AN AGILE APPROACH FOR INQUIRY-BASED LEARNING IN UBIQUITOUS ENVIRONMENT

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To my beloved father and mother

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ABSTRACT

Education is an evolving field where challenges are constantly changing of content and learners' needs. Thus, there was a shift in pedagogy from teacher-centric to student-centric learning with the advancement of technology. In recent times, the concept of smart classrooms or ubiquitous learning (u-learning) environment has been prevalent in the learning domain as it increases the accessibility of resources and learning activities anywhere, anytime using smart devices and internet. Also, enhance engagement by creating interactive, engaging, and enjoyable learning experience.

Inquiry-based learning (IBL) is an effective instructional strategy that can be in the form of a problem or task used for triggering student engagement and enhancing students' knowledge by introducing inquiring activities for fostering critical thinking, problem-solving, and student engagement. Also, ubiquitous learning environments integrate real-world and digital-world resources and learning scenarios, thus providing a new opportunity for implementing technology-enhanced inquiry-based activities to enrich student learning experience. But, implementing IBL in a ubiquitous learning environment within school settings presents its own set of challenges, especially in structuring and controlling collaboration effectively.

Collaborative learning is a process of sharing knowledge and constructing meaning by complete involvement of all the peers discuss what they know and gain more knowledge with the help of other peers. Agile methodologies are very successful in the software engineering domain for collaboration professional development environment. These methodologies have been used for quite some time to teach software engineering concepts and agile development using a project-driven approach in computer science. Due to their incremental, iterative, adaptive, and collaborative nature, they have gained popularity in educational domains. There is a lack in literature about the use of agile methods in IBL in ubiquitous environment. Moreover, there is also the opportunity to develop agile-based teaching approaches for other disciplines other than computing, particularly for school students.

The significance of this study is about the developing and evaluating the ScrumBan Ubiquitous Inquiry Framework (SBUIF) through the uASK application for collaborative IBL amongst school students. For evaluation purposes, computer-supported collaborative learning (CSCL) affordances, along with micro and meso levels of the M3 evaluation framework, have been applied. An experiment was conducted to test the effectiveness of the uASK application against Trello application.

The sample involved 205 seventh-grade students. Results showed that the uASK learners scored better than those using Trello. At the micro-level, student satisfaction score by uASK users was 77.14% in comparison to Trello users which was 54.12%. It showed significant improvement and revealing better results in technology, communication, and learning performance. The meso-level measures of students learning performance revealed that uASK users had better learning outcomes then Trello (68.88% vs 58.13% for post-test improvement). Also more efficient use of time (34.7% faster). Thus, the results showed that uASK users were more engaged, satisfied, and enjoyed uASK more than the other users. The study further recommends that uASK is more effective than Trello in promoting collaborative learning activities inquiring approach in any place.

The study demonstrates that the use of such framework and application based on SBUIF can support agile based collaborative inquiry learning at school level, thereby advancing knowledge in the fields of agile and inquiry-based education. Furthermore, by implementing the framework in a real-world classroom setting, it highlights its practical value, offering guidance for educators in designing similar applications to support future teaching and learning practices.

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LIST OF ABBREVIATIONS

IBL	Inquiry-based learning
u-learning	ubiquitous learning
SBUIF	ScrumBan Ubiquitous Inquiry Framework
CSCL	Computer-supported collaborative learning
IR	Infra-Red
GPS	Global Positioning System
RFID	Radio-Frequency Identification
UE	ubiquitous environments
AR	Augmented Reality
mIBL	Mobile Inquiry-based learning
QR	Quick Response
EcoMOBILE	Environmentally Situated Mobile Outdoor Blended Immersive Learning Environment
DSRM	Design Science Research Methodology
SBRF	Scrum-Based Research Framework
DSR	Design Science Research

IS	Information Systems
DSRC	Design Science Research Cycle
STEM	Science, technology, engineering, and mathematics

CHAPTER 1

INTRODUCTION

Education is rapidly shifting from teacher-centered to student-centered approaches. The integration of digital technologies and ubiquitous learning environments that enable anytime, anywhere, learning helps foster it. While collaborative learning enhances knowledge construction through peer interaction along with inquiry-based learning (IBL) supports this shift by fostering curiosity, critical thinking, and problem-solving. However, the main challenges remain in effectively structuring and managing this collaboration process in ubiquitous contexts. Agile methodologies, with their iterative, adaptive, and collaborative nature, provide a promising approach to address these gaps. This chapter introduces the study's background, problem statement, objectives, and contributions.

1.1. Inquiry-based learning (IBL)

The use of digital technologies has been prevalent in educational settings for the last two decades and so. Due to such advancement, there is a paradigm shift in learning environments from teacher-centric to student-centric (Kerimbayev, Umirzakova, Shadiev, & Jostov, 2023). In a student-centric approach, learners' needs and interests are at the central stage in the educational process. This type encourages engagement, collaboration and learners' autonomy according to learners' needs and goals (Kerimbayev, Umirzakova, Shadiev, & Jostov, 2023). Further, it can also facilitate learners to improve their learning quality (Murtonen, Aldahdouh, Vilppu, Trang, Riekkinen & Vermunt, 2024).

IBL is an effective instructional strategy that focuses on student-centric approach where learners are involved in investigating the underlying phenomena (Liu, Zowghi, Kearney, & Bano, 2021). This type of learning not only improves learner's knowledge and critical thinking skills but also enh ances their engagement and motivation towards inquiry investigations (Hava & Unlu, 2021). This learning follows the self-exploratory process of gaining knowledge about any topic in different domains. These domains can be mathematics, science or even arts and so on. The learning process in inquiry gives a hand on experience to students by performing experimentation and data collection about that topic (Wongwatkit, Panjaburee & Srisawasdi, 2017). In recent years, academicians and researchers are interested in using IBL approaches in different level of formal education such as University (Santana-Vega, Feliciano-García & Suárez-Perdomo , 2023), high secondary schools (Orosz et al., 2023) and primary school (Akaygun & Adadan, 2023).Inquiry based learning is considered as a discovery learning in which structural support is provided to learners in different phases including hypothesis generation to evaluate data for understanding the scientific phenomena Most of the researchers and scholars adapted these four levels of inquiry (Tan, Rusman, Firssova, Ternier, Specht, Klemke, & So, 2018); *confirmation*, *guided*, *structure* and *open inquiry*. In confirmation inquiry, learners are given instructions and procedures to find the answer to the question. Guided inquiry, learners are given a question by instructor. The learners devise a plan to answer that question. They explore and experiment with the results obtained. They provide proper reasons to support their answers. In a structured inquiry process, learners are given procedures and instructions to find the results to the question raised. They follow the procedure and provide proper reasons to support their answers. In an open inquiry, learners ask questions. They explore and experiment with the results obtained. They provide proper reasons to support their answers. Thus, IBL can be implemented for establishing high order thinking and metacognitive, questioning and explanation, critical thinking, problem solving, self-directness, collaboration and knowledge creation skills in learners (Yoshinobu, 2019).

On the other hand, constructivist theory is an active learning pedagogical style where the learners are not passive listeners, but they engaged in two aspects- doing some tasks and actively involved in constructing knowledge (Tan et al., 2018). This theory focuses on three things (Ahmed, Javed, Niazi, Alam et al., 2019) (i) Knowledge Construction, where learners construct knowledge according to their prior learning experience (ii) Active Learning, where learners are involved actively in articulating their own goals, making decision and applying strategies for finding solutions and (iii) Knowledge elaboration, where learners use critical thinking skills to reflect on their learning experiences encounter during the observed phenomena.

IBL follows the constructivist theory in such a way that learners are actively involved in constructing knowledge through observed phenomena and apply any type of inquiry level to solve the underlying problems and then reflect on their learning experiences using their critical thinking skills while performing IBL activities (Tan et al., 2018). These activities can be performed by learners in and outside of the classroom by designing advanced learning environments such as ubiquitous learning environments.

1.2. Ubiquitous environment

With the advancements of learning technologies, there is a paradigm shift from mobile learning (m-learning) towards context-aware U-learning (Ubiquitous learning) (Ahmed et al., 2019). In the literature, context-aware ubiquitous learning has been defined as "a learning approach that employs mobile devices, wireless communication and sensor technologies in learning activities" (Hwang, Tsai, & Yang, 2008). This type of learning environment is one that is supported and enhanced through technological devices and supports learning anywhere and anytime. Thus, in ubiquitous environment mobile devices through wireless network connects learners and teaching contents. It focuses on the interaction between content objects, activities and other humans like teachers and other students (Hwang et al., 2016). In addition, Context-awareness is also an important feature in ubiquitous learning as context of the situation, location, and learner's context are needed to facilitate learning process (Hwang et al., 2016). Therefore, to create a ubiquitous learning environment the first component is the embedded or mobile device provide processing, storage, communication medium and context-awareness are required.

So, by definition an ubiquitous learning environment refers to a technology-enhanced setting where learning can occur anytime and anywhere through the seamless integration of smart devices, wireless networks, and digital resources (Hwang, Tsai, & Yang, 2008; Mhlongo, Mbatha, Ramatsetse & Dlamini, 2023). It supports personalized, context-aware, and continuous learning beyond classroom boundaries. The devices and sensors are important in ubiquitous environment because they provide the interaction between components and users. Also, sensory data helps to create context of situations and objects. So, to create such an environment self-calibration, networking, computing, memory and mobility are some of the characteristics desired in these devise or sensors (Aljawarneh, 2020). Main purpose of sensors in ubiquitous environment is to gather contextual data from the surrounding (Tan et al., 2018). There are many types of sensors such as temperature sensors, motion sensors, proximity sensors, IR sensors, GPS sensors, RFID sensors and tags etc.

Mobile devices like laptops, tablets, Smartphones, E-Readers e.g. Kendle and Wearable devices e.g. Fitbit, Smartwatches and glasses can also be used. They have the ability of connecting with network, storage and processing capability. Moreover, there are some sensors available in mobile devices e.g. location sensors, proximity sensor etc. However, these mobile devices are not considered as ubiquitous because they do not provide seamless adaptive services, context-aware elements and learning activities as per ubiquitous learning environments (Hwang et al., 2016; Aljawarneh, 2020).

In the literature related to ubiquitous leaning environments, recent studies have taken advantage of ubiquitous technology to integrate IBL environment for guiding learners for interacting with the real-world contexts (Chen et al., 2023; Ruiz-Calleja et al., 2023). These studies indicate that learners can obtain instant assistance or feedback when collecting and analyzing data, and when explaining a phenomenon in the real-world environments. Nevertheless, it has been found that the level of learners' engagement may influence their inquiry learning effectiveness. That is, an effective inquiry learning activity still depends upon a higher level of participants' motivation indicating the significance of motivating factors for an IBL activity (Rutten, van der Veen, & van Joolingen, 2015). Such learning environments can also integrate real-world and digital-world resources and learning scenarios that can give an opportunity to implement technology-enhanced inquiry-based activities to enrich student learning experience (Schellinger et al., 2019).

These learning environments mainly focus on individual or personalized learning environments. However, collaborative learning for inquiry-based environments is gaining popularity in recent years (Haynes et al., 2023; Zambrano et al., 2023). This is because, it increases participation, enhances information retention & promotes critical thinking (Haynes et al., 2023). These learning environments are lacking in regulated process and assistance (Noguera, 2018) and need to foster deeper engagement of learners in participating in collaborative process (Chan & Pow, 2020).

1.3. Collaborative learning

Collaborative learning is a widely used strategy by which learners are involved to work in groups to accomplish certain common learning objectives. It calls for active engagement, conversation, and a shared responsibility for comprehending and producing knowledge (Griffths, Alsip, Hart, Round, & Brady, 2021; Le, Janssen, & Wubbels, 2018). During this collaborative learning process, individuals among groups use their cognitive and metacognitive skills while interacting and negotiating to solve the given problems and are responsible for their personalized learning (Chatterjee & Correia, 2020). There are mainly two types of interactions in collaborative learning (Lu & Smiles, 2022) (i) cognitive interactions in which learners are actively participated with each other in collaboration through thinking, reasoning, analyzing and discussing processes (ii) socio-emotional interactions in which learners are actively involved in solving a problem by understanding each other through their empathetic behavior and positive attitude towards their collaboration. In the literature related to collaborative learning, numerous studies showed that collaborative learning has a number of advantages, such as improve motivation, engagement and positive attitudes towards learning, enhance critical thinking skills and interpersonal skills, increasing learning outcomes and improve learners' academic accomplishment (Chatterjee & Correia, 2020; Griffths et al., 2021; Lu & Smiles, 2022). Collaborative learning can be applied in various educational settings, including liberal arts colleges, higher education, industry, and government. Such educational software and intelligent collaboration learning systems can be facilitated through the use of computer-mediated communication and other collaborative technologies. Collaborative learning practices have been implemented in a wide range of subjects, including mathematics, literacy, and teacher education, to promote student engagement and learning (Griffths et al., 2021).

On the contrary, four obstacles have been discussed in literature that hinder the effectiveness of collaborative learning (Le, Janssen, & Wubbels, 2018). They are: (i) collaborative skills in which learners have no prior interpersonal and teamwork skills (Sun, Looi et al., 2025)(ii) free-riding in which learners do not give contribution to the given tasks (Chang, 2023) (iii) competence status in which high-performers undermines the efforts of low-performers (Järvelä, Järvenoja, & Malmberg, 2019; Chang, 2023) and (iv) friendship in which learners do not focus on groups tasks instead they are more interested in socializing with each other (Zheng et al., 2023). All these problems highlighted in the literature are mostly based on collaborative skills among learners. There is a need to identify such approaches that can help collaboration among peers during learning activities.

Since the last decade, the use of agile methodology in classroom learning has increased because it creates an adaptive and collaborative learning environment due to its iterative and incremental nature (Battou, 2017; Vogelzhang, Admiraal, & van Driel, 2021). Agile methodologies have been effectively used in the academy to teach software engineering, mostly with a project-based learning approach where the final learning product is software produced simulating the agile practices in small groups (Matthies, 2018; Parsons, MacCullum, & Sparks, 2021).

Thus most of the work done is to teach agile methods or approaches in higher education to software engineering students which is understandable as agile is a software engineering concept and to teach it to project-based approaches were developed (Paul, 2019). The agile process is regarded as an efficient collaborative method because it defines specific roles of the team members, task-based work to team members, frequent communication among team members and overall iterative process (Durak & Uslu, 2023). Therefore, there is a need to explore such approach in ubiquitous inquiry-based collaborative learning environments.

1.4. Research Gap

While agile methods have been explored in various educational contexts, their specific application to inquiry-based learning, especially in a ubiquitous environment, remains understudied. Research may explore frameworks for adapting agile principles (e.g., iterative cycles, flexibility, user stories) to inquiry-based learning, which is one of the critical gaps.

Agile methodologies are widely used in software development, since last decade, they have been explored for their potential in educational settings (Gannod et al., 2015; Kumar & Govender, 2016; Muñoz-Arteaga, López-Torres & Muñoz-Zavala, 2023). The nature of agile development, with its emphasis on iterative cycles, flexibility, and user-centric approaches, aligns well with the principles of active learning and student engagement. Several studies have investigated the application of agile practices in the classroom, highlighting their benefits in encouraging student responsibility, promoting continuous improvement, and enhancing learner engagement (Dewi & Muniandy, 2014; Gannod et al., 2015; Kumar & Govender, 2016; Schön, Buchem, Sostak, & Rauschenberger, 2022).

IBLis an educational approach that fosters critical thinking, problem-solving, and self-directed learning. Integrating agile methodologies into IBL could potentially address some of the challenges faced in such settings, such as the need for flexibility, adaptability, and continuous assessment. Developing appropriate assessment methods for agile IBLin a ubiquitous environment is another area that requires further exploration. Research in this area can help educators and instructional designers navigate the challenges of implementing agile IBLin technology-rich settings.

While agile methodologies are widely used in software development for collaboration and team effectiveness, their application in educational settings, especially for inquiry-based learning, is still emerging (López-Alcarria et al., 2019; Bolmsten & Kitada, 2020; Thiyagarajan et al., 2023). By exploring frameworks for adapting agile principles to inquiry-based learning, researchers can address this gap and provide insights into how to effectively implement agile practices in this context. Therefore, this research aims to bridge the gap between agile practices as a collaborative approach for IBL to enhance learning effectiveness and learners' engagement in technology-rich educational settings as shown in Figure 1.1.

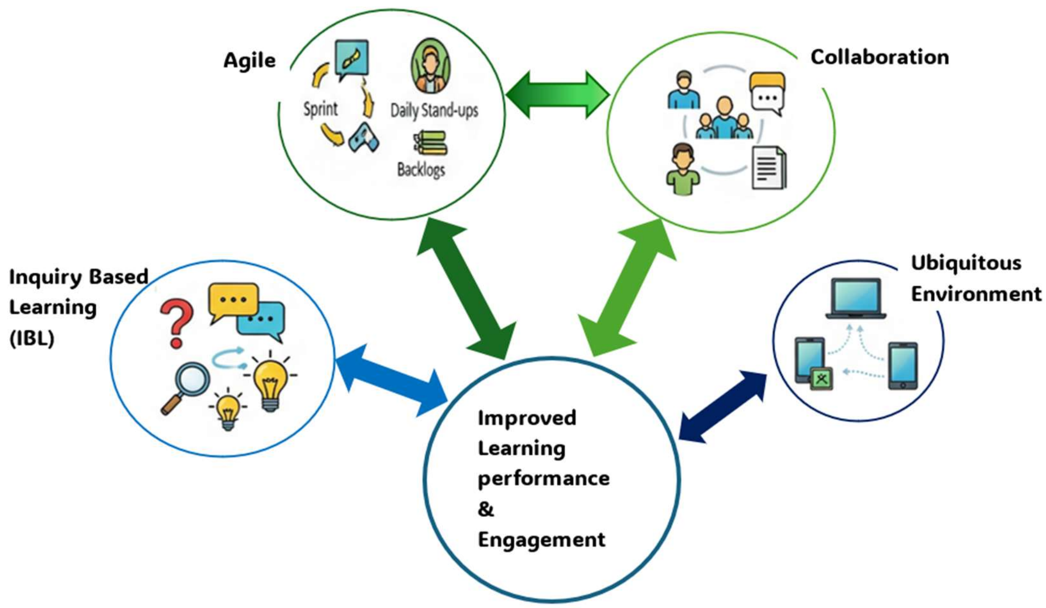

Figure 1.1. Conceptual diagram illustrating the relationships between Agile, Collaboration, IBL, and Learning Outcomes

1.5. Problem Statement

In the current school education, there are a few studies found in the literature that focus on collaborative IBL (Durak & Uslu, 2023; Ybanez & Barcelona, 2024). But these studies did not provide a structured process for collaborative learning and also no study demonstrated the practical implementation of collaborative skills among school students. On the other hand, few studies used agile methodology as a collaborative approach for project-based learning only (Voelzinger et al., 2019; Biswal et al., 2023). However, the use of such agile-based approach for ubiquitous IBL as a structured process and effectiveness of its practical implementation among middle school students was not addressed in the literature.

1.6. Research Objectives

The main research objective is to develop a learning environment using agile approach for ubiquitous IBL environment.

The sub objectives are:

a) To design a framework for IBL in a ubiquitous environment using an agile approach.
b) To develop an agile-based application for inquiry-based ubiquitous environment.

c) To evaluate the effectiveness of developed learning environment.

1.7. Research Questions

The research questions of this study are defined as:

a) How to develop a collaborative inquiry based environment on ubiquitous framework?

b) How can an agile approach assist in enhancing students' collaborative learning for inquiry based ubiquitous environment?

c) How does such an environment enhance students' ability to construct knowledge?

1.8. Research Contribution

The work in this research investigates the use of agile approach for collaborative inquiry in a ubiquitous environment for middle school students. The contributions of this research are threefold:

- Design a collaborative inquiry-based ubiquitous learning framework for integrating an agile approach to enhance collaboration among students.
- Develop an application to implement the proposed framework.
- Evaluation methodology for the developed learning environment in order to validate the proposed framework.

1.9. Thesis Outline

The thesis is divided into five chapters.

Chapter 2 provides a comprehensive review of the theoretical foundations and related literature. It elaborates on inquiry-based learning, ubiquitous learning environments, collaborative learning, and agile methods in education, exploring their types, benefits, and challenges. It further synthesizes how these approaches intersect to form agile collaborative IBL in ubiquitous contexts, concluding with related work and identification of gaps that this study addresses.

Chapter 3 discusses the research methodology consisting of proposed framework ScrumBan Ubiquitous Inquiry Framework (SBUIF) adapted from scrum-based framework and design science research methodology. It explains the framework's phases, roles, and responsibilities, and describes the development of the uASK application as its practical implementation. The experimental design is outlined, including evaluation methods based on CSCL affordances and the M3 evaluation framework at micro and meso levels.

Chapter 4 presents and analyzes the results of the experiments conducted with middle school students using the uASK application compared to Trello. It discusses findings at both micro and meso levels, covering student satisfaction, learning performance, and time efficiency. Comparative analyses, combined results, and interpretations are provided to evaluate the effectiveness of SBUIF in enhancing collaborative IBL within ubiquitous environments.

Chapter 5 summarizes the key findings, revisits the research questions, and reflects on how the study contributes to advancing knowledge in agile and inquiry-based education. It outlines the limitations of the research and suggests directions for future work, particularly in extending agile-based inquiry approaches to broader educational domains and refining technological implementations.

CHAPTER 2

BACKGROUND

This chapter explains background of the study by reviewing existing research. The focus is on inquiry-based learning, ubiquitous learning environments, collaborative learning, and the use of agile methods in education. The concept of IBL is based on constructivist theory. IBL focuses on active student participation through asking questions, exploring ideas, and investigating problems. While Ubiquitous environments expand this learning beyond classroom by linking digital tools and real-world learning situations. Collaborative learning supports this process by encouraging students to work together, share responsibility, and build knowledge as a group. Agile development approaches which originally came from software engineering for project management. It introduces flexibility, iteration, and teamwork elements into education and offer new ways to organize and support collaborative inquiry. By combining these areas of research, this chapter highlights gaps in existing studies and explains the need for an integrated agile-based framework to support collaborative inquiry learning in ubiquitous environments, thereby laying the foundation for the proposed methodology.

2.1. Theoretical Background

Constructivism is based on the idea that people build their own conceptions of reality via experience and reflection. The conventional teacher-centered learning model, in which the learner's job is to assimilate and repeat knowledge, is challenged by this method of instruction (Xie, Wang & Hu, 2018; Nurhuda, Al Khoiron et al., 2023). By nature, humans learn from their experiences, either they fail and succeed they will learn. Learning is an active process. Perception is an important part of constructivist theory. Humans construct their world according to their perception. The way they perceive, it is updated from time to time after experimentation. Constructivist theory promotes curiosity and the means to satisfy curiosity.

Learning is an ongoing process (Devi, 2019) whenever new information is encountered, learners have a better understanding, and they will evaluate, validate and update their knowledge. The learning process increases the cognition of the learner. Better understanding, and alteration of the perspectives (Devi, 2019). Constructivism centers the educational process around the learner, acknowledging their distinct viewpoints, past experiences, and the significance of their active participation in the learning process (Xu, 2019; Almulla, 2023).

From a constructivist perspective, the teacher plays a major role in the learning process rather than merely being a transmitter of content. Instead, the teacher serves as a facilitator, collaborator, and resource, working collaboratively with students to recognize learning opportunities, put their theories to the test, and develop their own knowledge structures (Pundir & Surana, 2016). This perspective empowers students by creating an atmosphere for them to take responsibility for their learning, giving sense of empowerment and agency for ensuing success in long-term learning.

Learning according to constructivist ideas requires participants to engage in social interactions which boost educational collaboration during the knowledge-building process. Students assemble understanding and develop knowledge in unison through collaborative discussions which involve idea exchange and perspective evaluation according to Xu (2019). The collaborative features of constructivism match growing recognition about the effectiveness of peer-to-peer education and effective learning communities. Criticism toward constructivism is that minimal instructor guidance in learning can become a barrier for students to learn detailed information correctly because lack of essential scaffolding supports hinders their knowledge development (Alanazi, 2016). The criticism requires educators to deliver acceptable guidance combined with appropriate teacher assistance for students to achieve active knowledge construction.

On the contrary, the criticism of constructivism advocates that it is a minimally guided style of teaching. It affects learning while working with minimalistic guidance, students have a feeling of loss and frustration (Lemos, 2020). The biggest criticism of constructivism is that students require to connect information to the real world for better understanding whereas it does not support the learning need. The lack of resources in support of constructivism is an issue in the application of this technique. Different mindset and thinking is another hindrance in the constructivist technique and another important factor is costly in term of equipment and teachers training (Kundi & Nawaz, 2010) . The concept “constructionism”, is defined as the successor constructivism, and mentioned learning by making (Patton, 2019), which simply means that convert your learned knowledge into a tangible object, to show what you have learned. Only then has the learner constructed knowledge. Constructivism is primarily the learning process and constructionism is about the teaching process according to (Patton, 2019). Inquiry based learning is an approach in constructionist framework that encourages learners to construct their own knowledge by exploring, engaging, questioning and investigating. IBL is an important part of the constructivist approach. This approach suggests that students learn best when they actively build their own understanding through experience and reflection, rather than just receiving information from the teacher. Constructivist classrooms learning is student-centered and real understanding. IBL is based on constructivism and uses inquiry cycles within authentic contexts, encourages students to explore, question, deliberate, and reflect, thereby deepening conceptual understanding (Li & Zhang, 2025).

