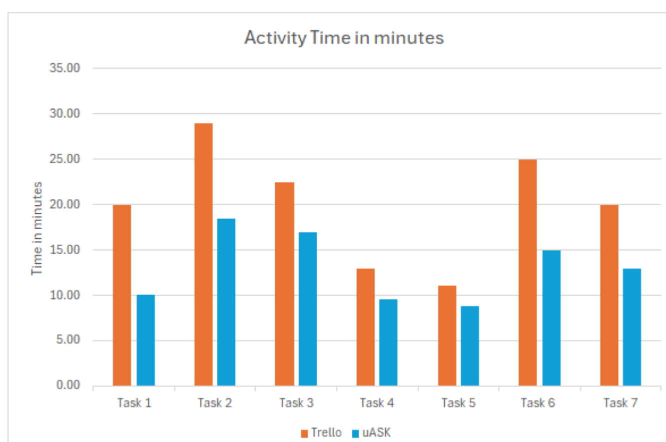

Fig. 9. Time analysis of individual activity in sprint.

The longer time spent by the Trello group suggests that the Kanban-only approach may not provide as efficient task guidance as the combined Scrum-Kanban structure in uASK, which offered hints and beacon-based support. In Task 2, where beacon tags directed students in the uASK group to specific sample areas, the decreased time suggests enhanced Monitoring and Regulation of Learning. This also suggests that uASK's guidance features facilitated quicker and more targeted completion of tasks, reflecting a higher efficiency in Establishing a Joint Task. Tasks requiring in-depth group discussion, such as Task 4, 5 and 7, saw lower completion times with uASK, possibly due to the aid of application prompts which reduced cognitive load and encouraged faster hypothesis generation.

Fig. 10 gives the total time comparison by each group to complete all tasks i.e. entire activity. The Trello group takes more time, while the uASK group completed the tasks in considerably less time. This total time difference reinforces the advantage of the uASK system in streamlining task completion through the Scrumban inquiry framework. The 34.70%-time efficiency in uASK. The reduced time highlights enhanced Communication and Sharing Resources, as students had quicker access to task instructions and peer input, thereby fostering more effective collaborative engagement. This shorter task duration for uASK demonstrates how the affordance of Monitoring and Regulation of Learning can be operationalized to optimize task efficiency.

Overall, the combination of questionnaire feedback, time logs, and pre/post-test results illustrates how the uASK platform, leveraging the Scrum-Kanban inquiry framework, better supported the collaborative learning affordances identified by Jeong and Hmelo-Silver. The findings emphasize the impact of integrating structured yet flexible methodologies to enhance both the efficiency and depth of collaborative learning among K12 students.

Thus, it is found that uASK showed a larger improvement in post-test scores compared to Trello, indicating that it was more effective in helping students understand the content. The additional features provided by uASK, such as structured hints and guided inquiry, may have contributed to deeper learning.

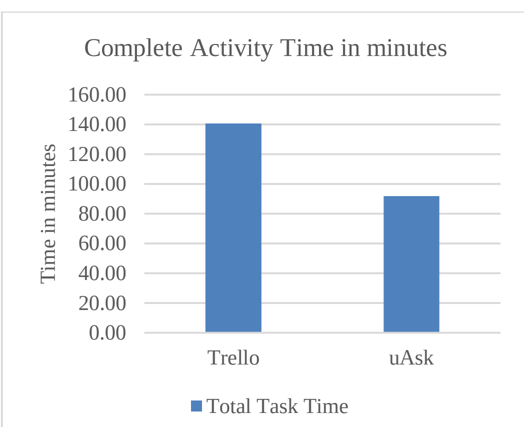

Fig. 10. Time analysis of entire sprint.

Students in the uASK group completed tasks more quickly on average. The combination of Scrum and Kanban principles allowed uASK to provide more structured guidance, reducing time spent on each activity. For instance, beacon tags helped students navigate the botanical garden and locate specific samples more efficiently.

Whereas Trello lacks the structured guidance found in uASK, making it harder for students to stay on track or find specific information without teacher intervention. In the study, this was evident in the longer time taken by the Trello group to complete each task. This lack of support might make it challenging for younger or less-experienced students to engage fully with complex learning tasks.

Additionally, uASK's features, such as hints and prompts, guided students through discussions and worksheet completion. This structured support facilitated Engaging in Productive Processes and Monitoring and Regulation of Learning, as students could focus on task goals without getting stuck or needing excessive teacher intervention. But Trello's Kanban approach is good for organizing tasks but may not provide enough scaffolding for inquiry-based learning, as it does not support features like hypothesis generation, structured hints, or guided navigation. This limitation could result in superficial understanding if students struggle to access deeper content on their own.

Furthermore, Survey results showed higher levels of engagement, satisfaction, and enjoyment in learning for students using uASK. The platform's design likely created a more enjoyable learning experience, as students had access to helpful resources and did not have to rely solely on peer discussion or teacher explanations. This positive feedback suggests that uASK's approach was more user-friendly and better suited to the students' needs. Along with uASK facilitated easier sharing of information and group work, as the platform provided collaborative tools that were more responsive to real-time group needs. The structured prompts likely encouraged smoother communication and better group cohesion. However, Trello's design does not inherently support features for monitoring student progress or self-regulation in the way uASK does. Without built-in prompts or navigation aids, students may find it harder to monitor their learning path or regulate their pace effectively, leading to uneven progress within groups.

VII. Conclusion and Future Work

In conclusion, this research demonstrates that the uASK application, based on the ScrumBan Ubiquitous Inquiry Framework (SBUIF), offers significant advantages over Trello in fostering collaborative learning among students. The SBUIF platform enabled more substantial improvements in test scores, with the group using SBUIF achieving an increase from 24.5% to 70.5%, compared to Trello's 27.5% to 60.5%. SBUIF's structured support, which included beacon tags, hints, and prompts, improved task efficiency, enabling students to complete activities 34.70% faster than the Trello group. This guidance helped streamline complex tasks, reduced the need for teacher intervention, and supported key collaborative learning processes, such as productive engagement and self-monitoring.

Additionally, survey results revealed higher engagement, satisfaction, and enjoyment among SBUIF users, indicating that its design better aligns with student needs for clear task instructions and collaborative tools. While Trello's simplicity may foster more independent problem-solving, it lacks the structured guidance that younger students or those new to inquiry-based learning may require, making it less effective for complex educational tasks.

However, there are certain limitations to the current study such as it does not explore the effects of SBUIF at macro level for instance how scalable the approach might be for institutions or how it could be integrated into policy. Also, there is a need to conduct longitudinal investigation for multiple sprints for deeper understanding of how the framework performs over extended learning periods.

To conclude, addressing current limitations while integrating AI-driven technologies for adaptive feedback and advanced data analytics will pave the way for a more comprehensive, personalized, and effective learning experience, ultimately enhancing student engagement, interaction, and learning outcomes in the future.

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