2.2.Inquiry-based learning (IBL)

Inquiry-based learning at its core is based on traditional teacher-centred classrooms. But instead of only receiving information, students are actively engaged in the process of building their own knowledge and understanding by exploring ideas , questioning, and investigation. This approach gives learners a more active role in their learning process which develops their critical thinking abilities, problem-solving skills and subject matter understanding (Saputro et al., 2019). The terminology of IBL constructs multiple distinctive categories through which we distinguish their separate characteristics and goals. The 5E Instructional framework provides learners with a five-step learning cycle going from Engage to Explore, Explain, Elaborate and Evaluate according to Duran and Duran (2004). Through this learning structure students experience an introductory engaging task followed by experimental exploration and inquiry before working to explain their findings. The learners move to describe their conclusions and share their understanding before instructors connect them to broader concepts and expand the knowledge base. Students and teachers use the final step of assessment to evaluate the learning process so both can determine the depth of understanding while identifying improvement areas (Gu, 2023; Arifin, Saputro & Kamari, 2025).

Another important factor to consider within IBL is the level of support to students. Some IBL approaches such as guided inquiry are highly structured. In which the teacher provides complete guideline and steps by defined questions and giving prompts for what to do (Gu, 2023; Orosz, Németh, Kovács, Somogyi & Korom, 2023). In open-ended or ‘pure’ inquiry, students have much more freedom in developing their own questions and designing their inquiries. Regardless of the variation used, the goal of IBL is to develop students' ability to think scientifically as they develop skills such as formulating hypotheses, collecting data, analysing data, and communicating findings. Students engage with the real-world problems and develop important skills such as critical-thinking and problem-solving (Wahyuni et al., 2017; Rude, 2025). Research is being done in this domain but, moving away from traditional forms of teacher-centred or driven instruction can have its own set of challenges for both teachers and learners. Despite this, research shows that inquiry-based learning improves learners’ engagement, deeper understanding, and the development of lifelong learning skills, make it make it a valuable approach for further study and improvement (Quigley et al., 2011). While Hava & Unlu (2021) reported that inquiry-based learning significantly improve engagement in secondary classrooms, Santana-Vega et al. (2023) found it had limited impact in higher education settings. These differences may be due to limitation in learner maturity and learning contexts. So, it suggests that IBL effectiveness is highly dependent on the learners’ levels and the amount of guidance provided.

In literature, inquiry-based learning approaches have been used in indoor environments using various technologies such as mobile, web, augmented reality, sensors. These environments were also used different kinds of inquiries including abductive deductive and inductive for primary, secondary and high school students. These technologies have enabled students to engage in virtual experiments, simulations, and collaborative problem-solving activities, enhancing their inquiry skills and conceptual understanding. It has also allowed personalized learning by using different technological tools by addressing different learning styles and learning speed. Research also shows that applying inquiry-based learning approaches in indoor classroom environments has its advantages. Such as students developed critical thinking skills, it improved their creativity, and scientific reasoning across different age groups. One example of such application is 'Thinknlearn'. That is an inquiry-based learning mobile application developed by (Ahmed & Parsons, 2014) for high school students and researchers. This application is based on an abductive inquiry approach which is rarely used in literature compared to deductive and inductive approaches. This approach encourages the learners to formulate hypotheses based on incomplete or uncertain information and help them think critically and solve problems creatively. The use of mobile applications like 'Thinknlearn' is an example of inquiry-based learning that shows how the use of technology can enhance student engagement and support more interactive and meaningful learning experiences. By incorporating various levels of inquiry and supporting techniques, educators can customize these technological tools to meet the different needs of students across different age groups and educational settings. In another research, weSpots developed a personal and social approach for students engaging in inquiry-based learning. In order to perform inquiry-based activities students can create their own learning environment using cloud services and tools by using weSpots. These activities can be uploaded for further investigation and feedback from their teachers and students on the weSpots network (Mikroyannidis et al., 2013).

The benefits of IBL after going through the research process are, it promotes the students to think critically and also encourages the students to improve their problem-solving skills in the learners, which promotes creativity in the learners. The IBL in the education system improves communication skills, which helps the students better understand the problem and collaborative learning (DiBiase & McDonald, 2015). The curiosity of the learners can be fulfilled using many ways, there are types of inquiry, confirmation, structured, guided, and open inquiry. they can be fulfilled in many ways, asking the teacher questions, fellows, searching through the books, or using devices to do the learning (Alameddine & Ahwal, 2016). Learning can be done in many ways with time. The most common and growing medium of satisfying one's curiosity is learning through handheld devices; mobile, tablets, computers, and laptops.

Mobile applications and platforms like 'Thinknlearn' and 'weSpots' are examples of educational technology that supports inquiry-based learning. These tools not only provide students with access to a wide range of resources. They also allow them to create and share their own learning environments, helping with collaboration, peer interaction and feedback. By allowing such technologies into the classroom, educators can create more personalized and interactive learning experiences that can support learners of different learning styles and encourage students to take ownership of their education. In other instance, Umer et al. (2017) developed a mobile augmented reality plant inquiry-based learning system called MAPILS. This application was tested with 42 high school students to identify the benefits of using MAPILS. The result showed a promising and enjoyable learning experience for the students (Umer et al., 2017).

But outdoor, ubiquitous and context aware learning is also gaining much popularity. As, it fosters Self-exploratory process of gaining knowledge, enhance problem solving skills, critical learning & understanding of concept. The MAPILS application demonstrates the potential of mobile augmented reality in enhancing plant-based education for high school students. This technology-driven approach to learning not only engages students but also provides interactive and immersive experience in studying plant biology. This also shows the shift in education towards outdoor and context-aware learning environments. That supports the growing emphasis on education through experiments and allowing students to develop critical thinking skills and a deeper understanding of different concepts through hands-on exploration (Umer et al., 2017).

2.2.1. Types of IBL

IBL can be further be divided into distinct phases with each having unique characteristics and objectives. These phases guide students through a structured process of scientific discovery. By drawing their attention to the key concept of scientific thinking and reasoning. The specific stages typically include five stages that are engagement, exploration, explanation, elaboration, and evaluation. They all work together to build a solid and cohesive learning experience (Pedaste et al., 2015). While inquiry-based learning has achieved a lot of credibility as a practical approach in supporting students to learn and understand. But it can often be challenging for teachers to implement, and educators may face some limitations when it. There may be some teachers who are not entirely comfortable or do not know precisely the best strategies and techniques needed to plan an inquiry-based lesson. That can result in a gap between the theoretical basis and the actual practice of being inquiry-based (Duran & Duran, 2004). Such a gap causes both students and teachers to struggle to carry out meaningful inquiry activities. These challenges often faced when teachers are not able to apply inquiry principles into classroom practice or provide proper guidance during learning activities. But for addressing these challenges, it often requires significant professional learning and continuous feedback. Also sufficient time for teachers to practice and adapt inquiry-based teaching methods to different classroom contexts (Kazempour & Amirshokoohi, 2014).

To create a meaningful and well-structured learning experience all inquiry phases follow such as engagement, exploration, explanation, elaboration, and evaluation, which work together to form an inquiry (Pedaste et al., 2015). Inquiry-based learning has gained recognition as an effective method for student learning. Yet teachers face many difficulties when implementation because of a lot of difficulties emerge during its application. Some teachers experience problems when planning inquiry-based lessons due to their limited understanding of appropriate strategies and techniques (Duran & Duran, 2004). This lack of understanding creates a gap between theoretical standards and real-world implementation. Such a gap can prevent the successful practice of inquiry, and students and teachers can have difficulties practicing inquiry when teachers are unable to take the principles of inquiry from theory to practice or provide an inquiry learning experience for students.

On the other hand, structured inquiry allows students with a pre-defined question or problem and a specifically determined procedure and set of resources to use for their investigation. Structured inquiry occupies a middle ground between the two extremes, providing a happy medium between teacher support and student independence. Although the teacher specifies the overarching question/problem in structured inquiry learning, students would be able to explore and investigate the concepts in their inquiry. This ultimately allows students to develop critical problem-solving and scientific reasoning skills in a more structured environment (Pedaste et al., 2015). Ultimately, the type of inquiry-based learning should be based on the learning objectives, students' prior knowledge and skills, the available resources, and the constraints in the classroom environment. Understanding the specific purpose and characteristics of the two extremes of inquiry-based learning will allow educators to stylize their instructional approach to meet the attributes and needs of their students moving forward, creating an active and interactive learning environment that enables students to be active participants in their learning (Bunterm et al., 2014; Hmelo-Silver et al., 2015). Regardless of the specific type of inquiry-based learning employed, these approaches draw students' attention to the critical features of scientific thinking and reasoning. Thus, creating a robust and coherent learning experience promotes deep understanding and the application of knowledge to real-world situations and challenges (Pedaste et al., 2015).

2.2.2. Previous use of IBL.

Table 2.1 summarizes some of the recent studies in inquiry-based learning. Research in educational technology offers a many of methods that have been implemented across all educational levels to improve learning experiences. Some litrature has been on applications designed for individual learners but mostly the focus is on STEM directed subject areas. Some of the applications like Lozano et al. (2023) and Zhang et al. (2024), developed Game-based methods to design applications for school learners. Becker et al. (2019) created an AR immersive experience focused more on teaching physics concepts. Finally, Siantuba et al. (2023) in their study were focused on university students and used Go-Lab-online digital laboratories to facilitate inquiry learning in physics education. Research relating to educational technology shows multiple of approaches that have been practiced enhancing learning experiences at all levels of education.

While many of these studies were for individual learning experiences such as by Becker et al.(2019), Lozano et al. (2023), Siantuba et al. (2023), Hu et al. (2024), Zhang et al.(2024) and Arifin et al. (2025). But some researchers worked on collaborative approaches, especially for university students like Riegle-Crumb et al. (2023) and Mueller et al. (2024) as shown in Table 2.1. These studies range from science (Arifin et al., 2025) to general education (Hu et al., 2024; Riegle-Crumb et al., 2023), with a few integrating inquiry-based pedagogy (Hu et al., 2024; Riegle-Crumb et al., 2023) that might improve learning outcomes better. Mobile technology has become popular and multiple studies used it to create interactive and engaging learning experiences such as it was used by researchers Becker et al. (2019), Lozano et al.

(2023), Siantuba et al. (2023) and Zhang et al. (2024), thus proving to be effective in modern educational contexts.

Table 2.1: Inquiry-based learning studies

Research Study	**Type**	**Domain**	**Learners**	**Platform or Application**	**Limitations**
Lozano et al. (2023)	Individual	Mathematics	General learners	Mobile game application	Improved motivation and conceptual understanding, but limited collaboration opportunities.
Hu et al. (2024)	Individual	General Education	University Students	None specified	Positive impact on engagement, but lack of technological integration limits scalability.
Riegle-Crumb et al. (2023)	Collaborative	General Science	Preservice elementary teachers	Collaborative inquiry projects (face-to-face)	Enhanced peer learning, but limited to higher education; little focus on digital environments.
Mueller et al. (2024)	Collaborative	Leadership	University Students	Online collaborative tasks using whatsapp	Improved teamwork and leadership skills, but study focused on university-level learners only.
Arifin et al. (2025)	Individual	Science Education	University Students	None specified	Strengthened scientific reasoning, but no structured collaborative framework used.

Siantuba et al. (2023)	Individual	Physics (Circular Motion)	University Students	Go-Lab Online module with digital laboratories	Improved inquiry skills, but issues with sustaining long-term engagement in digital labs.
Becker et al. (2019)	Individual	Physics (Uniform Motion)	School Students	AR app using Tablet PCs with specialized video analysis applications	Boosted visualization and learning performance, but limited collaboration features.
Zhang et al. (2024)	Individual	Science (biology & environment)	School Students	Experiverse (Mobile application for inquiry-based learning)	Encouraged self-directed inquiry; collaboration functions not fully integrated.

Although the studies in Table 2.1 shows the use of inquiry-based learning across various technologies such as using mobile applications, AR tools, and online laboratories. Most of the focus is on individual learning experiences (e.g., Becker et al., 2019; Lozano et al., 2023; Siantuba et al., 2023; Zhang et al., 2024; Arifin et al., 2025) and these approaches improved motivation and understanding of concepts, but they often overlook the collaborative context of learning. There are relatively fewer studies on collaborative IBL (e.g., Riegle-Crumb et al., 2023; Mueller et al., 2024) and are largely limited to higher education contexts, with few studies at the school level. This indicates a gap in literature and identifies the need to design and evaluate structured frameworks that can support collaborative inquiry at school level. Especially by integrating ubiquitous technologies to extend learning beyond classroom boundaries.

While IBL on its own can encourage development of skills to enhance curiosity, reasoning, and critical thinking but it has its limitations. Without the support of technology, IBL is often limited to classroom and, it reduces accessibility to resources and different environments along with flexibility, and opportunities for engagement of learners beyond school hours. Students rely on only textbooks and teacher-provided materials thus missing out on digital resources, real-world data, and interactive tools that could create meaningful inquiry (Roslan, Phang, Pusppanathan & Nawi, 2023). Moreover, in the absence of collaboration, IBL can become an individual activity rather than a shared learning experience. This limits students' chances to share ideas and engage in meaningful teamwork activities (Bektesh, Gollopeni & Avdiu, 2023). When real-time tools and collaborative platforms are not included teachers also face challenges in monitoring inquiry processes and providing timely support. As a result, IBL without ubiquitous environments and collaboration offers fewer opportunities for authentic, technology-enhanced, and socially meaningful learning experiences, thereby limiting the development of critical 21st-century skills.

2.3.Ubiquitous environment

The word ubiquitous means something present anyway, anywhere, and anytime. Combining the words environment and learning with ubiquitous can be defined as the learning environment that is learning environment that is present for the learner to learn from anywhere, anytime, and anyhow (Krumm, 2018).

In other words, Ubiquitous learning is stated as learning that improves the learning using different mediums anywhere anytime, and anyway (reference). P-learning (use of sensors to create a context-aware setting) as mentioned by(Krumm, 2018) , m-learning is also a part of U-learning. It enables the access of information from anywhere, at any time using any means like wireless, or mobile (Kumar & Nanda, 2019). The ubiquitous environment (UE) acts as a bridge between the formal and informal methods of learning. The ubiquitous environment provides a social way of learning (Krumm, 2018). It is an innovative approach for the learners. The ubiquitous environment is placed remotely, the use of different means to acquire knowledge. The use of innovative devices, the internet, mobile learning, using specific sensor-based devices i.e. p- learning comes under the heading of ubiquitous learning. It is a student-centered approach, where students have control, and their role is most important in this learning style (Pimmer, 2016; Mhlongo, Mbatha, Ramatsetse & Dlamini, 2023).

The main theme of UE is to encourage students to increase their knowledge base, by applying and using modern and innovative technology for learning, solving, analyzing, and searching. The word u learning is derived from the word ubiquitous computing, which states that the user can access the computer anywhere and in any physical environment they are present. Any user holding a mobile device with the use of the internet can perform computing regardless of the physical location. The idea of u-computing supports the pedagogical theory of constructivism (Lin et al., 2017). The concept of constructivism is mentioned above. The use of u-computing with constructivism helps learners build knowledge based on their prior knowledge. Incorporating u-computing with the learning methods while designing the learning system can enhance the learning base of the learners, easily adaptive with the proper guidance and knowledge of the system and modern technology (Kumar, 2019).

Mobile learning is accompanied by u-learning. Also, m-learning is a part of mobile learning, the learning that can be done using mobile devices, using wireless computing, and also learning new knowledge using mobile devices. The mobile device is another way to play its part in the ubiquitous learning environment (Pimmer, 2016). Using different applications to support learning, this helps teachers to teach, and students to learn, search, experiment, solve problems, and acquire knowledge. This helps in improving the learning method to learn new knowledge and solve complex problems (Pimmer, 2016). With the growing use of technology in every aspect of life, technology has impacted on learning methods and environments. Some of the benefits of UE are as follows. Much of the research considers ubiquitous inquiry such as smartphones bases environment for language learning SCROLL (Li & Ogata, 2012). Hwang & Shi (2011) proposed an RFID based confirmation inquiry system to study butterfly ecosystem using concept maps (Hwang, Shi, & Chu, 2011). Also, in another research, Hwang et al. (2012) introduced an inquiry-based learning application using context aware ubiquitous learning approach, to gain practical understanding of planetology and optics topics (Hwang et al., 2012). Alos , a web-based application for learning English as foreign language was developed by Huang (2019) to create an immersive learning experience to learn language skills individually (Huang, 2019).

These studies highlight the wide range of nature of applications of technology-enhanced learning in different environments across many subjects. Its examples range from application for learning language skills to understanding of natural sciences concepts. The combination of combining ubiquitous devices to create context-aware systems shows a shift towards more creating more interactive and engaging educational experiences. By creating such learning environments, it not only helps applying different learning styles but also promote active engagement and understanding of complex concepts. By incorporating context-aware systems and immersive technologies, educators can create more engaging learning opportunities that help individual student needs and preferences. This approach to education has changed traditional teaching methods and improved learning outcomes across various disciplines (Huang, 2019; Hwang, Shi, & Chu, 2011).

In addition, Brenner et al. (2017) developed an application for learning biology science using augmented reality mobile application. This application used guided inquiry which it lets the students explored the outdoor environment and then focus on an object like animal or plant for conducting inquiry (Brenner et al., 2017). These technological advancements in education also include mobile applications. This offers students the opportunity to engage in interactive learning experiences outside the classroom by studying different plant samples. Such applications can change learners everyday interactions into rich learning environment. By encouraging learners to explore and investigate real-world. Guided inquiry approaches combined with augmented reality (AR) tools can enhance students' understanding of complex subjects like biology. By supporting a more hands-on and immersive learning experience it will help foster an engaging learning experience. Fitbit, sensors and Smart gadgets like watches or glasses can also be used to create a ubiquitous environment. However, these studies are for individualized learning, and it is also necessary to develop an adaptive approach by taking learning experience into account (Hung et al., 2014).

One of the uses of UE is to increase social and communication skills among the learners and the teachers. This improves cooperation and collaboration learning (Lin, 2017). It not only benefits the collaboration but at the same time enhances the active learning process among the learners, with unlimited access to information and resources (Lin, 2017). The access to information and resources becomes timelessly available and accessible, ignoring the physical boundaries. The availability of information at the fingertips increases critical thinking in the learners, by the availability of authentic and contextualized information. It not only improves critical thinking and collaborative learning but also improves and enhances the problem-solving and analytical skills of the learners, with the use of IoT, AR, RFID, and sensor devices (Lin, 2017; Karuppiah, Ramana, Mohanty, Devarajan & Nagarajan, 2025). This helps the learners to apply the learned knowledge in practical applications, and to apply it in another kind of situation and area.

The application of UE is increasing day by day. Some of the applications of UE are the museum guide system, language learning system, science learning system, and location-based learning, these are a few of the examples of UE. Various applications have been developed over the past few years that incorporate UE in their learning method. The development of UE is a challenging task, it requires clear objectives and goals to be achieved, the selection of relevant data for learning, and the data should be properly organized. It is necessary to keep in mind the learner's aspects of learning, their physical, social, emotional, and cognitive aspects, and the effects these will have on the learners. Technology and the devices should be aligned with the learner's needs. The devices should be suitable, accessible, and reliable for the learners (Chen, 2016). For the development of UE, it is necessary to keep in mind the personalization and adaptation features. The UE brings improvement in the learners, and the development of the system should be aligned with the learners to achieve the goal and objective of UE in the learning system.

While UE are praised for enabling learning anytime and anywhere. The literature provides contradicting views about their value in supporting learning. For instance, researchers like Ruiz-Calleja et al. (2023) shows that UEs can be an effective tool by integrating real-world and digital tools to improve science learning outcomes. But Hwang et al. (2021) warned that if proper instructional design is not applied, these environments and resulting information overload will risk overwhelming learners and distracting them from meaningful inquiry and learning. Moreover, many studies stressed that it is technological affordances like mobility and context-awareness rather than the teaching that guides learning processes (Aljaraideh, 2022). This suggests that while UEs incorporating will increase access and flexibility, they may not promote deeper engagement if not supported by structured approaches such as inquiry-based learning. Thus, a clear gap exists in research on how to embed pedagogical strategies into UEs to maximize their effectiveness in school-level education.

2.4.IBL in a ubiquitous environment

Combining inquiry-based learning and a ubiquitous environment is said as done in inquiry, searching for a query at anytime, anywhere, and anyhow, using technology, with the use of the internet. Combining and Implementing IBL in ubiquitous environments in the learning process, in school, in education, business problem-solving comes with some challenges and benefits (Devincenzi et al., 2018). Using inquiry-based learning in the ubiquitous environment can greatly bring change in the education system or school. Empowering students to actively inquire, and transform their knowledge, and their critical thinking skills. This method facilitates the integration of technology in the learning process, enabling the student to cooperate with other members, and explore different means, and real-world problems. The application of Inquiry-based learning in the ubiquitous holds many positive effects on the learning or education system and affects the learners (Devincenzi et al., 2018).

This approach is rather more nontraditional, it is not teacher-centered learning but student-centered learning. This methodology gives the students the autonomy to inquire as they require. This allows the students to search and inquire using technology in a ubiquitous environment as they require. This empowers the students to structure their learning with the base learning. This enhances the motivation of the learner as they get control when they inquire and learn. With the availability of technology and the internet, every person has a device to acquire knowledge in their pockets. This promotes the ongoing learning process.

Inquiry-based learning inspires critical thinking, and with a ubiquitous environment, it satisfies curiosity instantly. Ubiquitous technology offers learners access to information instantly, which enables an active learning process. The access to information, all the time allows the learners to assess the knowledge and construct knowledge by critically analyzing the information. This methodology promotes cognitive skills, Metacognition, memorization, critical evaluation, and deeper understanding. Thus, ubiquitous technology can be used by learners for personalized experiences and learners can get personalized learning based on their progress.

Furthermore, the use of ubiquitous technologies in the learning process allows for better and close-to-reality information and experience. The learner has the opportunity to inquire as they need regarding the real world, using ubiquitous technology or devices allows the learners to get contextualized, location-based information, it helps the learners to relate the information to the real world (Aljawarneh, 2020). This type of learning improves knowledge, increases curiosity, and bridges the gap between knowledge and practical application. The advent of inquiry-based learning in the ubiquitous environment of the education system has transformed the role and responsibilities of teachers or facilitators. The information is in the hands of learners beforehand, the role of the facilitator is to give them guidance to do research and search, in the selection of technology, methodology of information acquisition, and information application. They play the role of evaluator, evaluate the performance, give feedback, and most importantly scaffold the process (Chu et al., 2019).

The ubiquitous allows the teacher to provide students with feedback. Teachers can use technology to give feedback, like Moodle, or learning platforms. The use of ubiquitous technology allows the student to self-evaluate their progress and track their growth (Hwang & Chen, 2017). Feedback, assessment, and evaluation an important features of the learning system, In the (Hwang & Chen, 2017) education system it is important to track the progress for the evaluation of the educational system . Inquiry-based learning in ubiquitous environments has another major impact like lifelong learning, creating opportunities for collaborative learning using technology, and overcoming limitations in the education system. With the evolution in the learning method, teachers use gaming in their teaching. Teaching and learning are improved using games. The games enable the students to improve their thinking, response time, knowledge, creativity and imagination, and critical thinking for problem-solving (Hwang & Chen, 2017) . Teachers using specially designed games to improve their knowledge can help the students creatively learn the course. This helps the student to stimulate their learned knowledge in stimulation.

Adopting IBL in a ubiquitous environment requires proper methodology, technique, and acceptability from the learners and the teachers. The inquiry-based learning in problem-solving by providing active learning method, critical evaluation, critical thinking, and problem-solving in the ubiquitous environment makes learning more effective and efficient.

Learning processes and techniques are evolving with time, but they need timely incorporation into the system to move forward with the fast-growing world. By incorporating IBL in a Ubiquitous environment, it holds many benefits not only for the learner but also for the teachers. Using IBL in a ubiquitous environment encourages learners to learn more, it increases the curiosity in the learners. Using Ubiquitous technology by the learners with the instantaneous access to the information (Aljawarneh, 2020). Immediate access enables and increases the motivation of the learners. This allows the learners to satisfy their curiosity. The IBL is ubiquitous and enables them to save the interactions, and their data and formulate the learning for more. This helps in future learning for the learners. Based on their past interactions show the results and recommendations upon the previous inquiry, learning, searching, and research.

This enables collaboration among the learners, due to inquiry, problem-solving, and cooperation to solve critical problems. This allows the learners to share their knowledge using ubiquitous technology in a ubiquitous environment. There is no fixed learning method for learning. They can formulate, and schedule the learning according to their availability, interests, and resources. The evaluation methods can evaluate their progress and provide assessments and challenges under their levels(Al Mamun et al., 2020) . One of the examples is doing mind training activities, the level of difficulty is increased according to the past performance in learning. The combination of inquiry-based learning and a Ubiquitous environment holds the potential to evolve the education system. Using different means to enhance the learning method can be effective and can improve engagement with education, critical thinking, and meta-cognition. Incorporating technology and education takes seeking knowledge and information to a whole different level.

2.5.Ubiquitous IBL Types

Technological advancements have opened up new avenues for learning, especially in the realm of science education, through the integration of mobile devices in inquiry-based learning (IBL) settings (Ishaq et al., 2020). There are various advantages to using these portable instruments. They offer flexibility to the varying levels of inquiry, help sustain student motivation and engagement, provide continual learning across varied contexts, and bridge formal and informal science learning. Leveraging sensor technologies for using mobile devices can create more experiential and engaging learning opportunities, which allow students to take ownership of their learning. This educational model is referred to as Ubiquitous learning, or U-Learning (Vallejo-Correa et al., 2021). Recent studies have shown that this learning environment is useful and beneficial to improve learner engagement and thinking critically (Wadtan et al., 2024; Adewale et al., 2024). Most importantly, those platforms can improve student learning, not only by gaining students' attention, but also by offering personalized and unique educational experiences (Ahmed et al., 2019). Thus, we can suggest ways to implement Ubiquitous inquiry-based learning types adapted from mIBL as summarized in Table 2.2.

Table 2.2: Ubiquitous inquiry-based learning types adapted from mIBL

Type of u-IBL	**Definition**	**Role in Ubiquitous Learning**
1. Authentic Scientific Inquiry	Real-world, evidence-driven investigations by students.	Mobile devices/sensors allow learners to collect field data and extend inquiry beyond classrooms.
2. Abductive Inquiry	Use of abductive reasoning ("inference to best explanation") to generate/test hypotheses.	Mobile apps enable observation logging, hypothesis creation, and iterative testing.
3. Collaborative Inquiry	Combines inquiry with collaborative learning models.	U-learning supports real-time communication, resource sharing, and peer feedback.
4. Collective Whole-Class Inquiry	Entire class engages in structured inquiry as a community.	Ubiquitous tools connect whole-class participation across formal/informal spaces.
5. Game-Based Inquiry	Embedding game elements (often AR-based) into inquiry tasks.	Mobile/AR tools situate inquiry in real contexts with playful challenges.

2.5.1. Authentic scientific inquiry

Authentic scientific inquiry is educational practice that it allows learners to be active participants in their learning by engaging with the world around them in a more meaningful way. Inquiry-based learning is a type of approach to teaching that is based on exploration, investigations, and discovery. Which are also key concepts for authentic scientific inquiry (Kuhlthau, 2021; Pedaste et al., 2015). The inquiry-based classroom is a different type of classroom compared to teacher-centric traditions. In an inquiry environment, students take on a more active role, they engaging in hands-on activities and asking questions formulate their own hypotheses (Yager & Akçay, 2010). The role of the teacher changes from teaching to facilitator students' scientific inquiry. The teachers job now becomes to providing necessary guides if students get stuck and support for a successful inquiry process (Drayton & Falk, 2001). The National Science Education Standards note that inquiry-based learning is important to science education and should be a tenet of instruction.

Authentic scientific inquiry extends to the entire educational environment and is not limited to the classroom only. Administrators, parents, and the community is reluctant to support types of learning as there is limited understanding and it requires more resources and support from the stakeholders for its successful implementation (Habig & Gupta, 2021). So their concerns and misconceptions are also needed to be addressed (Hmelo-Silver et al., 2015). The parents, and the community can be shown examples show complex aspects of inquiry are implemented and the frequent questions educators receive can be addressed. Also administrative support that is needed to carry out inquiry and its integration with the educational material can be discussed. Authentic scientific inquiry facilitated through inquiry-based learning engages and empowers students to be active participants in their educational experiences. Authentic scientific inquiry provides students with an opportunity to develop critical thinking, problem-solving, and deeper, more meaningful understandings of the natural world. Students practice inquiry when they engage in the scientific process; they can formulate questions, design experiments, analyze data and draw evidence-based conclusions - all of which are essential for success within the academic arena and the complex world we navigate (Quigley et al., 2011).

The core principle of authentic scientific inquiry is the pursuit of truth through disciplined and evidence-driven processes. Scientists are called to engage in research through an open, unbiased perspective which entails the careful design of experiments, data collection, and conclusions driven by the data and evidence collected. Authentic scientific inquiry is of utmost importance for informing policy and regulations as it provides the base evidence for evidence-based decision-making (Kretser et al., 2019). A key strength of authentic scientific inquiry is its ability to challenge current narratives and expand the limits of human capability and understanding (Maulucci et al., 2014). Authentic scientific inquiry relates to transparency and accountability as researchers are expected to provide their methods used, data generated, and findings to the scientific community enabling the peer review approval and replication of findings (Munafò et al., 2017).

However, the pursuit of authentic scientific inquiry also has its own set of drawbacks. Conducting scientific inquiry in its spirit in a rigorous manner and implementing evidence-based methods can take time and resources. Also, it can be subject to bias and limitations characteristic of research. Further, self-interested parties can deliberately manipulate the uncertainty of scientific process and affect the integrity of scientific inquiry and influence policy decisions (Ioannidis, 2018; Kretser et al., 2019). With the rapid evolution of education comes the growing integration of ubiquitous and mobile learning technologies contributing to authentic scientific inquiry with students as a powerful tool. Inquiry-based learning, which asks students, as part of their learning process to explore, question, and draw their conclusions, is a critical way to facilitate retention of information and engagement with the learning process. The ubiquity of these devices has enhanced student interactions with their learning environments. These broad sets of opportunities for students to exercise collaboration and hands-on exploratory experiences with scientific concepts have changing the notions of formal and informal learning spaces. With these technologies, students can collect and analyze data, access numerous virtual sources of information, and share their findings with peers and instructors, all in an individualized and evolving space (Thongkoo et al., 2019).

The effect of ubiquitous learning on inquiry-based learning has been investigated widely. The research has found consistent positive effects of learning with devices incorporated into inquiry-based learning, including learning gains, student engagement, and retention of information. This suggests that there is a synergetic edge when ubiquitous technology is merged with inquiry-based pedagogy that might change the learning experience and propel students to be active, self-directed participants in the scientific process (Chen et al., 2008; Ahmed & Parsons, 2013). Ubiquitous devices allow students to collect and contribute data to scientific research, allowing students' experiences to foster a sense of ownership and engagement in the scientific process. Through authentic investigations, students build critical thinking, problem solving, and connection to the scientific process.

Additionally, mobile learning environments, such as ubiquitous and individualized form of learning, are used to seamlessly integrate formal and informal learning contexts. Students can shift from guided instruction to independent exploration by extending their scientific inquiry beyond the walls of the traditional classroom (Heflin et al., 2017). This flexibility creates a greater sense of engagement, a more holistic and richer learning experience that generates meaningful understanding of scientific concepts. Thus, creating a real curiosity about different phenomenon and events in natural world (Pollara & Broussard, 2011; Zheng et al., 2018; Heflin et al., 2017). It is also important to consider the challenges and limitations involved as educators and researchers continue to investigate the affordances of ubiquitous learning and inquiry teaching and pedagogy. Several students experience difficulties navigating ubiquitous devices through technology which leads them to develop unsatisfactory experiences or become detached. Pedagogical approach, technology, and student support considerations are important in order to maximize these innovative learning experiences (Herro et al., 2023; Heflin et al., 2017).

2.5.2. Abductive science inquiry

Abductive scientific inquiry has been a well-established scientific investigation method. It has recently gained fame as scholars and researchers are trying to adapt it to the process of scientific discovery. This stems from the idea that scientific knowledge is a product of abductive reasoning. Where abductive reasoning generates a range of different explanations by observed natural phenomena that a scientist then evaluate to determine the most reasonable one (Aliseda, 2009). Abductive reasoning is defined by scholar as a logical form of inference that "moves beyond the information given" (Haig, 2010) to formulate new theories and/or hypotheses that are not obvious from what already exists. This means that abductive reasoning is the process of theory and/or hypothesis creation in which learners go through a cyclic process of generating hypothesis, testing, and modification of explanatory models. This means that abductive inquiry challenges the conventional notions of deductive reasoning in science as a process of producing knowledge. Therefore, abduction is also seen as a productive means of uncovering new knowledge and moving science forward, as its use encourages researchers to think creatively about new information by imposing alternative explanations for specific phenomena, or to even consider completely new explanations that are not initially apparent (Haig, 2012).

Abductive inquiry is one of the types or forms of IBL. It is a widely used, basic concept of the Abductive inquiry is a combination of deductive and inductive research approaches. The inductive approach is the series of observations that lead to the result. The approach starts with the observation that leads to the reasoning for the creation of the hypnosis and then lastly the generation of the theory (Brandt & Timmermans, 2021). The deductive approach is a top to down approach, the theory is constructed, which will lead to the possible hypnosis, then the testing of the hypnosis and the result shows the confirmation of the theory generated in the first step (Earl Rinehart, 2021). The Abductive approach is a combination of inductive and deductive approaches. Based on prior knowledge and observation the theory is made or predicted and then suggests the best possible hypnosis, the testing may result in favor of the hypnosis and may result in the generation of new hypnosis. This is applied in the modification of the existing theory (Janiszewski & van Osselaer, 2022).

The scientific inquiry method under abductive reasoning enables investigators to change the way we think about scientific processes through dedication between creative exploration and alternative hypothesis evaluation to discover fresh scientific perspectives for natural world study (Rozeboom, 2016). Multiple scholars have pointed out the many difficulties that must be carefully managed while working with the abductive approach. The process of observing experimental phenomenon and their characterization during the abductive process is difficult. It demands scientists to exhibit both exceptional observational skills and a willingness to break from accepted beliefs. The collection of this evidence may prove difficult because researchers need to accept new data that contradicts their current beliefs and available scientific knowledge. In abductive approach to determine the "best" hypothesis the researchers needs to evaluate various competing explanations. The process of detailed comparison between different hypotheses, followed by the selection of a strong candidate, requires researchers to display exceptional analytical capabilities, as they must review the coherence, simplicity, and evidence strength related to each explanation (Janiszewski & van Osselaer, 2022).

A key advantage of abductive science inquiry is its capacity to generate new explanations and hypotheses. The deductive reasoning depends on premises to come to a logical conclusion, or inductive reasoning seeks to infer generalizations about patterns observed from data. The abductive reasoning finds the best explanation based on a set of observations (Haig, 2012). As an "inference to the best explanation," it can allow researchers to provide more creative and innovative hypotheses that can facilitate innovation (Aliseda, 2009). Indeed, the multivariate statistical method of exploratory factor analysis, as described in (Haig, 2010), can be considered an abductive approach to theory generation, as it exploits the principle of the common cause to uncover underlying patterns in data. Similarly, the grounded theory method, when properly reconstructed, can be understood as an abductive account of scientific method, in which theories are inductively generated from qualitative data. These abductive approaches offer a definite advantage in fields where traditional deductive and inductive methods may fall short. Specially in the social sciences and other domains where there are many complex, multifaceted hypothesis are the norm which are contradictory in nature.

Another concept that is gaining importance is the Abductive inquiry using mobile devices. The use of mobile devices in IBL is quite effective as mentioned above through research in different domains. Mobile learning helps in the formation of hypnosis using observation about the particular domain (Williamson, 2016). An application ThinkLearn is developed to facilitate Abductive learning in uIBL. This application helps the learners create reasonable hypnosis based on their observation (Brandt & Timmermans, 2021). This mobile is the practical application of IBL for the students in the classroom environment. There are four phases in the Abductive inquiry model; exploration, examination, selection, and explanation (Earl Rinehart, 2021).

The researchers, after conducting many experiments and assessments to test the use of mobile as ubiquitous devices in the learning environment, the result of some studies show that its use was effective as it improves involvement, motivation, and knowledge retention, increases curiosity, cognitive process, and critical thinking among the learners. However, the process and boundaries need to be set while using devices in the learning environment. Some researchers concluded the no impact on the students improved their abilities nor negativity impacted the learning of the students.

2.5.3. Collaborative inquiry

Collaborative inquiry can simply be defined as combining two learning methods. Combining the inquiry-based model with the collaboration model. Encouraging students to inquiry, discover, exploration in the cooperative environment(Lu et al., 2021). In other words, as mentioned by (reference), collaborative inquiry includes students, teachers, and other professionals cooperating to systematically analyze the problems and find solutions. The collaborative inquiry involves four stages; planning, acting, observing, and reflecting (Lu et al., 2021). Collaboration learning is a social learning approach, where learners interact with each other in problem-solving and working towards a common goal. An Inquiry-based learning approach is a learner-centric approach where the learner searches for the solution to the potential question, topic, hypnosis, or observation. It is an active process, where learners learn cognitive, problem solving and decision-making skills (Lu et al., 2021). The learner communicates among them for feedback and reconstruction of the knowledge. The core concept of collaborative inquiry is to enhance the learning environment and improve engagement, motivation, and collaboration among the learners. This type of learning bridges the gap between theoretical learning and the practical implication of knowledge. collaborative inquiry also provisions another type of learning, previously mentioned (Lu et al., 2021) formal learning, informal learning, problem-based, project-based, case-based, and also game-based learning.

In the previous research done in the collaborative inquiry , the researchers have used the formal methods of research, mentioned in the (Bell et al., 2010). The research has been conducted in the practical environment, secondary school. The research method used was, problem-based, observation, and experiment based (Bell et al., 2010). The students were given problems and with particular guidelines there had to solve a problem. The methods, results, team building, team management, methodology, and challenges faced have been the key points of the research. The result of the experiment was quite expected, collaborative Inquiry is an effective method, and the method increases problem-solving and cooperation. Their understanding enhanced and improved. It increases motivation, and interest in the problem increases evidently, participation in the CI process.

After thorough research there are many challenges regarding collaboration inquiry-based learning. Firstly, designing a collaborative inquiry requires high cognitive and metacognitive skills for the teachers, to formulate challenging questions and case studies. Also, the learners require a high level of skills to solve the questions, problems, and complex data analysis (Chan & Pow, 2020). Also, collaborative inquiry demands high Self-regulation and conviction at the learner's end to be able to manage time, peers skills, and cognitive skills to face difficulties and manage uncertainties. Moreover, Good communication skills are required. High social and emotional skills are needed to interact with peers and colleagues. To communicate, define the roles, responsibilities, conflict management, and handling different behaviors (Chan & Pow, 2020). The learner should have enough knowledge to use high-level computing devices, search engine filters, devices, and technologies to avoid discrepancies. Additionally, there is a high risk attached to empowering the learners with handling goals, resources, and strategies.

The method of collaborative inquiry-based learning is to identify the problem, and problem statement, collection of the data or the data set for the problem, analysis, and sorting of the data, to overcome the challenges mentioned above, there are some strategies like Scaffolding and Structuring. Scaffolding is a technique used by the teaching technique for learners. It is an effective way which helps learners to increase their problem-solving through proper guidance from mentors. Mentoring the task structuring, suggestions, guideline, or hints without giving those correct answers (Lämsä et al., 2018). In other words, providing guided instructions on how to solve the problem or the case, and letting them follow the steps and instructions to reach the correct answer (Hastuti, 2020).

The challenge of collaborative inquiry can be overcome through proper guidance and mentoring that support learners' cognitive skills, learning, emotional, social, and motivational development(Lu et al., 2021) . Whereas the proper structuring of goals, processes, roles, and tasks, by the teachers or the instructors to set the concise goals, tasks, responsibilities, and criteria for the learners. The structure not only includes setting the goals but also the assessment of the goals, processes, and tasks. Feedback from the learners and the teachers is important and should be taken with importance. The evaluation of not only the teachers but also the self-evaluation and reflection of the learners. The learners need to self-evaluate their progress and shortfalls (Lu et al., 2021).

The collaboration with the learners to share their ideas, knowledge, skill, and experience. Use their knowledge and ideas for practical implementation. The benefits of collaborative inquiry using these strategies are firstly it increases the understanding of the subject, and the retention of the knowledge and skills learned in collaborative inquiry. Also, the learners in collaborative inquiry encounter vast exposure, collaborating with different people, in different environments, and learning out of their comfort space, which enhances their cognitive and problem-solving skills. Additionally Helps in satisfying the curiosity, interest, and confidence of the learners and helps in making proper teams and groups work in the future, with the help they enhance and polish their skills and abilities.

Teachers gain many benefits, this helps teachers enhance their professional skills, knowledge, and expertise. Also, polish their management skills and ideas of teaching. Collaboration inquiry not only helps the students but also the teachers to improve their educational knowledge. Knowledge and information changes with time, and teachers also need to move forward with discoveries, this helps teachers with educational improvement (Hastuti, 2020). Correspondingly, the best practice for teaching is to understand the student's mindset, behavior, cognitive level, and latest trends, collaborative inquiry improves the ways of teaching and creates the opportunity for teacher leadership in the community of teachers. Not only the teacher but also the schools get many benefits, the school will be able to design a different curriculum aligned with the grades. For school, it would be easy to incorporate different ideas and teaching methods (Bell et al., 2010). The implementation of the collaborative inquiry will help with the professional development of the teachers which would benefit the school in the longer run. Moreover, it will help in building a better culture in the applied premises (Bell et al., 2010).

Collaborative inquiry is of the best learning practices for the students. As it helps them to improve their learning and set clear and achievable goals. It improves the learner's motivation, increases curiosity, and helps the students with knowledge retention. It is proven by learning psychology that people learn more and retain when they acquire knowledge in a group and invest their time in research. Communication is improved when working in a group, leadership qualities also improve working in the group. Students learn to face the challenges in the group. It improves the critical thinking of the students. Through regressive research in school, at different levels(Hastuti, 2020) researching the feasibility needs to be assessed, the abilities of the students and the teachers need to be assessed, and the learning ability, cognitive ability, the resources need to be identified. The development of collaborative inquiry is a core part of the process. Although some of the collaborative inquiry has been developed in the past like ThinkLearn, and My Project. These platforms enable students to communicate with their teachers in remote places and at any time. The questions, assessments, and progress can be assessed online. This promotes the concept of online collaborative inquiry-based learning, collaborative science inquiry, and collaborative problem-solving learning. These all hold the same concept of collaborative Inquiry-based learning (Hastuti, 2020). Based on the research in designing and implementing collaborative inquiry it can be concluded that the use of collaborative inquiry can play a positive role in the metacognitive development of the students and the teachers. The collaborative inquiry increases problem-solving skills, cognitive skills, and group work among the students. These skills play an important role in building up the skill set. Collaborative inquiry may seem like an advanced learning method to apply in the learning environment but has been proven to be an effective and efficient learning technique for both the learners and the teachers.

Technology can change the culture and alter the general perspectives regarding any subject or object. Technology has made people a part of the community, teacher's community, student community, and many other communities. It was evident that if anyone wants to improve their cognitive ability. Being an expert helps to improve cognitive ability and helps in growth. If a person wants to improve a certain skill set, should join that desired community. One of the closest examples of community-based design is a school, the students, parents, teachers, and all the related people become a part of the community. (Al-Samarraie & Saeed, 2018) They use all mediums; including computers, multimedia, books, projects, and assessments to transfer the knowledge and information they contain. The factors that effect collaborative learning Group awareness, the awareness regarding the member's cognitive abilities is essential for the effectiveness of the group. Group awareness affects collaborative learning in many ways(Panitz & Panitz, 1998). If the group is aligned with the learning, task, or problem, this will help them to collaborate in a better manner, resulting in the efficiency of collaborative learning (Fu & Hwang, 2018).

2.5.4. Collective whole class inquiry

In education, the concept of collective whole-class inquiry has emerged as a powerful pedagogical approach that involves the entire class in a collaborative inquiry on a professional concept, enabling educators to explore student responses to instruction and derive new meaning that can lead to changes in classroom teaching (Brancard & QuinnWilliams, 2012). One of the key benefits of collective whole-class inquiry is that it creates an understanding of inquiry among teachers. Through engaging in inquiry experiences and reflecting on their practice, teachers can develop perception of inquiry, recognizing its process and providing a context for building connections between various stakeholders, including science and other content areas, as well as science and real-life applications (Moseley & Ramsey, 2008).

However, the implementation of collective whole-class inquiry is not without its challenges. Teachers may face obstacles such as the need for clear, focused, and support to transform their instructional practice. In conclusion, the collective whole-class inquiry approach has a lot of promise in education. By supporting collaborative knowledge-building, increasing teachers' understanding of inquiry, this approach can be very helpful for student and the continuous improvement of educational systems (Quigley et al., 2011).

2.5.5. Inquiry with Game Component.

"Game-based inquiry" is an educational technique combine gaming elements into problem-solving and investigative learning. Games serve as educational tool, using technologies like augmented reality (AR) to create lifelike experiences. For ubiquitous learning, this approach uses mobile devices, AR applications, or game-based systems to enabling students to interact with their surroundings at any time and place. Thus creating engaging and experiential education experience. It have many applications in ubiquitous settings of science education through AR games and Scavenger Hunts. Also programs like EcoMOBILE (Environmentally Situated Mobile Outdoor Blended Immersive Learning Environment) allow students to explore actual ecosystems, gather virtual specimens, and evaluate hypotheses. Learners use different tools like AR devices or to scan QR codes or AR markers in natural environments, to engage in an interactive learning activity (Dunleavy et al., 2009).

Another application by researchers Wojciechowski & Cellary (2013) used an AR-Based Historical Investigation game to create a TimeWarp initiative using AR to enable students to examine historical events by superimposing virtual characters and objects onto real locations. (Wojciechowski & Cellary, 2013). Bressler & Bodzin (2016) studied applications such as DragonBox using AR to transform abstract mathematical concepts into tangible and manipulable objects. Students resolve problems by interacting with virtual objects in their actual environment, thus improving their reasoning and problem-solving abilities (Bressler & Bodzin, 2016). Games like ChemQuest AR offer simulated chemistry lab experiences, where students can engage with AR representations of chemical reactions to investigate questions such as the impact of temperature on reaction speeds. This method makes experiments accessible without the constraints of physical laboratories (Akçayır & Akçayır, 2017).

In conclusion, game-based inquiry in ubiquitous learning environments using technology, particularly augmented reality (AR), to create immersive and interactive educational experiences. As technology continues to evolve, game-based inquiry in ubiquitous settings holds significant potential for transforming educational practices and improving learning outcomes across diverse disciplines.

2.6. Collaborative learning

Collaborative learning can simply be defined as learning in a collaborative environment from the beginning. Contrary to co-operation learning, co-operative learning holds a slight difference from collaborative learning i.e. the tasks a divided at the beginning and then comes the collaboration in the next phase. In collaboration learning the collaboration starts from the first phase of the learning. In other words, tasks are not assigned to individuals but instead, all of them are jointly involved in the task performance. The prime difference comes in the teaching world, in the cooperative environment the responsibility falls on the teacher, who merely has the knowledge and needed to be transferred to the student through her, and the student cooperates with the teacher in the transfer of the knowledge. The collaborative learning method is more applied for students in higher secondary and onwards. Collaborative learning is defined as the process of sharing knowledge and constructing meaning. This applies to the complete involvement of all the peers involved to open up their minds and discuss what they know and get more knowledge with the help of other peers. Lin & Lin (2015) has defined collaborative learning as the "social psychology of knowledge" (Lin & Lin, 2015). The teachers also play an important role in collaborative learning, and also the student uses different means to gain shared cognition.

When it comes to the application of collaborative learning, there can be many ways every applicant can develop and use their ways. Collaborative learning requires a significant amount of self-recognition, the ability to accept criticism, and most importantly requires maturity from the students. The strategies for the implementation of collaborative learning (Zheng et al., 2015) are exchanging of ideas, mediated opinion transmission, reciprocal peer assessment, assessing commission, participation symmetry, patterned critical discussion, critical debate with position alternation, the collective weight of alternatives in a decision-making situation, round table with a moderator and preparation of agreed conclusions, commented conference and fish tank. Collaborative learning is a learning technique that not only helps the learners grow but also the teachers grow and polish their different skills. Collaborative learning should be implied with a certain level of constraints and in a controlling environment. This factor may play a hindrance in the adoption of this technique by the teachers and the students.

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Collaborative inquiry learning provides a chance for students to work on and answer their inquiry questions collaboratively in ways unavailable to a single student. With support from group members, students can complete a learning assignment in the zone of proximal development (Fernandez, Wegerif, Mercer, & Rojas-Drummond, 2015). Chan and Pow (2020) studied collaborative inquiry-based learning by developing an application SoAn a web-based document review tool which had the functionalities of discussion and collaboration along with bookmaking, highlighting, annotation and sharing these with the group to discuss the document (Chan & Pow, 2020).

Similarly, Wiki Labs is another collaborative inquiry project which was used to study the laboratory component of an undergraduate third-level nanoscience chemistry course. Wiki pages and its discussion features were used for collaboration. Wiki pages keep log of each student activity and analysis of usage. This feature was used to measure student participation and engagement. However, the introduction of these tools alone did not fully meet students' collaborative inquiry learning needs (Lawrie, 2016). Moreover, the requirement to establish a better connection between the tools and students' collaborative needs and focus should be on learning environment and enhancing student's communication tools (Chan & Pow, 2020; Lawrie, 2016).

In the previous research done in the collaborative inquiry, the researchers have used the formal methods of research, mentioned in the (Bell et al., 2010). The research has been conducted in the practical environment, secondary school. The research method used was, problem-based, observation, and experiment based (Bell et al., 2010). The students were given problems and with particular guidelines there had to solve a problem. The methods, results, team building, team management, methodology, and challenges faced have been the key points of the research. The result of the experiment was quite expected, collaborative Inquiry is an effective method, and the method increases problem-solving and cooperation. Their understanding enhanced and improved. It increases motivation, and interest in the problem increases evidently, participation in the CI process.

Some of the benefits of collaborative inquiry with the strategies include that it increases the understanding of the subject, and the retention of the knowledge and skills learned in collaborative inquiry. Also, learners in collaborative inquiry encounter vast exposure, collaborating with different people, in different environments, and learning out of their comfort space, which enhances their cognitive and problem-solving skills and helps in satisfying the curiosity, interest, and confidence of the learners. Moreover, it helps in making proper teams and groups work in the future, with the help they enhance and polish their skills and abilities are (Hastuti, 2020). Teachers gain many benefits, this helps teachers enhance their professional skills, knowledge, and expertise. Also, polish their management skills and ideas of teaching. Collaboration inquiry not only helps the students but also the teachers to improve their educational knowledge. Knowledge and information changes with time, and teachers also need to move forward with discoveries, this helps teachers with educational improvement (Hastuti, 2020). Correspondingly, the best practice for teaching is to understand the student's mindset, behavior, cognitive level, and latest trends, collaborative inquiry improves the ways of teaching and creates the opportunity for teacher leadership in the community of teachers.

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Collaborative learning has long been identified as a powerful strategy for enhancing peer interaction and co-construction of knowledge (Dillenbourg, 1999). However, studies also report that there are challenges in maintaining balanced participation and how to create accountability among group members. Gillies (2016) noted that unequal contributions often damages collaboration and motivation to work in group as all members are not contributing equally, while Kirschner et al. (2018) argued that without proper structuring, collaboration can lead to meaningless discussions amongst the group members without creating any meaningful understanding or deep learning. Recent research by Durak and Uslu (2023) showed that although collaborative inquiry activities can greatly improved engagement. They struggled to ensure continuous knowledge building and sustained learning engagement due to a lack of coordination mechanisms. These findings highlight that collaboration alone does not guarantee effective outcomes and structured processes are necessary to regulate roles, responsibilities, and participation. This reveals a gap for frameworks that can provide systematic support for collaboration, such as agile-inspired methods, within inquiry-based learning contexts.

2.7. Collaborative learning and ubiquitous environment

The collaborative learning theory was introduced by Lev Vygotsky as the learners learning with the interaction with their peers. The learners depend on each other in the accomplishment of a task or problem that they would not be able to accomplish individually (Barbosa et al., 2016). This theory encourages critical thinking as a result the learners retain more knowledge as compared to orthodox learning methods. The ubiquitous environment as mentioned above is learning or acquiring knowledge regardless of time, place, and any way (Sun et al., 2017) . With the advent of smartphones, the internet in our hands has made knowledge just a click away, the information is in our pockets, and this creates the ideal ubiquitous environment. The ubiquitous applications include IoT, sensors embedded devices, PDAs, mobile, tablets, and many more (Barbosa et al., 2016). Combining collaborative learning theory with a ubiquitous environment opens a new chapter in the learning methods, theories, and environment. The use of modern technologies enables learners to collaborate in a very different manner compared to the traditional method of teaching.

Adopting collaborative learning in a ubiquitous environment has a positive impact on the learner, some of the prominent benefits are that it allows seamless connectivity, people can connect regardless of physical boundaries, and allows people from different cultures, origins, backgrounds, and races to interact or collaborate. This opens up the learners to different perspectives and better understanding. The ubiquitous environment of collaborative learning allows flexibility, allowing people having different schedules to easily interact, without missing out on any information, and participate actively. The biggest advantage of learning in a ubiquitous environment is real-time communication. The tools allow instant feedback and interaction at any time. Online messaging, meeting platforms, and conferencing applications are very useful applications in recent times (González-Davies & Raído, 2018; Illeris, 2018).

Learning environment considerably enhances student engagement therefore collaborative inquiry in ubiquitous environment has gained much popularity in recent years. Hung, Hwang et al. (2016) proposed ubiquitous problem-based learning (UPBL) model and studied the competence of collaborative learning in this environment by studying performance of grade 5-6 students' ecology observation outdoor study. They found that collaborative inquiry in ubiquitous setting improved student learning, but the disordered process created difficulties for students, especially novice students who face problems as to how to use the system (Hung, Hwang et al., 2016). Therefore, a structured approach is needed to control and monitor the collaboration process. In literature, agile process as collaborative learning approach is gaining popularity for the last decade.

Collaborative learning in a ubiquitous environment poses some challenges that might affect collaborative learning. The growing dependency on the internet may affect communication. It is necessary to have a stable internet connection for effective communication. Unequal access to technology can affect collaborative learning. While browsing, a load of information that is irrelevant to the topic affects the learning process. The loss of concentration and diversion negatively impact learning in the ubiquitous environment. Data and information privacy have been a concern and will remain a concern using internet technology. Fear of losing, hacking, and breaking in, are serious threats using technology. The security and privacy concerns may be minimized with time but cannot be eliminated.

To overcome the challenges and get maximum benefits from collaborative learning in a ubiquitous environment, it is necessary to develop and maintain an effective strategy in the development of collaborative learning in a ubiquitous environment. It is necessary to set clear goals and objectives. The goals should be aligned with the course goals and keep in mind the maximum capability of the ubiquitous technology to be used (Aljawarneh, 2020). In collaborative learning active involvement from the learner is necessary to achieve the objectives. To have active participation, proper structuring is required, as proper division of responsibility, and task breakdown, are assigned to the members according to their abilities. Listening to the tools to be used during the collaboration process is necessary to have a clear picture of what are the tools to be utilized in the learning process. The tools are communication tools, sharing tools, meeting platforms, and many more. The role of the teachers is important in the teaching and learning process. In collaborative learning, the teacher also plays the role of mediator and monitor. They also act as mentors, to guide learners about the process without telling them the actual solution. They facilitate the group in achieving the desired result, by giving effective and timely feedback (Aljawarneh, 2020).

The important stage is the evaluation method after getting feedback. The evaluation is the responsibility of the teachers, they will assess the progress, of the progress of individuals and as a group. The assessment is important for learners to improve meta-cognition and self-reflection. Being effective means that the degree to which something can produce the desired amount of result, the degree of effectiveness of collaborative learning in a ubiquitous can be determined by the enhancement in the meta-cognitive skills of the learners. The CLUE can be effective if carefully designed following the course and learning capabilities and realistic.

2.8.Collaborative IBL in a ubiquitous environment

In the past years, there has been a trend to make hybrid models. The same has happened with the education system, the integration of education or learning with technology has opened up a new way for the learners and the teachers. The new way of teaching combines collaboration and inquiry-based learning in a ubiquitous environment. This methodology enables the use of both collaborative learning strategies and inquiry-based learning strategies in a ubiquitous environment. It promotes the proactive learning approach enabling critical thinking, better understanding, and collaboration among learners.

Technology has become an important part of our life, in acquiring knowledge and transforming learning in other fields of life. The collaborative inquiry stands for collaborative inquiry-based learning, a learning technique that allows the learners to cooperate to solve problems, constructing hypnosis. This allows the learners to acquire new knowledge or construct new knowledge(Liu et al., 2021). This effective learning method allows learners to construct meaningful questions, analyze the queries, experiment, and move to conclusions. Combining the collaboration approach like discussion with peers, and sharing information and resources consents to the effectiveness of the IBL, and the inquiry with diverse opinions from a diverse group of people. The ubiquitous environment can be classified as the integration of technology into our everyday life, allowing technology interaction to seamless, the interaction be regardless of place and time(Cárdenas-Robledo & Peña-Ayala, 2018). These environments are not very complex to develop around us, and the use of IoT in our lives is common. The IoT are wearable devices, smartphones, and smart technology devices that are connected to the internet, offering better and contextualized learning.

Collaborative inquiry in ubiquitous environments has gained much importance over the years. The simplest scenario of collaborative inquiry can be imagined as, in higher schooling and universities, collaborative inquiry should be and has been made a teaching method. The topic is given to the students in class, the students have to research the topic in the given time. After thorough research in the time the flip classroom concept will be applied, here the students will explain what they have learned and the teacher will act as a facilitator or the mediator(Liu et al., 2021). This approach to teaching encourages students to learn and research their queries. Doing critical thinking, finding reasoning, and collaborative discussions, enables the students to get vast opinions from different people working in collaboration(Cárdenas-Robledo & Peña-Ayala, 2018). They inquire with proper guidance and get an instant evaluation from the teachers, which also gives a boost to motivation and confidence in themselves. Collaborative inquiry in ubiquitous environments has proven to be effective and knowledge-retaining in the long run.

Collaborative inquiry is used in many other fields of life, and one of the important areas is the health sector. The use of technology has increased drastically. Everything in the health sector is computerized or digitalized. Nurses use PDAs, or tablets to store, and analyze the data remotely. The use of AR technology in treating patients with physiological issues calms the patients. This gives the doctors the cases to study for the present and the future. The use of pagers, which can be accessed everywhere, is one of the forms of application of IBL in ubiquitous environments (Cárdenas-Robledo & Peña-Ayala, 2018). Patient case studies are discussed with fellow doctors in collaboration, discussing the reasons, medication, and procedures, and predicting the expected result in collaboration is a way of collaborative inquiry-based learning in a ubiquitous environment.

Some of the restrictions and considerations for collaborative inquiry in a ubiquitous environment. The unequal division of technology or unequal access to technology is a concern for learning in collaborative inquiry in ubiquitous learning. This is an important issue in implementing collaborative inquiry in the education system around us. Also Security issue regarding the data and personal information of the students is a concern while moving towards collaborative inquiry in a ubiquitous environment (Fakomogbon & Bolaji, 2017). Moreover, the acceptance on both sides, the teacher side and the learner side. Teachers need proper professional training to teach according to collaborative inquiry principles. To properly teach the students with collaborative inquiry in the ubiquitous environment using technology(Aljawarneh, 2020). Along with the fact that assessment in the collaborative inquiry in ubiquitous is different from the traditional assessments. Teachers are required to upscale the assessment method when using collaborative inquiry.

2.9.Agile in education

Agile development is a framework for project development. It was introduced the early 2000, for project management. The use of traditional problem-solving and project management was not very effective as the problems were getting more and more complex. It was necessary to have such as framework that would help in timely completion, be more flexible to change, and also cost effective. It is important to understand the problem and find out the correct and effective solution. Looking at a problem with a bigger picture is complex to solve, breaking down the problem makes the problem to be manageable, understandable, easy to solve, and less time-consuming.

Agile development is a fast and effective process, highly adaptable, collaborative, and cooperative, with the developers and customers. This framework is very effective in solving complex problems(Krehbiel et al., 2017). Agile development contains the process of preparation, sprint, and sprint planning. The significance of agile development ensures the timely completion of the project and within budget. It also improves communication among the customers, stakeholders, among developers. Agile is highly change-adaptive, it is easy to incorporate change in the development of the project.

2.9.1. Agile learning

Agile learning is inspired by agile development. Agile development breaks down the problem into smaller problems known as sprints. A sprint is a period in which the team or scrum team has to complete the amount of work (Krehbiel et al., 2017). Agile learning is referred to as a learning environment that is flexible, adaptive, and iterative. This learning environment takes iterative steps, with constant review, design, and review done iteratively.

Agile learning has four pillars on which it is constructed (Krehbiel et al., 2017):

- Working smarter and being focused is an important pillar of agile learning.
- Accept the difference and work in the direction to nullify the difference, accept the change and adopt the methodology according to change, accept the difference of opinion, work in a team, and collaborative learning.
- Accept and embrace failure, and work in iteration. If the sprint fails, it helps identify the failed area, and start again
- Feedback is important in education, helps recognize the problem areas and improve the problematic areas

Agile learning is taking incremental steps for learning, reviewing progress constantly, error correction, and making progress constantly in learning. Agile in education supports the agile methodology in the learning process. Agile supports collaboration with other members and helps each other in the learning process. Agile in education is the adaptation of agile methodologies in the field of education(López-Alcarria et al., 2019). Agile learning is certainly based on inquiry-based learning, with the agile methodology the team needs to have collaboration. Therefore, agile learning also supports collaborative learning. Agile learning is learner learner-centered approach, the goals and objectives of learning are merely determined by the learner (López-Alcarria et al., 2019). Agile provides the environment for learning, incorporating other techniques in the process of learning. The stakeholders in agile learning are learners, teachers, institutes, facilities and most significantly the material being taught(López-Alcarria et al., 2019).

The term Agile Education referred to incorporating the practices agile methods for developing projects like scrum or XP to learning process. Therefore, it is the process which iterates between the phases of learning and doing in incremental steps (Battou, 2017). There is a great amount of literature that supports the use of agile methods to teach software engineering concepts and practices (Melnik & Maurer, 2003), applying and understanding agile approaches like Scrum or Kanban to teach project development (Matthies, 2018) and supporting teamwork (Rico & Sayani, 2009). Thus most of the work done is to teach agile methods or approaches in higher education to software engineering students which is understandable as agile is a software engineering concept and to teach it to practice-based or project-based approaches were developed (Wiid, 2019).

The concept of using Agile methodologies to teach software engineering courses by practicing on real software projects and teacher manages students was (Alfonso & Botia, 2005). Then, it was found that Agile methodologies are also effective in teaching other subjects e.g., Mathematics (Duvall, Hutchings, & Kleckner, 2017). Thus, the need was identified to develop agile pedagogy as a user or learner-centric approach as in rapidly changing, technology, tools and concepts along with assessment methods are also changing, education needs to be also adaptive to meet the dynamic requirements of learners (Galés & Gallon, 2019).

Examples of agile approaches being tried out in schools and classroom teaching include Agile classrooms in the USA, Agile Schools in Australia, eduScrum and Scrum@School in Netherlands amongst others. In these a canvas or scrum board is used, along with collaborative teams and user-centric learning guided by the teacher. Teachers are provided with trainings and templates to execute agile teaching in class. The biggest challenge is the lack of formal literature about these projects but some other researchers addressed the connection between education and agile methods (Wiid, 2019).

The challenge in developing agile as a pedagogical approach was mapping agile values to classroom practices. Thus, many authors tried to rewrite the agile manifesto in terms of education such as Stewart, Peha, Kamat, Royle and Krehbiel. The goal of the manifestos is to synthesize the key principles of Agile Education and serve as an inspiration to educators willing to design and apply different experiences on their way to going full Agile.

There are four key values of Agile Manifesto.

- Individuals and interactions, over process and tools.
- Working software, over comprehensive documentation.
- Customer collaboration, over contract negotiation.
- Responding to change, over following a plan (Agile Alliance, 2001).

Stewart (2009), Peha (2011) and Kama (2012) proposed values for Agile Manifesto but they were more generic and most satiated e-learning environment. However, Agile Manifesto for Teaching and Learning by Krehbiel proposes an entirely new list of values focused on adaptability, collaboration and student-centric learning therefore more suited for collaborative ubiquitous environment (Krehbiel, 2017). They are:

- Adaptability over prescriptive teaching methods
- Collaboration over individual accomplishment
- Achievement of learning outcomes over student testing and assessment
- Student-driven inquiry over classroom lecturing
- Demonstration and application over accumulation of information
- Continuous improvement over the maintenance of current practices

Stewart gives the mapping of agile principles in educational context. Where the highest priority is given to student learning, change is welcome, even if late in the learning cycle, when it improves learning, collaboration between all stakeholders and emphasis on student-centric iterative approach to achieve learning goals (Stewart, 2009).

2.9.2. Agile education systems

There is much evidence of research being done to create an agile system for education using different agile methods. Melnik & Maurer in 2003 were amongst early researchers to use extreme programming in education context. Project-based approach was employed on class assignments and project in different courses e.g. Web-based Systems and Internet software techniques, to teach the concept of XP (Melnik & Maurer, 2003). Scrum and ScrumBan methodologies were employed in the learning environments for quite some time in education contexts (Parsons, Thorn, Inkila, & MacCallum, 2019; Guerra, Gomes, & Cardoso, 2019 ;Naik & Jenkins, 2019; Vogelzang, Admiraal, & Van Driel, 2020). For designing agile education systems, the following agile methodologies have been discussed in the literature.

2.9.2.1.Scrum

Scrum is an iterative and incremental agile methodology used for project development. The success of agile development inspired educators to apply agile methodologies in education.

Scrum is the methodology of the agile framework. Using scrum, the goals are made into smaller achievable goals, the teams work as a unit to solve the problems. The teams are designated to solve the smaller segment of problems (Müller-Amthor et al., 2020). Agile follows the principles of inquiry-based learning and collaboration-based learning. The main stakeholders of the agile process are team members, the coach or mentor, and the owner. These are the fixed roles in agile. The owner defines the goal and objectives and monitors the project, then performs the necessary tasks to accomplish the goal, the coach provides the support that is needed by the team and helps in removing all the obstacles to accomplishing the goal (Müller-Amthor et al., 2020).

With the emergence of technology, it helps to accomplish tasks and communicate regardless of the state, place, and time. This provides a more comfortable and compatible scenario for the team and learner. In agile learning collaboration is the basic principle that is necessary to use different tools and procedures to incorporate remote communication.

Sprint is defined as the adaptive team to accomplish a task is a sprint. A sprint is a fixed duration, in which teams work together to accomplish the goal. Sprints are fundamentally part of the scrum methodology of the agile framework. Sprints require adaptive teams, coaches, project owners or stakeholders, breakdown goals, or sprint breakdowns(Kuz, 2021; Müller-Amthor et al., 2020). Key features of sprints are that they need to be time-boxed, goal-oriented, multifunctional team, or adaptive team. The sprint needs to have a fixed scope, evaluation, and reflection daily, and most importantly retrospective. It is an iterative process that allows the learners or teams to manage and control the risk and development. This allows the teams to react to change constructively.

Scrum methodology is quite flexible and easily modifiable, this helps the different fields to adapt the way they require to (Kuz, 2021). It is customizable according to the needs of the organization, developers, teams, and learners, providing the important feature of being constructive to change and change management.

“eduScrum” is one attempt on an agile educational system based on the scrum method (Wiid, 2019). Scrum is used in teaching software engineering by real-world project-based approach (De Souza, Zorzo, & Da Silva, 2015; Parsons, Thorn, Inkila, & MacCallum, 2019; Guerra, Gomes, & Cardoso, 2019). While other researchers have made attempts at implementing

Scrum as teaching pedagogical approach (Naik & Jenkins, 2019; Vogelzang, Admiraal, & Van Driel, 2020).

2.9.2.2.ScrumBan

ScrumBan is the cross between the scrum and Kanban methodology of the agile framework, holding the features of scrum and Kanban. Kanban features the visual representation of the work in progress. The project will start with the scrum practices and later on incorporate the Kanban for the uninterrupted and smooth flow of the project, ensuring flexibility (Stoica et al., 2016). It is a flexible and lightweight method. Scrum contains the objectives and aims of the project, on the other hand, Kanban is a managing tool that monitors and observes the progress of the project. ScrumBan needs tools like, product backlog, requirements, sprint, board, and ScrumBan board. The roles that hold importance are owner, team master, and team (Albarqi & Qureshi, 2018). During the ScrumBan process number of meetings are conducted which are, eliminate waste meetings, sprint planning, daily meetings, quality test meetings, sprint review, and sprint retrospective meetings. The process of carrying out is the same as of the scrum with the incorporation of the Kanban management tool(Albarqi & Qureshi, 2018).

Scrum2Kanban is hybrid approach that combines the structure and process of the scrum to flow and visualization of Kanban to improve the scrum process. They used a combination of GitHub and online survey for collaboration, communication and testing (Matthies, 2018). Thus, Scrum is applied to manage the learning process and Lean Kanban boards are used to monitor the learning. The Kanban method limits the simultaneous execution of tasks by limiting number of tasks in “work in progress” section thus giving more control over scrum sprints (Parsons et al., 2019). The hybrid approach proposed by Parsons uses ScrumBan method as it has the properties of supporting collaboration, ubiquity and ease of use. The two most popular ways in which agile and lean concepts have been adopted in education have been 1) applying agile processes such as Scrum to manage learning, and 2) monitoring that learning using lean Kanban boards (Parsons, Thorn, Inkila, & MacCallum, 2019).

The Kanban board visualizes the workflow by having cards progress through several columns named, for example, ‘Backlog’, ‘Ready’, ‘In Process’ and ‘Done’. The key feature that differentiates a Kanban board from typical agile storyboard used in Scrum is that a Kanban board has a work in progress (WIP) limit, to how many cards can be in process at any one time. With Scrum, the amount of work that is time commitment and is limited by the Sprint. In ScrumBan, there are no timeboxed sprints, so the team must limit itself using WIP limits on the board.

Within this activity, the students work through a Scrum process using Kanban boards to enable pull and flow of agile story cards. The column headings are specified so that they relate to the learning process. Despite using Kanban boards, they aim was to maintain the rhythm and the feedback ceremonies (stand up meetings, retrospectives) of Scrum, so their process miniature is based on Scrum sprints with a Kanban board of user stories with WIP limits, not a full ScrumBan approach. In their experiment Parsons et al. (2019) used Trello application as Kanban boards to visualize progress and scrum as learning process (Parsons, Thorn, Inkila, & MacCallum, 2019).

Similar approach was proposed by Matthies (2018) who proposed that Scrum method is employed in four sprint iterations in the beginning of the course activities for each sprint is decided. Participants form self-teams of 5 to 8 members, each with their own Product Owner (PO) and a Scrum Master (SM), roles which are also performed by students. For every sprint, a Scrum planning, sprint review, retrospective as well as a weekly stand-up meeting is organized by the students. These meetings are held in the presence of a tutor, who can answer questions and provide guidance and advice, if needed. In order to elicit the initial requirements for the system to be developed during the project, the POs meet with a member of the teaching staff, the customer. Guided by an instructor, taking the role of "chief PO", the product backlog is filled with user stories (Matthies, 2018) .

Kanban boards were used for visualizing workflow and limiting work in progress (WIP) through WIP limits are presented in detail. Therefore, the concept of a Sprint iteration, at the beginning of which the set of user stories to work on are decided and which is shielded from interference for the duration of the sprint, is not ideal (Matthies, 2018). Kanban is a Japanese word, which means "signboard." it was developed at Toyota, adopting the agile principles.

It is a process management model, following agile. It is a visual method of process management with objective waste and delay management (Al-Baik & Miller, 2015).

During the development process, the developers experienced waste and delays, which rested on the extended time of the project as a whole. The developer used Kanban to minimize the delays and lack in the project. The objectives of Kanban are as follows (Al-Baik & Miller, 2015).

- Monitor the workflow of the project or a particular task using visual methodology
- To minimize the overall cost of production of the project
- Maximize the quality of the product
- Limit the work in progress
- Minimize the cycle time to deliver the product faster.

The methodology can easily be adapted to different fields. It can be adopted in education, in the course compilation phase also in the teaching phase. Students can apply agile scrum, Kanban, and ScrumBan methodology while acquiring knowledge, preparations, assignments, projects, and case studies.

Applying agile in learning requires proper planning and involvement from the stakeholders, stakeholders in education or learning are; educators, administrators, learners, and owners(Angelov & de Beer, 2017). The basic need for applying agile is to understand agile carefully, the agile principles, and its basic knowledge. All the stakeholders need to be on board for the implementation of agile methodology, and the goals and objectives need to be identified and broken down into smaller goals and objectives, team is important while implementing the plan, assigning the roles of the educators, facilitators, leaders and clearly define their responsibilities they need to carry(Angelov & de Beer, 2017). Before the formal implementation of agile, the owner can perform the test, to evaluate the potential to carry agile. Training sessions can be organized to give an overview of Agile. After the evaluation of the feasibility, the next phase is the implementation phase, feedback, and reflection. It is an iterative process, and an ongoing process takes data to alter and makes improvements in the process. Implementation of agile requires patience, flexibility, adaptability, and collaborative inquiry. Implementing agile will create a great shift in the learning approach from; the traditional teacher-centered approach to the student-student-centered approach(Angelov & de Beer, 2017).

2.9.3. Agile for collaborative learning

Agile for collaborative-based learning is using agile with collaborative learning. Agile is highly adaptable and can be adapted to the collaborative learning environment. Collaborative learning is learning in cooperation, and agile is all about collaboration and teamwork. The flexibility agile provides allows it to be easily adaptable to any environment providing positive outcomes(Noguera et al., 2018). Agile is most commonly applied where problems are very complex, software development is one of the most applicable areas of agile. Precision and accurate results are needed, but the error margins are very narrow(Krehbiel et al., 2017).

Features of agile are flexibility, adaptability, continuous improvement, error management, and most importantly adaptive to change, these traits are important to education or learning, and they are adapted to the educational domain with collaborative learning(Noguera et al., 2018). Agile can be applied to collaborative learning settings for learners. The biggest feature of agile is to divide complex problems into smaller problems also known as sprints and make teams according to the requirements of the problem. Sprints help in better understanding the problem and solving complex projects and cases. The continuous involvement of the monitor, teacher, or mediator in the education aspect helps to monitor the progress and provides guidelines for the achievement of the result(Krehbiel et al., 2017). Iterative learning in a continuous learning process, agile proves to have iterative learning, combined with collaborative learning, the continuous feedback helps the students to learn from their mistakes and work for betterment(López-Alcarria et al., 2019). Helping the learners to divide difficult projects into smaller ones and work for sprints and work in teams, where they collaborate for problem-solving. Learners work in collaboration on a project, where they learn from team members, within the given time frame, continuous feedback helps to reflect and improve learning and skills.

The agile methodology can be applied to the learning process, with collaborative learning, sprints can be made according to the course. The agile roles can be defined, as the scrum master or the facilitator to monitor the progress and ensure the constructive meeting and collaboration among the fellows. Progress tracking is another feature of Agile, scrum master records the progress of the ongoing learning(D'Souza & Rodrigues, 2015). The success rate of agile is high in software development, the principles of agile are so flexible that they can be applied to any field and have proved to be successful. Applying the educational field, to the learning system allows the student to develop high cognitive skills, problem problem-solving skills, improve communication skills, and polish the skill of working in teams and cross-functional teams regardless of status, educational status, culture, and origin(Krehbiel et al., 2017). Applying agile to the education world provides the student with the stimulation of the corporate world, the upcoming world to step in(Noguera et al., 2018).

2.10. Agile for IBL

Agile in inquiry-based learning combines two learning areas, agile methodology is merely used in software development, and another is the type of learning, learning through inquiry. Using inquiry, question, and curiosity to enhance one's knowledge(Longmuß et al., 2016). Curiosity can be satisfied by asking questions, searching, or having discussions. Agile methodologies are used in the development process, commonly used for software development, focusing on flexibility, adaptability, and receptiveness in the project. main focus in agile is iterative learning and iterative development, agile breaks the project into smaller iterations, helping teams to focus on the designated problem, focusing on a problem one at a time, and ensuring continuous feedback to make continuous adjustments as required.

The cross-functional teams in agile have members from different domains as needed by the project. Various people from different backgrounds and skill sets collaborate on a project to find the optimal solution is the beauty of agile methodology. Continuous involvement of the stakeholders allows them to maintain their interest in development and feel motivated. The involvement ensures the right alignment of the project with the customer's needs. The adaptability feature of agile allows them to adapt to change at any time, the change can be in requirements, technology, or in any other phase, and agile can compensate for change. The feature of adaptability allows for continuous improvement in the process and the product. The team also identifies the areas that need improvement in the team, planning, training, and resources.

Inquiry-based learning is active learning and learner-centered learning. This learning method allows the student or learners to actively participate in the learning process. Learning includes learning through investigation, inquiry, and critical thinking and also includes learning through problem-solving. Inquiry-based learning is student-centered learning, the main role of the student, formulating the learning domain, resources, topics, and curriculum. IBL promotes critical thinking in the learners and critical evaluation of the topic and the solution. Critical evaluation involves the analysis and evaluation of information for the solution. IBL also facilitates collaborative learning or collaborative work for the solution of the project. The teacher or mentor plays the primary role in the learning process either collaborative or Inquiry based. Teachers play the role of moderator and monitor, to facilitate the learning to carry out, carry out the guidelines for learning, and in achieving learning goals.

Incorporation of agile methodology in inquiry-based learning aiming to improve the learning and corporation while learning. Inquiry-based learning is also used in educational institutes, the courses and their objectives should be designed in a way to incorporate incremental cycles, providing students with the opportunity to review topics, room for feedback, and informal guidance for the refinement of inquiries(Sakulviriyakitkul et al., 2020). Agile has power distribution rather than power concentration, agile with learning provides students with the power to shape learning and learning experience. Agile is a flexible method, of learning that allows the student to flexibly use means for inquiry, no fixed methods to inquiry, for better understanding of the subject and problem statement(Sakulviriyakitkul et al., 2020). Agile provides continuous feedback for the learner to reflect on what they have achieved and progress. Positive feedback helps in refining the inquiry approach.

Incorporating agile methodology in the learning process develops some challenges, the biggest challenge is to maintain the balance of power, the balance of authority, and role definition. Giving enough room for individual development and a learning environment(Longmuß et al., 2016). It is required to have innovative assessment techniques. The paradigm shift institutes will face challenges in acceptance and adaptation from the teachers, and proper training for acceptance. Institutes will require resources for applying agile in the learning process either collaborative or inquiry-based learning. Incorporating agile in inquiry-based learning will open a new area for learner engagement, new opportunities, cognitive skills, critical thinking, problem-solving, teamwork, and inquiries. Inquiry-based learning is active learning, allowing learners to satisfy their curiosity by inquiring. Inquiring can be done through formal and informal methods. The main idea is to satisfy the curiosity of the learner.

The use of technology is increasing day by day, it is involved in every aspect of life. Technology can make us close enough, one click is far. Technology in communication has played an incredible role, communication between workers, employees, students, families, professionals, and many more has helped them to communicate in a better and more organized way. Implementing agile learning with the help of technology has become easy to implement and maintain. Learning is an ongoing process, engineers, doctors, technicians, teachers, and all professions require learning from time to time. Agile in collaborative inquiry-based learning can be implemented in learning institutes and also in any stage of learning either advanced or school level(Owen & Dunham, 2015). Learning is not only for students at the school level, but companies also provide training to their employees to enhance their skills, for the betterment of the company. Companies use training courses, informal training methods, supervised learning, and workshops, for their employees to grow.

With time collaborative inquiry-based learning has gained popularity and implemented with agile has helped it to gain another level of attention. The advanced approach of using a student-centered learning approach with inquiry has gained importance with time. Agile methodologies originated from software development and aim to be iterative, adaptive, flexible, and collaborative(Owen & Dunham, 2015). Collaborative inquiry is a learner-centered approach aiming to gain knowledge by problem-solving, critical thinking, and gaining knowledge through investigation either assigned or self-driven. By combining these two approaches the teachers or educators aim to create an environment that helps learners with curiosity, collaboration, teamwork, and compliance. The intersection of agile with collaborative inquiry-based learning is the center of attention by learners and educators. Agile and collaborative inquiry supports interactive interaction to achieve the desired result. With the view of agile splitting up the problem into minor problems and solving the problems in iteration. This continuous iteration allows the learners to transform their research and learnings(Sandström et al., 2016). Gathering the relevant information, filtering information that is needed continuously analyzing, collecting data, and performing retrospection on what they have achieved and what they need to achieve.

Collaborative learning is one of the common points with Agile and collaborative inquiry. In agile development cross-functional teams come together to work for the common cause of development, learning with collaboration with people having diverse backgrounds comes together to learn and increase their knowledge domain. In both people learn from fellows' knowledge and experience. People from diverse backgrounds and knowledge hold diverse perspectives on problem helping the learners increase their critical thinking and cognitive skills. Agile and collaborative inquiry are learner-centric, with learners having the core responsibility for the knowledge. This allows the learners what they want to learn and how they want to learn. Learners have an active role in forming, adapting, acquiring, and application of knowledge. Through agile the responsibilities are equally divided, and power or authority is diluted to the subordinates as per the structure (Sandström et al., 2016).

Inquiry, asking questions, and research is a form of learning. Learning by observation, experiments, case studies, assignments, and projects, all help in giving the learner the answer they want. The educators and teachers can help the learners' inquiry; they act as a moderator and mentors to the learner for proper guidance. They help learners transform and refine the inquiry method. Both agile and collaborative inquiry are prone to change, they are adaptive to change and incorporate change as required. Agile methodology is designed in such a way that can adapt to any change in requirement, also collaborative inquiry learner transforms, refine, and change their inquiries according to the result they accomplish (Sandström et al., 2016).

The intersection points are of high magnitude, this interaction can help learners learn in a more organized and adaptive manner. This learner can apply the agile methodologies, and the team member of development can use collaborative inquiry to learn in a better way, using the minimum resources of the organization and using the experts to attain new skills and knowledge. Agile and collaborative inquiry have different strategies when applying, using technology in applying agile with collaborative inquiry. Using digital spaces, and digital platforms for interaction, communication, and research. Agile companies use the digital medium to communicate, as a resource for the completion of projects, and as a tool for collaboration and inquiry (Lang, 2017). All these factors give birth to the E-learning and m-learning paradigms in learning. These factors include engagement with different people, cross-functional people having different backgrounds and skills helps learner increase motivation, involvement, and participation. Also, improvement in cognitive skills and critical thinking helps them to analyze information, improving problem-solving, and cognitive skills. Agile and collaborative inquiry help them improve their cognitive skills unmeasurably and undefinably (Lang, 2017). Collaboration and acquiring knowledge with peers is a way where learners acquire knowledge in an informal method.

Moreover, applying agile in learning helps them to understand real-world problems and cases. Agile helps learners acquire knowledge that is close to the real world and provides the scenarios of case studies, projects, and assignments that stimulate the real world (Owen & Dunham, 2015). Along with communication, it is the key to solving problems and acquiring knowledge. Communication skills are required by the corporate sector and for the students to communicate with their mentors, peers, and team leaders. Learners need to present and deliver what they have understood, their research, and the results of the research. This skill is important in collaborative learning and agile team development (Lang, 2017).

While incorporating agile in collaborative inquiry-based learning it is necessary to consider some factors that include, assessment and reflection; assessment for the learner by their educators should be designed in an innovative way, traditional method of assessment will not evaluate the performance of the learner. This nontraditional method of learning can be assessed by nontraditional assessments (Medeiros et al., 2017). Nontraditional method of assessment includes open book exam, project-based assessment, case-based assessment, practical assessment, and online time-constrained assessment. Teacher or educator involvement, acceptance, and training are important in applying agile with collaborative inquiry. Acceptance by the educator is important and necessary in implementing this new version of collaborative inquiry in educational institutes (Medeiros et al., 2017). The impact of agile in collaborative inquiry-based learning will take some time to assess. This area still requires experimentation and assessment to assess the impact on the educator and learners in the long run (Sandström et al., 2016).

The application of agile in ubiquitous learning has gained much popularity in recent times. This approach focuses on the intersection of agile development principles with learning technique, ubiquitous learning. Infusing agile in technological-based learning, this learning is flexible, remote, and adaptive. The ubiquitous environment can be defined as acquiring knowledge anywhere, anyhow, and using any means can be elaborated as the use of technology, incorporating technology in the acquisition of knowledge. Use of mobile devices, sensors, PDAs, and IoT (internet of things) (Alkhafaji et al., 2020). These all help the learner in acquiring and enhancing knowledge. These devices make the data available to be accessed all the time and anywhere, regardless of location. This environment helps in integrating learning in all physical and virtual spaces. An example of a ubiquitous environment is the use of VR (virtual learning) in learning, VR devices used by pilots in their training time for flight stimulation, are widely used by doctors in the stimulation of complex operations other than performing on the human body, risking human life, it is safe to perform with all the risk involved in a stimulation (Alkhafaji et al., 2020).

Agile is originally a software development project management methodology, used in the development process by the companies to carry out the development in an effective manner. The main idea mentioned above is flexibility, adaptability, collaboration, effectiveness, iteration, and active change. Incorporating agile in the learning medium requires molding in such a manner adopting its iterative nature, responsiveness, and collaboration, empowering students on knowledge acquisition, and making learning student-centric (Edele, 2022). By amalgamation of agile learning in a ubiquitous environment, the educators search for an environment that is student-centric, adaptable, following the new technology, and adaptive to change i.e. new knowledge, accepting new and latest knowledge and technology (Edele, 2022).

2.11. Agile collaborative IBL in a ubiquitous environment

In recent times the incorporation of technology in the education sector is increasing. After COVID, it has transformed the learning and education sector differently. Home-based learning and working from home is the new normal. The knowledge and information available ubiquitously have changed and will be changing the education sector, transforming the educational system drastically. Combining all agile, ubiquitous environments and collaborative inquiry-based learning leads to an innovative learning model. The combination of agile process and development management, nontraditional environment, and learning methodology gives birth to new teaching practices (Uskov et al., 2018).

Integration of a ubiquitous environment has allowed evolving learning and education. Agile focuses on teamwork, flexibility and adaptability, and time management to maximize effectiveness and effectiveness. Collaborative inquiry is an active learning process satisfying curiosity in people, emphasizing a nontraditional way of learning. Combining the three diverse methodologies provides many benefits that help learners in their learning and enhance their overall skill set (Uskov et al., 2018).

Also, personalized learning is the biggest benefit the learner gets, having a personalized learning experience, using the available resources, and benefiting from collaboration in gaining knowledge, according to the interest and requirement (Wang, 2023). Continuous and real-time feedback from ubiquitous resources helps the learners evolve and get knowledge in a better manner. Feedback plays an important factor in every field, in education, development, and merely for future development (Wang, 2023). Moreover, flexibility is the easiness of adopting the change as required, the change can be forced or self-directed. Incorporating change in education is necessary, adopting the new way of knowledge attainment and implication (Wang, 2023). The ubiquitous environment enables the learner to access the information that they require and inquire.

Collaboration is also an important factor in gaining knowledge and information. Using all the means rather than the place, time, and method for gaining knowledge. The collaboration feature allows them to interact with each other regardless of their geographical placement, interaction is possible using advanced technology (Wang, 2023). Using digital means to collaborate to achieve their goals has become easy and information is at their fingertips. Agile learning with collaborative inquiry in the ubiquitous environment signifies education. Using all the features of knowledge acquisition helps to create dynamic and personalized learning experiences (Kek et al., 2017b; Uskov et al., 2018). The potential challenges are always there, and it is important to cater for creating a non-traditional environment of learning. Along with these challenges, all the above-mentioned factors help the learners to enhance critical thinking, cognitive skills, and engagement. With the rapid development of technology, there is room for improvement in the learning and education sector (Kek et al., 2017). Using the latest technology and information will help in redefining the learning method, acquisition, training, and learning future (Uskov et al., 2018).

2.12. Related Work

These are a summarized snapshot if the literature in Table 2. that shows recent trends. This table shows an increasing popularity of ubiquitous learning and agile techniques. Also inquiry-based learning, and collaborative tools to enhance educational experiences across many disciplines. In many different educational environments, these strategies have demonstrated great potential to improve collaboration, student involvement, and learning performance.

Table 2.3: Agile Approaches Used in Inquiry-based Learning Ubiquitous Environments

Research Study	**Ubiquitous Inquiry Type**	**Agile Method**	**Platform**	**Learners**	**Domain Knowledge**
Thongkoo et al. (2023)	Authentic scientific inquiry	-	Forum based application (ULMCI)	University Students	Programming
Ybanez & Barcelona (2024)	Collaborative Inquiry	-	Google Docs, Ms Teams	University Students	Writing Skills
Adhami & Taghizadeh (2024)	Authentic scientific inquiry	-	Edmodo, and Google Docs	University Students	Railway engineering
Lopes et al. (2024)	Game-Based Inquiry	Agile-inspired approach	Classcraft, Edpuzzle	University Students	Engineering and technology
Noguera et al. (2018)	-	General Agile Practices	-	University Students	Project Management
Ciancarini et al. (2019)	Game-Based Inquiry	General Agile Practices	GitHub	University Students	Computational thinking

Durak & Uslu (2023)	Collaborative Inquiry	General Agile Practices	Trello, Slack	University Students	Group Regulation
Naik & Jenkins (2019)	Game-Based Inquiry	Kanban	Unity, Gamify	University Students	Agile Software Development
Vogelzang et al. (2019)	-	Scrum	-	School Students	Chemistry
Biswal et al. (2023)	-	Scrum	-	School Students	Electric concepts
Khabbali et al. (2023)	-	Scrum	-	University Students	Project Management
Thiyagarajan et al. (2024)	-	Scrum	-	Nursing Students	Healthcare
Milićević et al. (2019)	Collaborative Inquiry	Scrum	Openproject	University Students	E-Business Project Management
Parsons et al. (2018)	Collaborative Inquiry	ScrumBan	Trello, Kanban	Teachers	Professional Development

The application of agile methodologies, such as Scrum, EduScrum, and Kanban, has also gained popularity in educational settings. The majority of the studies focus on computing and software engineering teaching as they employ doing by teaching concept. Some studies are found for teaching other domains like, Vogelzang et al. (2019) in their research studied how Scrum methodology can be used to enhanced motivation and learning in secondary chemistry education. They used tools like Kanban boards and lab notebooks to create classroom collaboration (Vogelzang et al., 2019). Parsons et al. (2018) studied the use of task management tools, such as Trello , to enhance teacher professional development, enabling better organization and project management (Parsons et al., 2018). Including Scrum into e-business project management education, Miličević et al. (2019) gave students practical skills for the real-world use. This shows how flexible agile approaches are in promoting project-based learning and teamwork in many different educational environments (Miličević et al., 2019). But more work need to be done in teaching using agile in other domains.

Inquiry-based learning, which emphasizes student-driven exploration and problem-solving, is another key focus of the reviewed studies. Using tools like Classcraft and Edpuzzle, Lopes et al. (2024) investigated a gamified Agile inquiry approach in flipped classrooms to show how well it improved collaborative learning in STEM education (Lopes et al., 2024). Also, By use of platforms, such as GitHub, Ciancarini et al. (2019) highlighted game-based Inquiry and offered a cooperative-thinking approach for software engineering education (Ciancarini et al., 2019). Using Unity and Gamify to develop interactive and interesting learning opportunities, Naik and Jenkins (2019) studied gamified inquiry for Agile Scrum and found success (Naik & Jenkins, 2019). While these studies demonstrate the effectiveness of inquiry-based teaching in fostering critical thinking and teamwork, very few studies on its application in school setting and on how it fits with a spectrum of other learning objectives.

The modern collaborative tools have made it possible for implementation of modern educational practices to create supporting group work, resource sharing, and real-time communication. Thongkoo et al. (2023) created Ubiquitous Learning Management Using Collaborative Inquiry (ULMCI), a forum-based application for programming and Yildiz Durak & Atman Uslu (2023) created a study using Slack, and Trello. They highlighted how using such tools can facilitated effective collaboration in group-based tasks and learning environments (Thongkoo et al., 2023; Yildiz Durak & Atman Uslu; 2023). Biswal et al. (2023) created EduScrum templates for working together in the classroom, with a focus on new ways to teach K–12 students (Biswal et al.; 2023). In another study, authors encouraged the use of Google Docs and how they can help college students work together improve their writing skills (Ybanez & Barcelona, 2024). Even though, these tools have shown they work, more research is needed to make sure they meet the needs of learners. Also most of the studies are catered around individual learners and very few are for collaborative learning assessments and evaluation.

Ubiquitous learning, defined by its accessibility at any time and place, has been successfully employed in multiple studies. For instance, Thongkoo et al. (2023) applied Authentic scientific inquiry through ubiquitous learning management systems, forum-based application in programming courses at several universities. This strategy emphasized uninterrupted collaboration and learning vast areas (Thongkoo et al., 2023). In a similar vein, Durak and Uslu (2023) investigated the use of Trello and Slack for real-time collaboration. They demonstrated how these tools improved group regulation strategies, how to regulate georp policies, group structure, and participation in educational contexts (Durak & Uslu, 2023). Ybanez and Barcelona (2024) further expanded the application of ubiquitous tools in language education, utilizing platforms such as Google Docs and Turnitin to facilitate collaborative writing, both remotely and on-site (Ybanez & Barcelona, 2024). While these studies emphasize the significance of ubiquitous tools in promoting accessibility and collaboration, there remains a gap in research regarding their implementation agile inquiry context.

Despite the advancements highlighted in these studies, several research gaps remain. Most of the studies focus on higher education, leaving a gap in understanding how these methodologies can be effectively applied to school education (Vogelzang et al., 2019; Thongkoo et al., 2023). Also, while some studies have integrated agile methodologies with inquiry in ubiquitous environments, further research is needed to develop cohesive frameworks that can optimize the potential of these approaches (Yildiz Durak & Atman Uslu, 2023). Taken together, these patterns reveal a significant gap: while agile practices have demonstrated potential to enhance collaboration and engagement in inquiry-based learning, there is limited evidence of their systematic application as a structured educational framework in ubiquitous learning environments at the school level. This gap provides a clear rationale for the development of the ScrumBan Ubiquitous Inquiry Framework (SBUIF), which aims to integrate agile principles with inquiry pedagogy to support structured, collaborative, and technology-enhanced learning for school students

2.13. Summary

This chapter discusses the theoretical underpinnings and applied practices of modern pedagogical models: constructivism, inquiry-based learning (IBL), ubiquitous environments (UE), and Agile frameworks. First, constructivism illustrates that students learn through experience and through reflection upon their experiences, emphasizing that education has been transformed from teacher-centred to learner-centred practices. Inquiry-based learning empowers students through exploration, questioning, and investigation. Forms of IBL can include guided inquiries or open inquiries. When IBL is unified with UE and mobile learning (mobile, IoT, etc.), learning can be flexible and occur anywhere-anytime. agile methods are applied from the software development industry, providing collaborative, iterative, processes of learning while instilling a sense of adaptability and a commitment to student-driven outcomes. Studies cited various projects, such as AR-based scientific inquiry and collaborative software Trello, or another applicable technology to build collaborative learning within classrooms. Studies subsequently demonstrated both successful and unique uses of these models and methods but cited limitations in the adaptations of IBL or Agile for middle school learners, as well as limitations in structure when developing and applying frameworks for educators and students in UE. In summary, it could be said that these practices provide the opportunity to create educational learning experiences that are dynamic, collaborative, and engaging.

CHAPTER 3

METHODOLOGY

This chapter describes methodology that can bridge the gap identified in literature by proposing a framework for collaborative inquiry in ubiquitous environment using agile to facilitate collaboration. By building on the research gaps identified in the literature, this chapter first the study the Design Science Research Methodology (DSRM), which is used in this research to provide a structured and iterative process for developing research artifacts. The chapter begins by presenting DSRM as the research methodology. It maps its six stages to the objectives of this study. Scrum-Based Research Framework (SBRF) by Parsons et al., (2021) which combines the properties of various Design Science models with Scrum methodology and the 5E Inquiry Model (Song & Wen, 2018) to provide a balanced structure for inquiry learning ScrumBan Ubiquitous Inquiry Framework (SBUIF) is proposed in this research. Then SBUIF is elaborated and its practical implementation through the uASK application is explained. Along with detailing the roles, responsibilities, and learning processes it supports. Finally, the chapter describes how the experiment is designed, including participants, procedures, and evaluation methods. For this studye M3 framework and CSCL affordances are used. Which were employed to evaluate the effectiveness of the proposed framework in real classroom contexts. At the end, a summary of this chapter is presented.

3.1.Design Science Research Methodology

Design Science Research (DSR) is a method for addressing problems in Information Systems (IS) research that balances research rigor with practical relevance when constructing new artifacts, like models, methods, or tools. DSR follows an iterative process of design, test, and redesign of technology artifacts to deal with complex problems, while theory is aligned with practice. There are several frameworks for DSR, each giving a unique structure to apply in research. The Design Cycle (Takeda et al., 1997) offers an iterative process of development based on abduction and deduction, as does a framework by Vaishnavi & Kuechler (2011) called the Design Science Research Cycle (DSRC) that allows for multiple iterations in the process to develop problem awareness. Hevner & Chatterjee (2010) improved on the DSR method by introducing structure to it by integrating practicality to the real world to academic practices. Yet the problem with this model was its linear process with no provision of multiple starting points. This was rectified by was Peffers et al (2018) an empirical six-step process known as Design Science Research Methodology which provides an effective structure to work.

Thus, the DSRM gives a systematic process for research, having concrete steps to guide the research process. The steps include identifying the problem from literature, then design and implementing a solution, validating it through experimentation and finally sharing the results with the wider community. This method focuses on both theoretical and practical contribution by giving designing and implementing an artifact along with adding to the body of knowledge of research.

3.2.Agile Inquiry based learning framework for ubiquitous environment

The problem with traditional collaborative systems is that they lack structure for inquiry process. To address these and other challenges an Agile Inquiry-Based Learning Framework for Ubiquitous Environments was proposed. Which combines structured learning stages of the 5E Inquiry Model from Song & Wen (2018) to Scrum-Based Research Framework (SBRF) developed by Parsons, MacCallum et al. (2020) to introduce iteration and adaptivity to the linear process of inquiry. Both these frameworks are discussed below. ScrumBan has been strengthened by its advantages over either of Scrum or Kanban alone. While Scrum provides structured roles and iterative processes and Kanban emphasizes flexibility and workflow visualization. ScrumBan combines these strengths to offer both qualities in one model (Bertolini, Mezzogori, Neroni & Zammori, 2024). This makes it particularly suitable for school-level inquiry learning as flexibility is needed to adjust to different student needs. Also structured processes are very important to guide collaboration in young learners.

ScrumBan is hybrid of Scrum and Kanban that is well suited to school-level for technology-supported inquiry-based learning. It blends structured iterative activities with adaptive workflow. Scrum offers defined roles, regular planning, and standard ceremonies but can be rigid in dynamic classroom settings. In contrast, Kanban excels at visual task flow and limiting work in progress (WIP), yet it lacks the learning-oriented checkpoints which are very important for collaborative inquiry.

3.2.1. Scrum-based Research Framework (SBRF)

SBRF was proposed by Parson, MacCallum et al., (2020) which is centered on Scrum like research structure that combines the benefits of scrum to research design elements for capstone project. This structure is adapted from Design Science Research Methodology (DSRM), guaranteeing a methodical and cyclical strategy for innovation (Parsons et al., 2020).

3.2.1.1.Phases of SBRF

Based on design science research methodology (DSRM), Parson, MacCallum et al., (2020) proposed the Scrum based research framework (SBRF) with three distinct phases; pre scrum, scrum and post scrum. These phases encompass the six stages of DSRM. The six stages are required for guiding the research process and ensuring a systematic and iterative approach to research, according to Parsons et al. (2020). These stages include i. the identification of research questions, ii. the collection and analysis of data, iii. the interpretation of findings, and iv. the application of results as shown in Figure 3.1. Following this method ensures that the research thorough, rigorous and well established with the latest research practices. Also the cyclic nature of the research ensures that the findings of the next stage in build on the findings of previous stage and iterative nature ensures that detailed understanding of research topic (Glen et al., 2015).

Then the iterative process ensure that the hypothesis and methodology are thoroughly refined and through experimentations findings are both reliable and valid. Additionally, if there are any inconsistencies or gaps in the study they are timely addressed and corrected thus creating a deeper understanding of the research. The continuous refining ensures that both the research process and findings are both accurate. (Atoum, 2019).

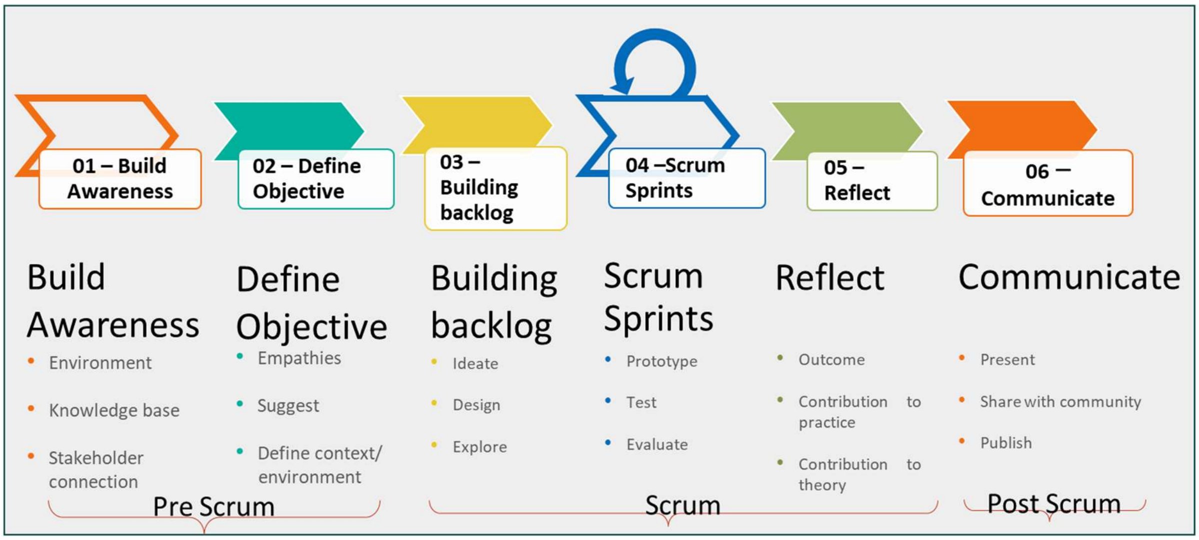

Figure 3.1: A Scrum-based Research Framework adapted from Parsons et al., 2020

There are several key components of framework of creating and achieving precise and trustworthy results in scientific research. Those include careful and detailed planning and execution of experiments. Detailed and through data analysis and interpretation of results without any bias, along with peer review and evaluation of findings. Scientists can only yield reliable and meaningful results by applying established methods for continuous improvement and refinement (Glen et al., 2015; Atoum, 2019; Parsons et al., 2020).

3.2.1.2.Pre-Scrum Phase

Most scrum projects tend to disregard the significance of raising awareness due to their primary emphasis on meeting customer needs. Usually, it is believed that the Product Owner is responsible for ensuring that the team is informed. To address this an initial research phase is incorporated and its purpose is to focus on the environment, the knowledge base, and engaging with stakeholders. These concepts are derived from Design Science in Information Systems Research (Hevner & Chatterjee, 2010).

In this phase of them for adapting to academic setting a detailed literature review is conducted along with a thorough analysis to obtain relevant technical information. In this stage the role of product owners in scrum is replaced in favor of establishing stakeholder connections. As in projects typically information is collected from customers and client organization. Sor students in capstone needs to connect with a variety of stakeholders such as clients, supervisors, ethics committees and affected communities, during this stage" (Ashraf & Aftab, 2017; Neumann & Baumann, 2021).

The "Define Objectives" stage is one of the important stages of Design Thinking as it focuses on creating a knowledgebase by thorough analysis of available literature and getting relevant information from clients. This stage is critical to ensure that the product designed is in line with the client's expectations. In scrum the first step is to create a product backlog which is done by the product owner, and these will be implemented during sprints. Adapting this concept to student research this role falls to the student teams to create and set their own research objectives. This includes creating the context of their research by establishing what is included and environmental settings. This phases is adapted from the Design Science Research Cycle (Vaishnavi & Kuechler, 2011), to deduce new research possibilities from analyzing gap in literature (Peffers et al., 2018).

3.2.1.3.Scrum Phase

In this research the entire process to develop the project is centered on scrum cycles. The scrum phase is divided into three sub phases in which first project backlog is created. Then activities are designed for sprints and last is the reflection phase. This gives us a structured approach to managing research projects. Also, it has the benefits of scrum framework such as clear communication and continuous motoring of progress. Which has a positive impact on teams' collaboration and helps maintain project momentum (Parsons et al., 2020).

The Scrum Cycle comprises three stages: the "Build Backlog," the "Scrum Sprints," and the "Reflection." The first stage the "Build Backlog" is adapted from Design Thinking and Collins' (1992), where the concept is to identify and visualize the basic idea of research. Students are encouraged through literature to identify a novel and innovative are to conduct their research thus creating their backlog. Also, students should also consider the potential impact of their innovation on society and the environment. Potential benefits and cost can be another consideration when creatin a backlog. In doing so, students can ensure that their innovation not only meets their own needs and desires but also contributes positively to the greater good of society and the environment (Neumann & Baumann, 2021). The scrum provides a framework for sprint to ensure that the project remains on track based on regular check-ins and status updates. Thus, the team can report and identify any issues in a timely manner. Scrum Sprints also play a crucial part in project time management, helping to break down tasks into manageable chunks and ensuring that the project stays on schedule (Atoum, 2019).

The Sprint Review is also an important part of the process along with Sprint Retrospective. These are in place to evaluate the Sprint process and practices by suggesting improvements based on lessons learned during the previous iteration. In review meeting the team deliver and discuss the work completed to stakeholders and gather feedback (Parsons et al., 2020). Usually it is common to time-box Scrum at two to four weeks, which would be suitable for most students. But it's better to determined length of a Sprint by duration of student's research program and consider the specific requirements and objectives of a student's research (Glen et al., 2015).

Depending on the nature of the project, a student may find it advantageous to have longer Sprints that extend over several weeks or even months if they are working on a long-term project that spans multiple semesters. On the other hand, if the project has a shorter timeframe of a few weeks, it might be more effective for the student to have shorter Sprints that last only a few days or a week. This allows students to focus on those areas of their research that require the most attention and thus enable them to progress towards achieving their objectives (Ashraf & Aftab, 2017; Parsons et al., 2020).

3.2.1.4. Post Phase

The "Post Scrum" phase focuses on the sharing of results with the wider communities, as shown in Figure 3.2. This phase aligns with the Scrum process in software development in delivering the product to the customer. Whereas in an academic context, this is only one of several deliverables of the research process. This is done in form of contribution to body of knowledge in form of publications, presentations, and research reports (Parsons et al., 2020). While the format of communication may vary, there is an expectation that the work will be submitted for evaluation in some manner. Additionally, it should be shared with the relevant community of stakeholders, with the possibility of being published in a more accessible platform (Glen et al., 2015; Parsons et al., 2020; Parsons et al., 2020).

However, the problem with Scrum-Ban-Research Framework (SBRF) (Parsons et al., 2020), Design-Science Research Methodology (DSRM) (Peffers et al., 2018) is that these methods are for project based. So, by nature they are goal driven and does not cater to student-driven exploration and learning, which is important in inquiry-based learning. Also, SBRF is designed for iterative research and project work, which may not be suited for traditional classroom structures. Adapting SBRF for classrooms require modifications. In addition, SBRF lacks integration with digital tools or platforms. Such as learning management systems, dashboards, or real-time feedback. In modern educational settings are these are essential for supporting adaptive learning and tracking student progress. So, there is a need to adapt these for collaborative student learning.

3.2.2. "5E" of Seamless Inquiry Framework

"5E" inquiry framework proposed by Song & Wen (2018) is a formal method used to promote active learning. In this model five stages of learning are proposed that are Engage, Explore, Explain, Elaborate, and Evaluate. The process is initiated by the teacher by engaging students by asking questions to make students curious about a new scientific topic. The question might be one that has no answer, or a video, or discussion that provokes thinking about the topic. This engaging of student interest is used to stimulate recalling any previous knowledge they have and helps students create a bridge to the new learning. Then in Explore segment, students participate in hands-on activities, experiments, or other situations. In these activities they collect data, make observations, and/or discover concepts on their own, rather than being directly told via instructional explanation (Song & Wen, 2018).

In next stage Explain students examining their observations through discussions and build their own explanations. At this point, teachers can introduce formal definitions, theories, and/or models to further explain and deepen students' understanding of the topic. The Elaborate phase is where students apply their learning to new contexts to conduct further inquiry, or work on authentic problem-based projects in the real world. This is done to enhance understanding of the concept. Lastly, in the Evaluate phase, students evaluate their learning through their reflection, peer assessment, and teacher assessment. This tis done to check understanding, learning performance and retention. A formal assessment can be done such as a question and answer, quiz, or presentation.

These five stages of 5E model are particularly defined to improve critical thinking skills of students. This is especially effective in STEM education as experimentation is integral part of scientific process thus instead of receiving information passively the students engage actively in their education. But the problem is 5E seamless inquiry framework is not designed for collaboration so it might lose its effectiveness in such setting. So, in this research it is proposed to harness the benefits of 5E inquiry for collaboration by combining it with scrum to benefit from its iterative nature.

The 5E inquiry while effective in introducing structure to the learning process, which will benefit in collaborative inquiry when applied to different educational contexts but its has its own set of limitations. One main issue with collaborative inquiry can be its linear nature. This model lacks flexibility and feedback as it is often implemented in rigid sequential manner which also makes it difficult for it to cater to students' engagement needs. Also, 5E does not define roles and responsibilities for students, teachers or any supporting tools or roles which can cause confusion and chaos in collaborative setting thus impacting its effectiveness. Which leads to the need of a collaborative iterative framework which not only harnesses the benefits of 5E but can be equally effective in collaborative technology enhanced settings. This study proposes to integrate 5E with scrum to combine its iterative and role-driven principles to inquiry process.

3.3.ScrumBan Ubiquitous Inquiry Framework (SBUIF)

In this thesis the ScrumBan Ubiquitous Inquiry Framework (SBUIF) is proposed. This proposed framework combines the features of Scrum-Ban-Research Framework, which combines DSRM with Scrum, and components of Inquiry Based Learning (IBL). The purpose is benefit from their advantages and counter their drawbacks and challenges to create an effective learning environment (Pedaste et al., 2015; Peffers et al., 2018; Parsons et al., 2020)

SBRF implements Scrum principles for research-based student inquiry and the 5E model structures engagement using inquiry. Still, both SBRF and the 5E model carry certain limitations. While SBRF introduces structuring to scrum process by incorporating the principles of Scrum. It is believed to be more suitable for research projects rather than for everyday classroom instruction. It also focuses more on monitoring than student inquiry. Similarly, the 5E model is often implemented linearly and tends to lack components for collaboration. It does not define roles for students or teachers, making it less suitable for younger school students.

So, by introduction the elements of 5E and SBRF to SBUIF, we can create a comprehensive inquiry framework to support and improve student learning. This thesis not only evaluates SBUIF but also its potential in improving use of inquiry in education. Besides this, SBUIF incorporates collaborative by introducing specific roles for both the teacher and students. This approach ensures that students play an integral part in their educational journey by allowing greater role flexibility, enhanced collaboration, and the promotion of active learning.

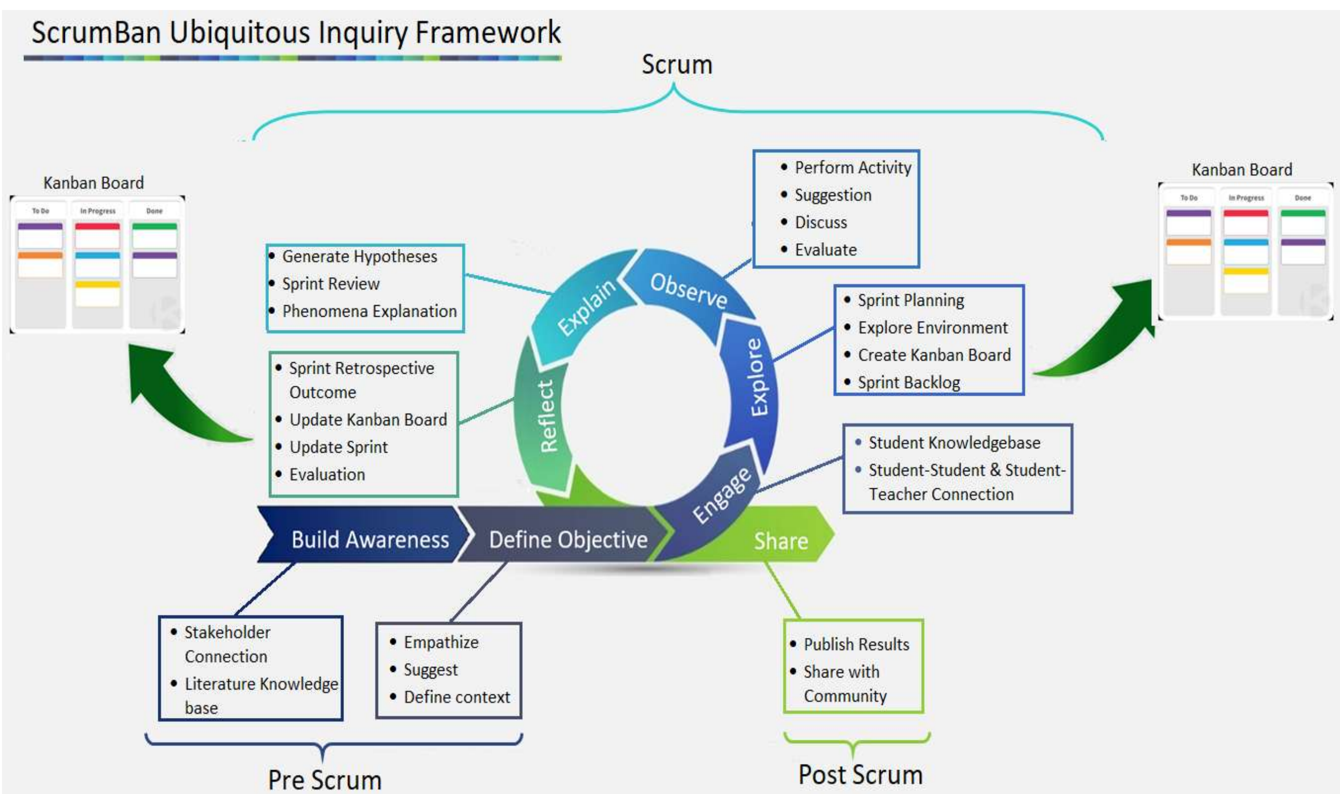

Figure 3.2: Proposed ScrumBan Ubiquitous Inquiry Framework adapted from (Parsons et al., 2020) & (Song& Wen, 2018).

SBUIF also provides a more adaptable structure, where learning activities are broken into small, manageable sprints, and progress is continuously evaluated and adjusted. The proposed SBUIF given in Figure 3.2 further divided into three distinct phases i. pre scrum, ii. Scrum & iii. Post scrum. These phases guide students through a structured process of scientific discovery and students become equipped with the skills necessary to engage in scientific inquiry, as they learn to apply critical thinking and reasoning to their observations and experiments. Following are the phases of SBUIF.

3.3.1. Roles and responsibilities

The application of SBUIF mapping to Scrum roles in the educational sphere presents an innovative method for defining educational activities as shown in Table 3.1. The teacher is the product owner in this method, responsible for creating lesson plans that make the product backlog. This allows for a clear definition of the learning objectives and thus building a logical sequencing of a curriculum. Here the teacher, the product owner, prioritizes learning goals and decides the sequence of activities, as the product owner manages a product backlog in normal Scrum methodology.

Table 3.1: Scrum roles, artifacts in SBUIF context

Scrum Concept	**Role in SBUIF**
Product owner	Teacher
Scrum Master	uASK application
Development Team	Students Teams
Product Backlog	Curriculum (Lessons)
Sprint Backlog	Specific activities and objective for learning.

Either the teacher or SBUIF may assume the role of the Scrum Master, which consists of coaching and facilitating the process. By adopting this approach, it creates a unique learning environment Either the teacher or SBUIF may assume the role of the Scrum Master, which consists of coaching and facilitating the process. By adopting this approach, it creates a unique learning environment. In this scenario it is responsibility of scrum master to facilitate the learning environment and provide support to create engaging activities. Learning activities are termed as sprints and individual tasks are it iterations of this activity. This provides a cyclical and iterative approach to learning, where teaching methodologies and learning progression can be regularly assessed and adjusted. By splitting the learning process into small sprints and iterations, the model may provide a more flexible and adaptable teaching method, and thus potentially elevate student engagement and learn outcomes.

Lastly, in a learning context, the role of development team is reimagined as student who would be performing the said activity. Students will move through the emphases of SBUIF to engage in the learning process. Thus, creating their individual and group knowledge. Then again, the software development sprints are mapped to the learning sprints and students will participate to achieve a learning objective in a time-boxed period. Within these sprints, students would work collaboratively on tasks and assignments that relate to the curriculum goals. As students move through the Scrum phases of SBUIF, they engage in a variety of learning experiences. This is an iterative process in which students build upon each other's understanding, make applications of new concepts, and refine their knowledge.

3.3.2. Pre-Scrum Phase

In preparation prior to scrum, in this adaptation there are two sub-phases i. Build Awareness and ii. Define Objectives. These pre scrum phases are there to lay foundation for the implementation of scrum. Building awareness consists of the process of creating knowledgebase and stakeholders’ identification and preparation. While Defining objectives is primarily focused on setting clear goals for the lesson. Together, these steps prepare the Teachers to the encounter the complexities of the scrum framework.

3.3.2.1.Build Awareness Stage

The initial "Build Awareness" is very important for the successful implementation of the SBUIF approach is it lays the groundwork. This phase the focus is on generating learning objectives. During this phase, connections creating between all relevant stakeholders, including educators, administrators, and the broader learning community (Anderson-Butcher et al., 2010). This stage, emphases developing effective assessment strategies that align with the learning objectives. This is ensured by getting valuable feedback from all stakeholders (Hmelo-Silver et al., 2007). By establishing these connections, the process can benefit from diverse perspectives that ultimately leads to a more comprehensive understanding of the learning objectives. Additionally, this phase ensures the construction of a thorough knowledge foundation that corresponds to the product backlog concept of scrum. The knowledgebase is constructed by generating lesson plan and learning curriculum. This ensures that teachers and other stakeholders possess clear understanding of the current state of study, best practices, and emerging trends in the field (Aldenaini et al., 2020).

3.3.2.2. Define Objective Stage

The second stage, "Define Objective" which correlates to the Sprint backlog in scrum. In this a deep exploration is conducted for a thorough understanding of the learners' perspectives and needs. At this stage, a careful analysis of the target audience is conducted to clearly define and outline content for the learning objectives that will prove to be most relevant and engaging. This exploration is done by the instructional team which comprises of teachers, administrators and other stakeholders belonging to the educational organization (Padzil et al., 2021; Berger & Thanh, 2004). It is done by carefully evaluating the unique behaviors and learning styles of the target audience. The activities are designed in such a way that not only do they meet the students' needs but encourage active involvement and participation (Garrison & Vaughan, 2008). So, by employing this approach, the created learning environment is more engaging and interactive, which helps students to achieve better outcomes (Brodie et al., 2017).

3.3.3. Scrum Phase

The scrum phase is divided into stages that are Engage, Explore, Observe, Explain and Reflect which are adopted from 5E of inquiry. That is done to ensure students actively participate in construction of knowledge as stages are used in implementing the scrum methodology to work together in collaboration to create a structured approach for learning and each stage is responsible for a specific task that can be from starting the learning process to evaluating its outcomes. Students' teams can effectively manage their learning, foster collaboration, and continuously improve their practices by following this framework, (Parsons et al., 2020).

3.3.3.1. Engage Stage

This is the first stage which is centered on activating and improving the students' prior knowledge and experiences. Thus, creating meaningful connections between the students and the instructor along with establishing peer connections between the students as well. At this stage of the framework the emphasis is on the importance of engaging students. That is done by activating their prior knowledge and experiences. By fostering meaningful connections among peers, and between students and instructors improves collaborative learning.

Thus, learning applications and blended learning approaches to use to foster engaging and participating in learning activity, this helps students to actively create knowledge. By utilizing advance technological tools to support the learning experience and nurturing a cooperative environment the purpose of this stage is to generate a dynamic and interactive educational experience.

3.3.3.2.Explore Stage

The purpose of "Explore" Stage is to map the structured and iterative elements of scrum to design lesson components. The first step is sprint planning, where students collaboratively plan the upcoming learning sprints amongst themselves or the instructor and students jointly do it. The sprint planning process is important as through this process both instructors and students can clearly identify the objectives and build goals, which will allow the learning expectation to be meet and which ultimately leads to more effective and efficient learning outcomes.

Therefore, it is important for educators to carefully plan and communicate the objectives, goals, and expectations for the upcoming learning sprints to ensure effective and efficient learning outcomes. During the Explore Stage, instructors and students collaboratively examine the learning environment, investigating with the help of technology resources to interact with environment for effective learning. For exploration multiple technological tools can be used such as mobile phones, cameras, Bluetooth beacons or QR codes.

Also, in this stage the creation of a Kanban board and sprint backlog is included. That helps to organize and visualize the learning process, so team can then use the Kanban board and sprint backlog to prioritize tasks and track progress, leading to an efficient and streamlined learning process and continuously monitoring the progress of each task and sprint, the team can identify potential roadblocks and make necessary adjustments to ensure that the project stays on track. Additionally, the team can use the Kanban board to visually represent the status of each task, making it easier to communicate progress and identify areas that may require additional attention.

3.3.3.3.Observe Stage

The third Stage focuses on the engagement students as they actively participate in the learning activities. During this Stage students focus on performing the activity tasks and provides real-time suggestions, feedback, and guidance to support their learning process and address their diverse needs (Wang, 2019).

The instructor closely monitors the students' engagement and performance during the learning activities by kanban board thus can provide real-time suggestions, feedback, and guidance to support their learning process and address their diverse needs or this support can be provided by or technology enhances application. This Stage also involve discussions and evaluations of the activities, supporting a continuous improvement process (Goedhart et al., 2019).

3.3.3.4.Explain Stage

In the fourth Stage, known as the "Explain" Stage, students are guided to formulate hypotheses. This is done by engaging in these critical thinking and problem-solving activities, where students are able to develop a deeper and more comprehensive understanding of the subject matter. First, the students formulate thoughtful hypotheses to explain the observed phenomena. Next, engage in comprehensive reviews of the progress made during the previous sprint, by engaging in group discussions with each other to reflect on their learning journey, and the last step is creating a clear explanation of the underlying concept which students achieve by engaging in these critical thinking activities. The Explain Stage aims to promote meaningful learning and the construction of knowledge base to improve student learning.

Also, the Explain Stage encourages students to challenge their assumptions and refine their hypotheses, all of which are needed for their growth as independent learners and problem-solvers. So it can be said that collaboration helps in hypothesis generation which can improve their critical thinking skills and empower them to tackle real world problems as well as solve complex problems.

3.3.3.5.Reflect Stage

"Reflect" stage imitate sprint retrospective which is used to conduct a detailed review and analysis of the entire learning process. Through this analysis weaknesses or issues encountered during the sprints can be identified and based on them improvement in individual learning along with the learning process can be made. In this stage instructors and students collectively reflect on the sprint iteration to study the outcomes, effectiveness, difficulties and overall findings of the previous sprint. Based on these findings the next sprint can be improved to tailor it to the learning style of the individual and improve the sprint design to yield better learning outcomes. This review optimizes the learning framework and ensure the resultant learning experience better response to needs of both instructors and students (Weinstein et al., 2018).

3.3.4. Post-Scrum Stage

This is the last phase and contains only one stage i.e. share. This is used to share the findings of the scrum phase.

3.3.4.1.Share Stage

The sole purpose of this phase is to share the findings and analysis of the evaluations with the stakeholders which include students, parents, administrators and other parties concerned.

This phase serves as a platform for reflection on the outcomes of the scrum phase, progress made and lesson learned. It focuses on evaluating the strengths and weaknesses of the adopted process and how to improve it to better facilitate the students learning process. Then sharing these findings to the larger community to not only improve individual learning but to also have part in overall policy decisions.

3.4.uASK Application

In this research a uASK application is created on the principles of SBUIF to test the effectiveness of this approach on student learning. The purpose was to introduce concept of agile practices to student learning through a user friendly application in a controlled yet flexible learning environment. It is achieved by combining Scrum's iterative cycles with Kanban's visual task management. So the students begin with awareness and know their current standing, it builds to spark interest and end with reflection to gather knowledge in this framework in which students are encouraged to take charge of their learning and develop critical thinking abilities at each step.

The uASK application serves as the technological support for implementing SBUIF in educational settings which is done by letting the students visualize their learning, organize activities, and collaborate online. The software provides agile project management like task boards, progress tracking, and communication options which helps motivate students, improve their knowledge retention, and teach them qualities needed in today's workforce, such as self-management, teamwork, and adaptability. There are interfaces for students and teachers to support learning. The dual nature of student-teacher interfaces help optimize learning and instruction. In the student interface, it is easy to find the course materials, complete the assignments, engage in dialogue, and check the history. It also helps students keep on track as tasks are arranged in a manner to minimize distractions. Students can run through their courses, achieve learning objectives, and monitor their progress, thus promoting self-directed learning.

But whereas, the teacher interface has functions for course management, designing activity material and student evaluation which can be customized according to specific student learning levels and needs, teachers can create multimedia lessons or use various learning activities to adapt different styles of learning. The interface includes kanban boards to assist teachers in monitoring student performance. This method enables SBUIF to achieve continuous improvement and individualized education. The teacher interface also facilitates peer-to-peer support by giving access to chat options, in line with the SBUIF's emphasis on connection.

3.4.1. Roles and responsibilities

In this Agile framework, the traditional roles and artifacts are reimagined to fit the classroom context. The teacher assumes the role of the product owner, taking responsibility for defining and prioritizing the overall learning objectives and curriculum goals which ensures that the educational outcomes better align with the academic requirements and student needs. The uASK application functions as the sprint master facilitating process and manages the workflow. The lesson plan serves as the product backlog which contains a comprehensive list of learning objectives and topics. From which specific lesson activities are derived to form the sprint backlog and the tasks are assigned to be completed in each sprint.

These sprints are timeboxed, ideally set to one week, thus providing a structured framework focused on learning and regular assessment of progress this approach allows for iterative improvement of teaching methods and content delivery, as well as the ability to adapt quickly to student feedback and changing educational needs. Which is given in Table 3.2. Using Scrum terminology Teacher will be Product owner and uASK will act as scrum master. It will be the teacher's responsibility to create product backlog i.e. Lesson plan. Sprints are lesson activities designed by the teacher and sprint backlog are the task in each individual sprint. In this scenario created for this study both sprints are timeboxed at 1 week each. The procedure of the activities in this experiment was designed by consulting curriculum books in collaboration with teachers to design an effective activity to enhance learning and according to the SBUIF, the application behavior is comprehensively outlined in the subsequent section which provides a detailed explanation of the experiment scenario and the application design is elaborated. All the tasks of experiment are discussed with application interactions.

Table 3.2: SBUIF roles in experiments

Scrum Concept	Role in SBUIF	Experiment
Product owner	Teacher	Teacher
Scrum Master	uASK application	i. uASK application for uASK ii. Teacher for Trello
Development Team	Student Teams	Student teams
Product Backlog	Curriculum (Lessons)	i. Reproduction in plants ii. Transport in plants iii. Heat on the move
Sprint Backlog	Specific activities and objective for learning.	Lesson- Reproduction in plants **Sprint 1: Reproductive parts of plants & pollination-Time 1 week.** Task 1: Initial knowledge -parts of plant Task 2: Botanical Garden Tour Task 3: Sample Dissection of flowers to identify different parts Task 4: Worksheet Completion Task 5: Hypothesis Formation-identify parts of plant ask 6: Initial knowledge -Pollination Task 7- Hypothesis Formation- identify type of pollination **Sprint 2- Germination Daily Log-Time 1 week.** Task 1: Day 1 log of seed & discussion Task 2: Day 2 log of seed & discussion Task 3: Day 3 log of seed & discussion Task 4: Day 4 log of seed & discussion Task 5: Day 5 log of seed & discussion Task 6: Day 6 log of seed & discussion Task 7: Day 7 log of seed & discussion

3.4.2. Pre-Scrum Phase

This phase coordinates the Building Awareness and Defining Objectives processes, which basically consist of building a knowledge base by means of lesson logs matching the idea of the product backlog in scrum. Teachers mostly engage in these tasks; they will create lesson plans. The instructor will decide which activities to include within the course of instruction, layout of the learning environment, and schedule how the students will interact with it. This phase also consists of group development and task assignment. In this phase ubiquitous environment is set up, that is how students will interact and engage to create their knowledge, what devices will be used, i.e. mobile camera, scanning QR codes to engage or Bluetooth beacon tags to guide the students and engaging with specific specimens.

Designed closely with the SBUIF, the teacher interface on this educational platform is a complete tool meant to improve the teaching and learning environment. Figure 3.3 shows some of the features of this application including lesson planning, task information, and student progress. Teachers will be able to make lessons in a particular course and activities in the lesson which correspond to sprints. Like in the scenario designed for this research the focus is on seven grade science courses where two activities are designed each corresponding to a sprint. After discussion with the teachers at the local schools and using oxford science book for the lesson design, a lesson “plant reproduction” was selected to conduct experiments. This lesson was divided into three parts reproductive parts for plant, pollination and germination. In the first sprint, the first two parts are performed by the students that include a need to identify reproductive parts of the plant and pollination focusing on wind and insect pollination performed in the school. In both these activities, these seven tasks including initial knowledge, botanical garden tour, sample dissection of flowers, worksheet completion, hypothesis generation, and pollination tasks. In a similar vein, in the second sprint, students are involved in the third part of the lesson germination in which they need to select seeds and observing germination process. This activity will help students to understand the practical behaviour of plant biology through uASK application.

The Central Dashboard is teacher’s main control center of uASK application is shown in Figure 3.3. Teachers may quickly evaluate and monitor classroom activities and identify areas needing work just through this one site. The dashboard helps teachers make data-driven decisions to improve learning and classroom operations by offering real-time insights. Main components of the teacher module is curriculum management along with sprint tasks, teams building and management and monitoring of student through kanban. The comprehensive Lesson Planning Feature helps teachers construct structured and interesting classes. This tool lets teachers create subjects and subtopics for a coherent curriculum. Teachers can build sprints for each activity to promote focused, timed learning. Each class can have clear objectives to meet educational goals. Teachers can also include videos, worksheets, and interactive content to meet varied learning needs.

This feature helps the ScrumBan Ubiquitous Inquiry Framework (SBUIF) "Build Awareness" and "Define Objective" stage by clarifying learning goals and aligning them with the curriculum. By doing so, teachers can offer effective and impactful lessons, improving learning outcomes. The Central Dashboard and Lesson Planning Feature help teachers improve classroom management and instruction for a planned and flexible approach to education.

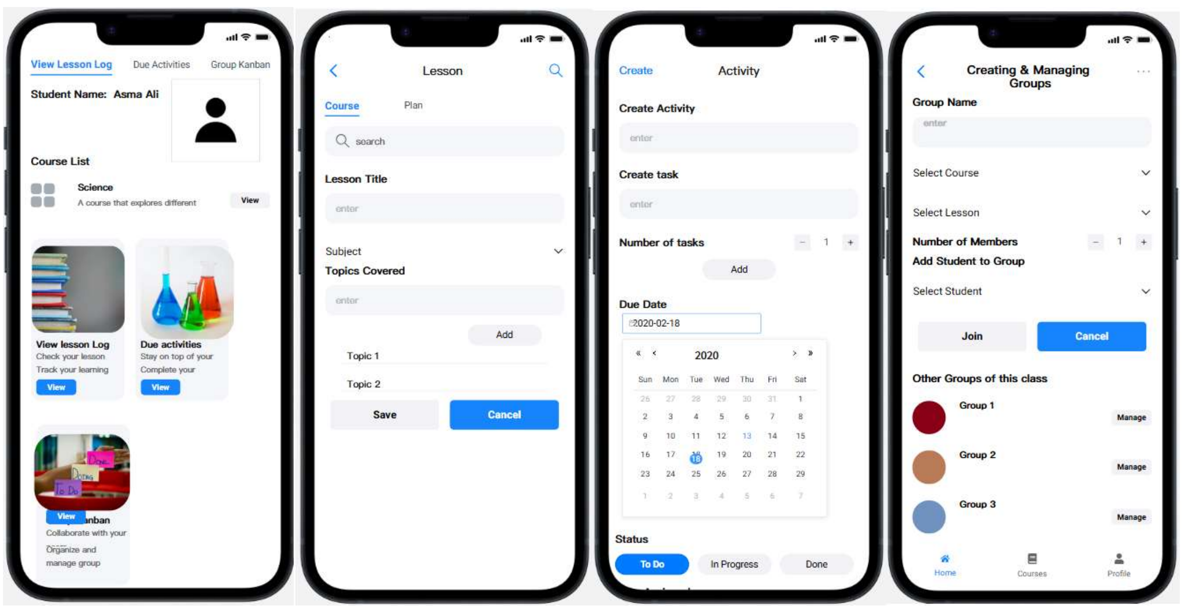

Figure 3.3: Teacher Interfaces

3.4.3. Scrum Phase

Scrum phases have integrated the inquiry instruction phases into one scrum cycle using 5E stages of inquiry that are engage, explore, observe, explain & reflect. The student interface is basically to support learners as they navigate through various phases of learning activity, as the framework helps in the way which they engage in a structured inquiry as items in the student interface helps support in creation of customized dashboards, engaging learning experiences, progress trackers, and spaces for collaborative peer interaction and these are carefully arranged so to establish a step-by-step framework for the student, where they are able to navigate through course materials, assignments and assessments in an efficient manner as illustrated in Figure 3.4. Student interface is a complete platform which caters the varied needs of learners at each stage of inquiry. SBUIF, making sure that the user flow is uninterrupted, and user friendly.

The uASK application, the student interface is a complete platform providing elements for a student's diverse learning needs. SBUIF to fully give a seamless & user-friendly experience uses interface including the comprehensive set of features and activities that support students through a learning from initial engagements to advanced capabilities thus for explore, observe and explain the students interact with the ubiquitous environment by using the application. They perform the activity i.e. sprints, discuss their findings, generate hypothesis and report their progress.

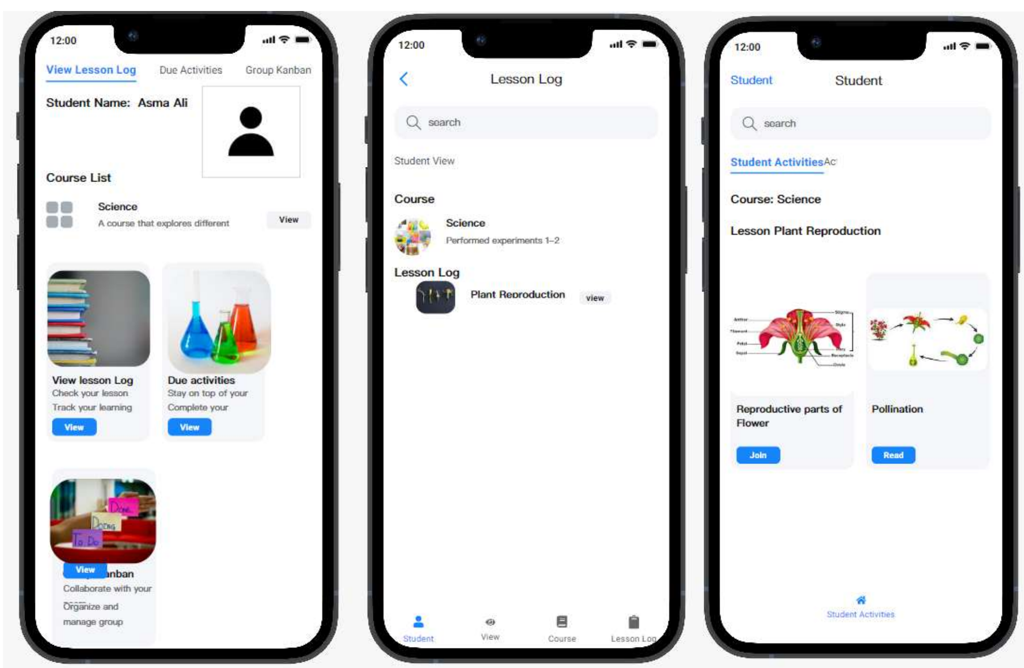

Figure 3.4: Student Activity Interfaces

3.4.3.1.Sprint 1

The first sprint is divided tasks to correspond with different parts of a lesson. First activity of sprint is based on identification of the reproductive parts of a plant and its different components, and the second is dealt with the understanding of the pollination and its types through continuous observations by the students overall seven tasks are performed by the students.

Task 1: Initial knowledge -parts of plant

In uASK a video-based introduction serves as a starting point in the learning process, providing students with a initial knowledge as overview of the topic at hand to activate their prior knowledge. By presenting foundational knowledge this means, helps caters to diverse learning styles and helps establish a common baseline understanding among all students. This can be replaced by traditional teaching activity to impart foundational knowledge if using another platform. The content typically includes key concepts, historical context, and real-world applications, which collectively form the groundwork for deeper exploration in subsequent stages of the lesson as shown in Figure 3.5 and follows the "Explain" stage of the SBUIF, this initial exposure to the topic through video allows students to begin forming mental connections and generating questions. As they absorb the information presented, students can start to identify areas of interest or confusion. That will guide their engagement

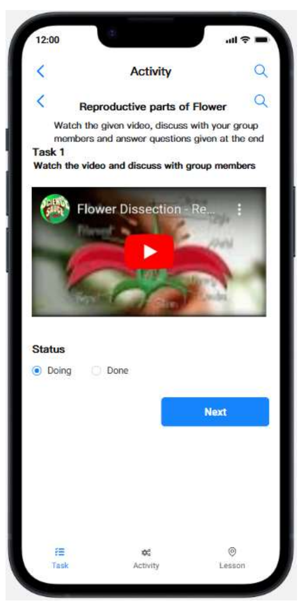

Figure 3.5: Screenshot of uASK showing video

in later stages of the learning process. This approach not only prepares students for active participation but also helps to spark curiosity and motivation, thus creating a setting where students will engage in more in-depth inquiry and exploration of the phenomenon being studied. It helps in creating meaningful understanding of concept.

Task 2: Botanical Garden Tour

In this activity, the students were tasked with observing and exploring a botanical garden to collect samples of flowers. It was supported by using beacon technology, the app directs students to specific areas in a botanical garden to collect samples which are preselected by the teacher. This immersive experience, supported by location-based prompts, aligns with the "Explore" and "Engage" stages of SBUIF, encouraging hands-on investigation and integration of Bluetooth beacon technology in the app creates a dynamic and interactive ubiquitous learning environment within the botanical garden, as students move through the garden, strategically placed beacons trigger location-specific prompts and information on their mobile devices. This system can guides students to particular plant specimens. By providing instructions for sample collection and observation. The app's functionality aligns closely with the "Explore" stage of the SBUIF, by facilitating self-directed discovery which enables students actively navigate the garden to complete their required task with minimal hindrance and making decisions about which areas to investigate based on the app's guidance, this approach not only helps improve curiosity and encourages students to form initial hypotheses but it minimises distractions and aspect will be missing thus leading to confusion for students if another platform is used for implementing SBUIF.

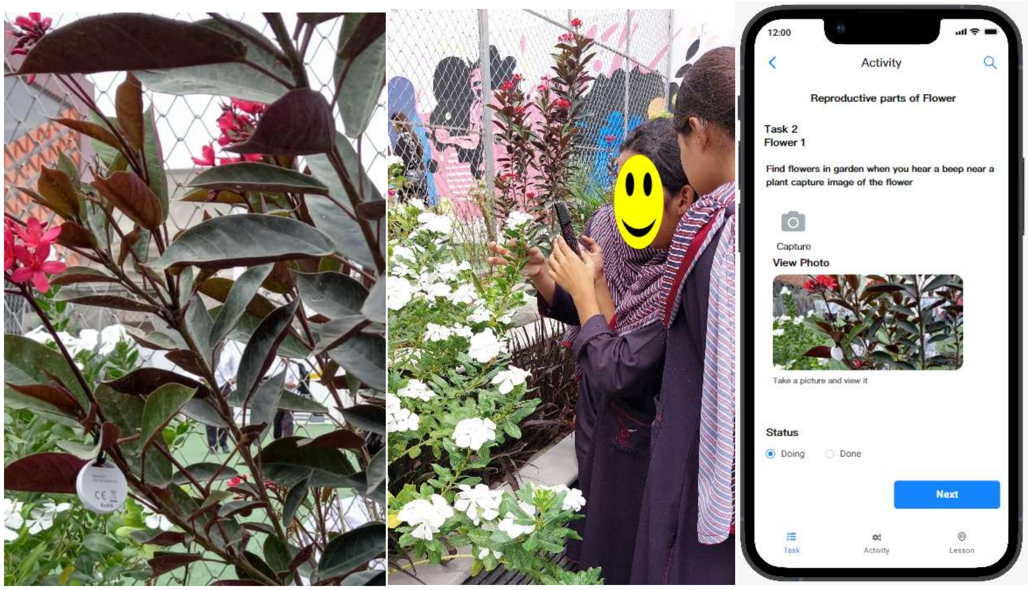

Figure 3.6: In the image at left the beacon tag is shown, the image at center shows students scanning and taking picture of the flower & the image at right shows the screen of application

The "Engage" & “Observe” stage is supported through the hands-on nature of the sample collection process. As students interact with the physical environment, they are prompted to make detailed observations. By either taking photographs or collect small specimens (where permitted) as shown in Figure 3.6. By integrating digital tools, it allows several benefits to the students like real-time data collection as they can upload their samples and observations immediately. So, this facilitates collaborative learning and data sharing. Along with increasing physical interaction utilises multiple senses that can potentially improving retention and understanding as it engages tactile memory.

Task 3: Sample Dissection of flowers to identify different parts

Now the next task after collecting the samples is to dissect then on the bases of the knowledge gained through task 1. To help this process hints are provided through the application. This task aligns with the "Observe" stage of SBIUF. This helps students’ observation skills along with participating in the interactive activity improves their engagement in the learning process. It improves understanding of flower structure through hands-on exploration. Also, utilization of simple tools for detection and tools and a smartphone application to examine real flowers up close enhance their learning experience. This process of helps to learn how to handle delicate specimens and apparatus with care, along with developing fine motor skills. It also encourages curiosity and close observation as students takes apart the flower apart which are key skills in scientific inquiry.

In the next activity students engage with third Stage where focus is on the engagement students as they actively participate in the learning activities by dissect collected samples to identify their parts. To help with this activity hints provided through the application provide feedback, and guidance to support their learning process to support understanding. This aligns with the "Observe" stage, where students deepen their observational skills. The instructor closely monitors the students' engagement and performance during the learning activities by kanban board thus can provide real-time suggestions, feedback, and guidance to support their learning process and address their diverse needs or this support can be provided by or technology enhances application. This Stage also involve discussions and evaluations of the activities, supporting a continuous improvement process.

Next, step of the task is to identify different parts of the flower based on their acquired knowledge. They learn to differentiate between different components such as petals, sepals, stamens and pistils. This helps then understanding the structure of flower along with the function of each part. Which is than uploaded on the application interface as shown in Figure 3.7. This corresponds to “Reflect” and “Explain” stage of the Scrum phase. This activity is supported by application as it helps the students photographs and record their observations which not only helps improve their observation skills by create digital record of their findings. Which can be shared with their team and teacher. This allows creates an interactive activity which allows the students to engage more in the learning process.

Besides by the end of the activity, students will have gained a deeper understanding of flower structure, which will improved their observational skills, and help them becoming familiar with botanical terminology, whereas this knowledge forms a strong bases for further studies in plant biology, ecology, and environmental science. This activity combines hands-on work with technology to make learning about flower structure more interactive and engaging.

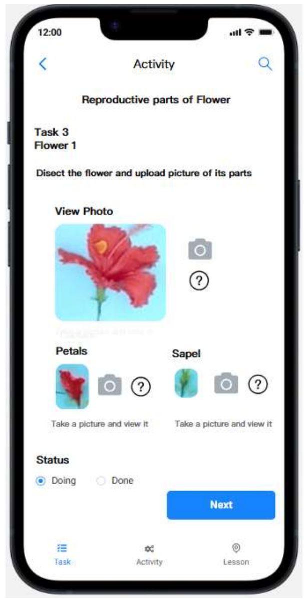

Figure 3.7: Uploading images of dissected parts

Task 4: Worksheet Completion

Including worksheet into the application helps in making to app a more structured tool for students to organize and analyse their findings, as students' progress through the activity, they are prompted to fill out various sections of the worksheet, encouraging them to record their observations as shown in Figure 3.8.. Also, helps focus on key aspects of the learning objectives. The hints available within the app act as to students who may need additional explanation or prompts to complete a task.

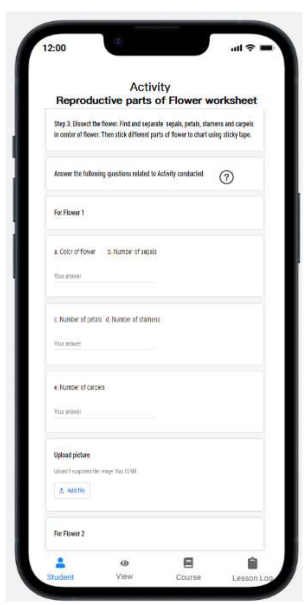

Figure 3.8: Answering worksheet questions

These hints are placed to encourage critical thinking skills so that if students encounter a problem, they can consider alternative solutions or if needed explore basic concepts more thoroughly. This process is part of reflect stage as workshop activity helps students in the process of gathering information. Also, by engaging with worksheet students pause and process the information rather than proceeding to the next task. This reflection promotes deeper understanding of the topic and help student to be aware of their learning process and progress. As well, the structured nature of the worksheet allows educators to evaluate students' understanding, learning performance and identify areas where further instruction or support may be needed, facilitate the learning process by introducing support to create for the students a more personalized and effective learning experience.

Task 5: Hypothesis Formation-identify parts of plant

Students create hypotheses based on observed data, facilitated by hints in the app. This aligns with "Explain" and “Reflect” where students make sense of observations by forming logical conclusions or hypotheses. As in this activity the students were shown different flower parts. They were required to identify them and give reasoning for their response as shown in Figure 3.9.

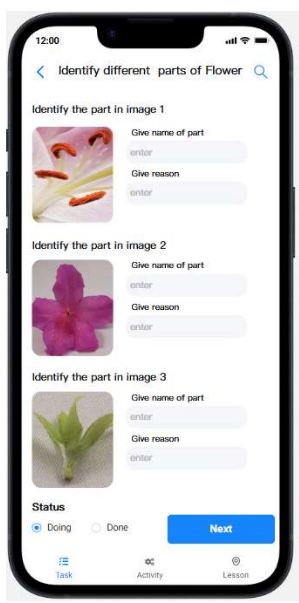

Figure 3.9: Interface for hypothesis generation

Task 6: Initial knowledge -Pollination

The second part of the task, much like Tasks 1 and 5, was aimed at learning how plants reproduce and their various mechanisms of pollination. In task 6 through a video lecture on the uASK platform that would cover the basic introductory theoretical knowledge, a hands-on examination of real flower specimens was to be conducted in order to contextualize what they had learned. This involved challenging students to observe and analyse the external characteristics of flowers-such as, but certainly not limited to, its shape, colour, scent, and features of the interior structure as shown in Figure 3.10.

Task 7- Hypothesis Formation- identify type of pollination

Then in task 7 As such, they are encouraged to formulate hypotheses about the flower specimen, given through the application inform of pictures, in relation to some type of pollination, linking contents learned in the lecture with observations made. Hence, this activity boosts critical thinking and observational skills in various aspects such as nectar guides, flower symmetry, pollen presentation, and such other adaptations that are indicators of one or another of the pollination syndromes. Henceforth, with this coming together of hypothesized evidence based on observation, they will appreciate the beautiful way in which flower morphology enhances and supports any particular pollination strategy - bridging the theory with its application in plant biology as shown in Figure 3.10.

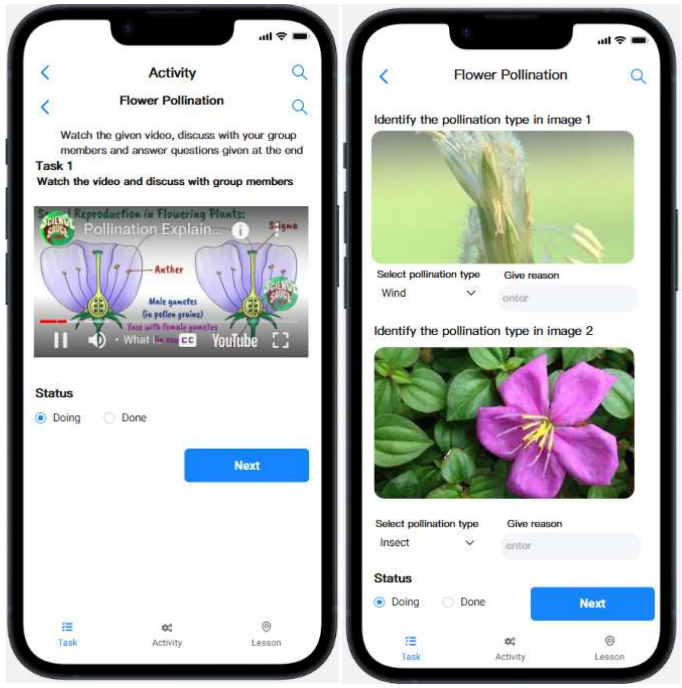

Figure 3.10: Pollination of flower

3.4.3.2.Sprint 2

In the second sprint, students engaged in a germination experiment. It is a hands-on activity in which each student use various seeds sourced from their home pantries and try to germinate them. Every student will be doing this activity with a different seed in a different environment. This activity aimed to provide a practical understanding of plant biology and the germination process. Students began by selecting a different seed, such as beans, lentils, or grains, and soaking them in water. These are then placed in containers covered in moist cotton in well lighted environment and their progress in carefully monitored. It is a week log activity in which the students are asked to create daily logs to study the progress of growth of the seeds over time by sharing and discussing with their group members as shown in Figure 3.11. They are encouraged to share their observation and any issues and problems that they encounter during this process. This will not only improve their understanding of the topic but also peer interaction.

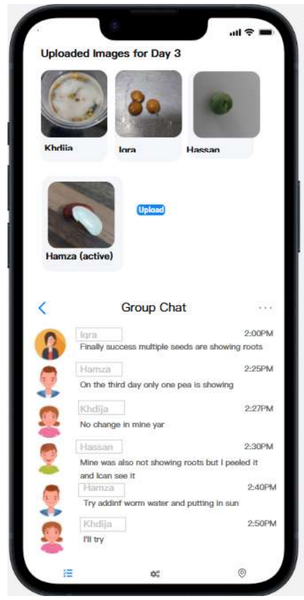

Figure 3.11: Sprint 2 Gemination of seeds

Progress reporting is done and shared by Kanban interface shown in Figure 3.12 that aligns with the SBUIF by promoting sharing progress flow. This capability supports the "Engage" and "Explore" stages of the SBUIF by maintaining consistent student engagement and providing a clear instruction for learning activities. By including these features, the teacher interface creates a complete system that supports the entire learning process as outlined in the SBUIF. It also enables educators to create, manage, and adapt their teaching strategies by providing them a tool where support for these activities is provided and it is also providing students with a structured, engaging, and reflective learning environment.

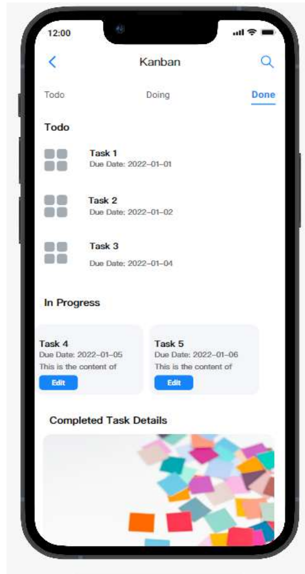

Figure 3.12: Kanban Visualization of group task progress

3.4.4. Post-Scrum Phase

The Post-Scrum phase focuses on disseminating results and comprehensive evaluations of student performance. This phase share individual, group progress and activity performance-evaluation scores to stakeholders. In the reflective stage of the Scrum process, teachers analyse the performance of each student to give a meaningful evaluation, indicating the student's strengths and weaknesses. The sharing of these assessments and results with administrators, parents, and the very same students serves to improve students learning. It opens up the learning process to let every stakeholder involved understand how each student stands academically. Open communication helps to make room for collaboration in such support from other stakeholders. In addition, this is a chance for students to self-reflect and come up with a goal for themselves, thereby empowering them to take charge of their learning process.

3.5.Experimental Design

In this study, for the purpose to evaluate the effectiveness of our developed application experiments were conducted. For this purpose, uASK was compared with an existing project management application Trello which has been used in the literature (Parsons et al., 2020). Trello is more compliant with the principles of Kanban so it is included to find if it is effective in this study. This study aims to observe the learning efficacy and user experience for these applications. The study was divided into two experiments conducted at two local schools selection criteria was random selection. The experiments were conducted with middle school science grade 7 classes of 12–13-year-olds after getting approval from the principal of a high school and getting informed consent form students' parents as guidelines of Bahria University ethical committee (Forms attached in the Appendix I, II and III). As per the Scrum terminology, a teacher will be behaved as a Product owner and uASK will act as scrum master but in case of Trello this role will also belong to a teacher. It will be the teacher's responsibility to create product backlog i.e. Lesson plan. Sprints are lesson activities designed by the teacher and sprint backlog are the task in each individual sprint. In these experiments, both sprints are timeboxed at 1 week each. In Scrum terminology Teacher will be Product owner and uASK will act as scrum master but in case of Trello this role will also belong to Teacher. It will be the teacher's responsibility to create product backlog i.e. Lesson plan. Sprints are lesson activities designed by the teacher and sprint backlog are the task in each individual sprint. In this experiment both sprints are timeboxed at 1 week each. The procedure of the activities in this experiment were designed by consulting curriculum books in collaboration with teachers to design an effective activity to enhance learning.

Total sample size is 205 middle school students as per power analysis this is appropriate sample size moderate or large significant difference. In this quasi-experimental research, we had two groups: (1) participants using Trello (n = 103), and (2) participants using our designed application uASK (n = 102), which resulted in a total sample size of 205 participants. The study was conducted using traditional significance level (α) of .05 and aimed to detect a medium effect size (Cohen's d = 0.5). A power analysis using independent samples t-test indicated a statistical power of .945, which is far greater than the traditional 80% threshold. The probability of identifying a true effect, if it exists, is very high and the possibility for a Type II error is greatly minimized. Therefore, the study is statistically competent and has sufficient sensitivity to identify moderate (or larger) differences between the two groups on performance, usability or satisfaction. The strength of this design contributes to the credibility of any significant results found in analysis.

3.5.1. Experiment 1 Design

The first experiment of this research involved a sample size of 127 seventh-grade students (76 boys and 51 girls) of a local school which appears to be sufficient for medium to large effect size. For the purpose of direct comparison, the students were divided into two groups: one group was assigned to use Trello, while the other group utilized uASK. This experimental design was suggested to allow researchers to conduct a side-by-side evaluation of how each tool performed in enhancing students' learning experiences through inquiry-based methodologies.

The proposed SBUIF was implemented through an experiment to evaluate its effectiveness. The study utilized the uASK application, which incorporates both Scrum and Kanban methodologies, and compared it with Trello, a Kanban-based project management tool that has been studied in various studies for education using agile as a learning pedagogy. The sample consis of grade 7 students as middle schools was targeted for this study and their teachers also participated. That was done to better evaluate the impact of the framework on the learning process A quasi-experimental research design was implemented which divided the participants into two experimental groups. 64 students belong to Experimental group 1 and 63 to Experimental group 2. The first experimental group utilized Trello, while the second experimental group employed uASK. This design hoped to study a comparative analysis of the two approaches in facilitating student learning and engagement. The scrum lesson, which served as the primary activity for the experiment, was structured into separate tasks. Thus, representing a sprint in the agile methodology. Both activities were performed and micro and meso level evaluation as discussed in section 3.4.

3.5.2. Experiment 2 Design

A year after the initial study, a follow-up experiment was conducted in other school setting, involving sample size of 78 students (42 boys and 36 girls). The follow up research was conducted to validate the findings of the initial experimentation. It is to further explore the effectiveness of developed collaborative tool in supporting student learning. The research design for this second experiment also used the same a quasi-experimental approach. The participants were divided into two experimental groups, with 33 students assigned to the first group and 34 to the second. This balanced distribution ensured that both groups had a similar number of participants, enhancing the validity of the comparison.

The first experimental group replicated the conditions of the original experiment by utilizing Trello as their collaborative tool and the second experimental group uASK. This consistency was employed in hope to allow for a direct comparison with the results obtained in the initial study, providing an opportunity to assess the reliability and generalizability of the findings across different school environments and student populations. The results obtained from this second experiment were used to validate the findings from the original study. Thus appearing to support or challenge the initial conclusions as additional evidence. The outcomes and implications of both experiments are discussed in detail in Chapter 4 of this thesis and explores the similarities and differences in results between the two experiments, the comparative effectiveness of Trello and uASK, and the broader implications for implementing collaborative tools in educational settings.

3.6.Evaluation Methods

Defining appropriate criteria for the evaluation of models is one of the key factors in the investigation into how successful and effective any proposed model or framework really is. In the absence of such clearly defined evaluative metrics, it becomes nearly impossible to gauge the effectiveness of one framework as opposed to others in existence or in which areas it needs to be modified. Thus, these criteria can represent reference points through which the model can actually measure up against and hence provide insight into its strengths and weaknesses (Hinyard et al., 2023).

Research has shown that ICTs can influence student learning experiences when integrated into the educational process (Wang et al., 2016). The last few years have seen a considerable increase in the use of collaborative software development in providing tools and platforms for students to engage in group-based learning and problem-solving experiences. These collaborative activities can usually emphasize user interaction and collective solutions to real-life problems, aiming to help development of essential skills for the 21st century (Shawky et al., 2014; Jeong & Hmelo-Silver, 2016). Moreover, the implementation of computer-supported collaborative learning has been explored at different educational levels.

The findings suggesting that these strategies can be effectively applied to education. The introduction of technology supported collaboration into educational setting has been is assumed to support both the way individuals learn and the digital and informational skills they acquire (Gómez et al., 2013; Sung, Yang & Lee, 2017; Lipponen, 2023). In conclusion, the collaborative affordances of computer-supported learning might have significantly transformed the educational landscape.

3.6.1. Collaborative affordances

Hmelo-Silver (2016) centres on the key features and capabilities of collaborative environments that enable and enhance interactions and learning, as well as knowledge construction among participants. This includes combing of the components of technology, structure of the task, and group dynamics, whereby creating deeper engagement and collaboration. Computer-supported collaborative learning has potential to become as a powerful approach to manage the effect of group-based learning. Jeong and Hmelo-Silver identify seven central affordances of computer-supported collaborative learning, which can enhance considerably the experiences involved in the learning processes (Jeong & Hmelo-Silver, 2016).

3.6.1.1.Establishing a Joint Task

The first affordance of CSCL is to establish a joint task. This activity corresponds to the scrum concept of self regulating teams which is to create a a shared task or goal among group members (Oakley et al., 2004). This enables the learners to come together to achive a common objective, thus enhancing their sense of common responsibility and investment in the learning process. By establishing a joint task, group members were able to specify both the scope and objectives of the work. Its ensurs that all members were aware of and works towards the attainment of the same goals.

The learners might identify the work with the use of technology, assigning it specific qualities based on the roles and responsibilities of the participants in the work and coordinating whatever collaborative efforts were undertaken. Online project management platforms, task boards, and shared calendars used for organizing the work allow the learners to delegate tasks and track progress, which is a great way to facilitate the collaborative efforts of the group (Douligeris & Seralidou, 2017; Hùng, 2021).

3.6.1.2.Communication

Since communication is essential for productive computer-supported collaborative learning, the use of technology, such as video conferencing, chat rooms, and online discussion forums, allows students to engage in meaningful dialogue, whether in real-time or asynchronously, share ideas, and clarify concepts (Douligeris & Seralidou, 2017). Such open communications make possible knowledge transfers, negotiation of meanings, and construction of a common understanding among group members. Using such means of communications, learners may come together and partake in rich discussions to clarify issues and come to a common understanding regarding misunderstandings or disagreements, making their collaborative learning even more effective (Hathorn & Ingram, 2002; Sung, Yang & Lee, 2017; Lipponen, 2023).

3.6.1.3.Sharing Resources

In computer-supported collaborative learning, the students become facilitated to view and share many educational resources, ranging from digital documents, multimedia files, online databases, and even expert-curated content by subject matter. The collaborative contribution and distribution of such relevant, valuable, and quality information can enrich the group's knowledge base and profoundly strengthen learning. With such easy sharing of resources, learners can build on the input of one another; this greatly helps learning by enriching it with synergy (Al-Jarrah & Pontelli, 2018).

3.6.1.4.Engaging in Productive Processes

The different ways of participation of learners in some productive processes through technology in computer-supported distributed learning could easily incorporate the processes for online whiteboards, mind mapping software, and collaborative writing into the problem-solving processes that they tackle as ways of brainstorming ideas and organizing their thoughts toward developing solutions. In this light, technological affordance provides opportunities for learners to be able to interact, build on each other contributions, and engage in knowledge construction activities which will enable the process of learning to take on a dynamic and productive nature (Shawky et al., 2014; Douligeris & Seralidou, 2017).

3.6.1.5.Engaging in Co-construction of Learning

Computer-supported collaborative learning enables learners to actively engage in the co-construction of knowledge. Thus, Learners using computer-supported collaborative learning come to actively engage in co-construction of knowledge with the aid of collaborative tools, group members build on each other's ideas, challenge preconceptions, and synthesize new understandings. This co-construction offers an engagement process by which learners shape knowledge and meaning making within their learning group. By introducing digital tools to enhance the collaborative environment it makes peer interaction easy. These were difficult in the previous models as it restricted learners due to manual and geographic limitations and instead of activity interacting the learners were only passively receiving information (Porumb et al., 2012; Douligeris & Seralidou, 2017).

3.6.1.6.Monitoring and Regulation of Learning

Computer-supported collaborative learning environments can provide many benefits by the integration of digital tools in leaning process. One such benefit is support in monitoring and regulation of the learning process. By incorporating features to support tracking, progress monitoring, guidance through the usage of sensors and prompts for learners. It allows us to better identify the weaknesses and how they need to be addressed. Along with giving real time help to provide better support to resolve any issues that students encounter. When learners enhance such technological affordances with appropriate applications possibilities by collaborative environments, they are better able to monitor their learning, tackle any obstacles that arise, and tether their collective efforts toward attaining their common goals (Vaughan, 2014).

3.6.1.7.Finding and Building Groups and Communities

Computer-supported collaborative learning allows for the creating groups and communities. Learners can connect with peers and discuss in online forums, and participate in learning communities to benefiting from having a sense of belonging. This while creating openings for collaboration, sharing of knowledge, and social networking. Technological innovations give learners unique chances to surpass geographical limitations and network with like-minded individuals. Such virtual communities would therefore be able to facilitate collaborative and transformative process of learning (Porumb et al., 2012; Sung, Yang & Lee, 2017; Lipponen, 2023).

Overall, the seven key affordances identified by Jeong and Hmelo-Silver show its potential as an effective tool for evaluation for computer-supported collaborative learning.

3.6.2. M3 Evaluation Framework

The advancement in technology have exponentially influenced the how it is incorporated in education settings, and thus, it has created new and advanced ways of technologically enhanced learning. The growing acceptance of devices requires the creation of solid frameworks that can evaluate the effectiveness and implications of learning process, performance and retention by incorporating technology (Firssova et al., 2014). The M3 evaluation framework, which Vavoula & Sharples (2009) proposed, is one such method that is used by many researchers and can be a suitable option for evaluating mobile learning (Vavoula & Sharples 2009; Ahmed & Parsons, 2013; Fabian, 2018; Fatima et al., 2024).

The M3 framework is made up of three levels of evaluation micro, meso, and macro. The micro level examines the learner's actual experience in terms of usability, user satisfaction, and learning experience (Ahmed & Parsons, 2013; Fatima et al., 2024). The meso level is concerned with evaluating and facilitating interactions between educators, students, and stakeholders across different learning environments. The macro level is focused on the institutional or organizational context. It is used by examining variables and adoption of policies that effect organizational change. These policies can include equity, accessibility, and impact on educational systems (Ahmed & Parsons, 2013; Dirin & Nieminen, 2015; Ahmed et al., 2019; Liu et al., 2021). The M3 framework is a comprehensive and multi-faceted approach to evaluating mobile learning and by covering all micro, meso, and macro levels, researchers and practitioners can achieve some degree of understanding about the unique complexities surrounding the implementation and assessment of mobile learning initiatives (Ahmed & Parsons, 2013; Okai-Ugbaje et al., 2022).

The continuous advancement and development in mobile and ubiquitous technologies has changed how we approach learning giving rise to the idea of ubiquitous learning. Ubiquitous learning or "u-learning" is a learning paradigm in which students access the learning process, anytime and anywhere, using the ubiquitous computing capabilities of wireless and mobile technologies (El-Sofany & El-Seoud, 2022). Evaluation of u-learning environments, however, faces peculiar challenges, hence a more holistic evaluation framed in theory would be necessary. The rapid advancements in mobile and ubiquitous technologies have transformed the landscape of learning, giving rise to the concept of ubiquitous learning (u-learning) (El-Sofany & El-Seoud, 2022). This study, therefore, investigates the M3 framework's possibility of exercising fit adaptation in the context of evaluating the effectiveness of u-learning environments, along with respecting uniqueness in characteristics and requirements of this new conceptualization in learning. Rationale for Adapting the M3 valuation Framework. The M3 evaluation framework, which stands for "micro, meso, and macro" levels of evaluation, was developed to address the complexities and challenges associated with evaluating mobile learning (Ahmed & Parsons, 2013; Fatima et al., 2024). The adapted levels for M3 evaluation framework for ubiquitous learning (Montes et al., 2024; Ahmed & Parsons, 2013; Dirin & Nieminen, 2015; Ahmed et al., 2019; Okai-Ugbaje et al., 2022):

3.6.2.1.Micro-Level Evaluation

Micro-level evaluation focuses on feedback from individual users. It aims to evaluate their individual u-learning experiences as well as user-friendliness of the u-learning system. It involves looking at the system's interface, navigation, and overall user-friendliness. Along with learner satisfaction and engagement, and apparent effectiveness of the learning activities (Ahmed & Parsons, 2013; Fatima et al., 2024).

3.6.2.2.Meso-Level Evaluation

In this regard, meso levels of evaluation consider factors involved in the u-learning experience at a group level to evaluate factors like the availability of resources, integration of u-learning system within the wider learning ecosystem and support available for learners and instructors. This level of evaluation also includes consideration of how this is aligned with u-learning activities and with the learning objectives (Montes et al., 2024).

3.6.2.3.Macro-Level Evaluation

Macro-level evaluation supports organizational and institutional issues that affect u-learning. What initiatives should be taken for its introduction and sustainability as policy decision at organization level. This involves processes for establishing whether the u-learning is consistent with the institution's strategic objectives. Weather there is support available for resources and toward u-learning; and what policies and regulations should be introduced that guide usage of ubiquitous technologies in learning environments (Dirin &Nieminen, 2015). But this study is not incorporating macro level due to limitation of time. But this does not deny its significance in adapting the M3 evaluation framework to the context of u-learning, researchers can gain a deeper understanding of the factors that contribute to the success of u-learning initiatives.

Table 3.3: The M3 evaluation framework (adapted from Vavoula et al., 2009)

Micro Level	Meso Level	Macro Level
• Technology usability (Usability and mobile quality aspects) • Individual and group learning activities	• Learning experience as a whole • Learners' assessments (Pre-post and retention tests)	• Longer term of impact on the educational practices • Emergence of new practices

3.7.Adapted Evaluation Method

Our researched evaluation system includes parts from M3 Evaluation Framework & Collaborative affordances for technology supported learning (Vavoula & Sharples, 2009; Ahmed & Parsons, 2013; Fabian, 2018; Fatima et al., 2024; Jeong & Hmelo-Silver, 2016: Wang et al., 2021). M3 Evaluation Framework combined with the computer-supported collaborative learning (CSCL) components creates an effective evaluation method to evaluate collaborative learning application. CSCL was an established approach of using digital tools in education to promote group learning. The authors Jeong and Hmelo-Silver (2016) identified seven affordances: establishing joint tasks, facilitating communication, sharing resources, engaging in productive processes, co-constructing knowledge, monitoring and regulating learning, and building groups and communities. These affordances create the framework in which the environment of digital group-based learning is structuring interaction, collaboration, and shared learning objectives (Jeong & Hmelo-Silver, 2016).

Table 3.4: Adapted Evaluation Method from Jeong & Hmelo-Silver (2016) & Fatima et al. (2024)

<table>
<tr><th rowspan="2">CSCL affordances</th><th colspan="2">M3 Evaluation Framework</th></tr>
<tr><th>Micro Level Method</th><th>Meso Level Methods</th></tr>
<tr><td>C1- establishing a joint task</td><td rowspan="7">Learners perspective Evaluation</td><td rowspan="3">Time log & Observation through application</td></tr>
<tr><td>C2- facilitating communication</td></tr>
<tr><td>C3- sharing resources</td></tr>
<tr><td>C4- engaging in productive processes</td><td rowspan="3">Pre/post-test & Sprint evaluation</td></tr>
<tr><td>C5- co-constructing knowledge</td></tr>
<tr><td>C6- monitoring and regulating learning</td></tr>
<tr><td>C7- building groups and communities</td><td>Time log & Observation through application</td></tr>
</table>

The connection between micro and meso evaluation and Computer-Supported Collaborative Learning (CSCL) affordances are described in Table 3.4. Thus, an all-encompassing basis for assessment is provided through this dimension of the CSCL tools and environments. On the micro level, assessment of the different affordances (C1 to C7) is related to usability and application-oriented survey. In this way, it becomes possible to carry a more detailed account of the interaction between the user and the CSCL tool, thus yielding indicators on its user-friendliness, function, and user overall experience. On the other hand, the meso evaluation of affordances seems much more refined and target specific. For affordances with labels C4, C5, and C6 that occasionally refer to learning outcomes and knowledge construction, pre-test and post-test scores serve to measure student advancement as well as the degree of efficiency gained through the CSCL environment regarding learning. Complementing this, affordances C1, C2, C3, and C7 are evaluated by time logs and observations of activities performed by users of the uASK application.

The combining of Computer-Supported Collaborative Learning (CSCL) affordances within the M3 Evaluation Framework can give a comprehensive approach to analysing learning activities. This multi-level analysis may allow for a detailed examination of both individual learner experiences and the larger operational effect of the learning system. By considering these distinct levels, evaluators can gain complete understanding of how CSCL tools and strategies evaluate the learning process and outcomes. At the individual level, the framework enables researchers to assess how learners interact with the CSCL system. It can evaluate their engagement patterns, and the development of specific skills or knowledge. Simultaneously, at the operational level, it provides understandings of how the system's functionality. Also. how user interface design, and overall effectiveness in facilitating collaborative learning. This dual-focus approach allows for a more detailed evaluation of the CSCL approach, it can highlight areas of strength and potential improvement by offering an evidence-based assessment of the effectiveness of collaborative learning interventions, thus M3 Evaluation Framework equipped with CSCL affordances provides educators and instructional designers with valuable data to refine and optimize their learning systems, ultimately enhancing the quality of collaborative learning experiences.

In conclusion, the M3 Evaluation Framework, empowered by CSCL affordances, provides a vigorous and comprehensive tool for assessing the effectiveness of collaborative learning interventions. By addressing the micro and meso levels of learning environments, this framework offers understanding of the complex dynamics involved in implementing and effective collaborative learning systems. This approach may facilitates the evaluation of current practices and development of future strategies to enhance collaborative learning in educational institutions.

3.7.1. Data Collection Methods

Without a proper data collection process no research can be successfully conducted. In literature there are multiple applied including but not limited to questionnaires, interviews, tests, observation, and secondary data (Johnson & Turner, 2003; Parker, Anderson, Stone & Oh, 2024). Trustworthiness is defined as the extent to which readers can trust in the results produced through the use of trustworthy and credible data collection methods (Leydens, Moskal, & Pavelich, 2004; Kurniawan, 2024). For this study multiple methods are applied which are shown in Figure 3.13.

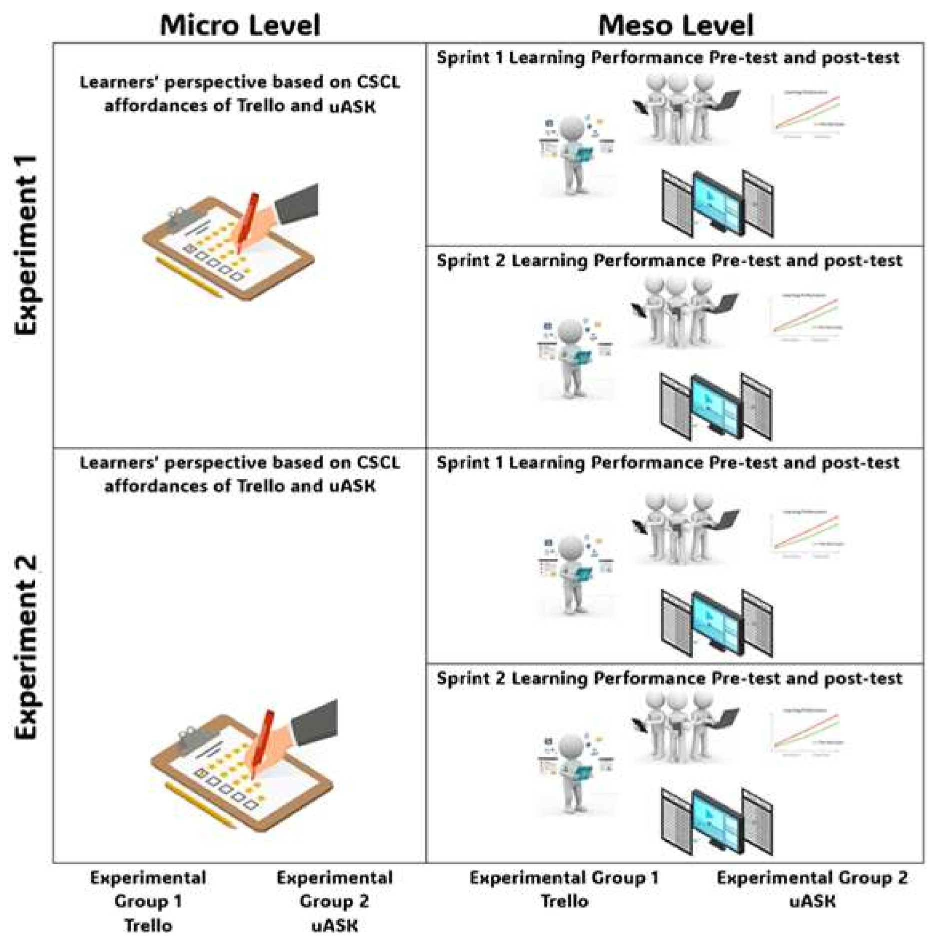

Figure 3.13: Use of Micro and Meso levels of M3 Evaluation Framework (adapted from Ahmed & Parsons, 2013)

3.7.2. Learners' Perspective of Technology Usability Evaluation

Application survey for learner's perspective of technology usability evaluation is a commonly used technique for collecting information across various research methodologies, providing multiple benefits. According to Johnson & Turner (2003), there are three primary advantages of properly constructed surveys i. they appears to support comparatively high measurement accuracy, ii. they can be disseminated and answered quickly, and iii. questions with predefined responses allow for simpler data processing due to reduced error occurrences.

Questionnaires, although beneficial, may have several potential shortcomings. These can range from flaws in survey design, sampling and non-response errors. To unreliable participants, knowledge deficits, complications in data processing and statistical analysis (Bryman, 2008; Matolić et al., 2023; Al Kalbani, 2024; Cebrián Cifuentes & Guerrero Valverde, 2024; Ishmuhametov, 2024; Parker et al., 2024). This study seeks to minimize these possible issues to the greatest degree and literature provides evidence for its effectiveness as many scholars have employed questionnaires to assess learners' opinions on applications, particularly their usability (Uzunboylu, Cavus, & Ercag, 2009; Wang, Shen, Novak & Pan, 2009; Parker et al., 2024).

learners completed a quantitative survey to accomplish this goal. The survey was composed closed-ended questions designed at gathering learners' opinions on various aspects of collaborative inquiry which had question about of the experiences with the app, its operation and interface, along with support for hypothesis formation, topic relevance and comprehension. Whereas analytical skills, and overall efficacy with the survey also evaluated the app's user-friendliness and performance. All participants answer same questions after completing their learning activity. In this study for the survey a 5-point Likert scale was applied to collect responses. Where its is important to note that, no questions were asked about participants' personal attributes and to verify the survey's reliability, a scale reliability Cronbach's alpha testing was performed using experimental data from this study(as shown in the Appendix IV).

In the Table 3.5 questions for survey of learner's perspective is given to evaluate the technology usability. These are designed to evaluate the affordances of a Computer-Supported Collaborative Learning (CSCL) application and mapped to seven questions, each to specific affordances at the micro-level of the framework. These affordances are represented as C1 through C7. The first question focuses on task clarity (C1). As it is very important to assess whether the tasks were well-defined and if users encountered any challenges in establishing a common understanding due to the application. The second question is mapped to facilitating communication (C2) thus focus on the facilitation provided by the application for understanding of the task. For evaluation of effective collaboration and learning, clear task definition is crucial as it ensures all participants are aligned in their objectives and reduces potential misunderstandings.

Table 3.5: Learners Perspective Questions

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 communication through application	C2
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
Q7. It was easy to share information and files with our group	C3

The third question evaluates the application's contribution to learning performance and how helpful the learners found it to be (C5). This is a important aspect of any educational tool, as its main purpose is to help, support and enhance the learning process, thus positive response to this question would indicate that the application is successfully fulfilling its educational role. Question four addresses the enjoyability of the learning experience (C4) which is important for maintaining user engagement and motivation as an enjoyable learning experience can lead to increased participation, better retention of information, and a more positive attitude towards the learning process. The fifth question assesses the ease of navigation within the application (C6). User-friendly navigation is essential for reducing confusion and frustration. It allows users to focus on the learning content rather than struggling with the interface. Questions six evaluate the application's support for group work (C7) and the ease of sharing information and files within groups (C3). Effective group work features can enhance teamwork, promote knowledge sharing, and improve overall learning outcomes. The survey provides an analysis of how these affordances contribute to user engagement, satisfaction, and the effectiveness of the application. It also shows that if the task is clearly defined and application is fun to use and engaging in nature and not a lot of effort is required to use it thus it is easy to use and easy to learn. It also contributes to learning and the enjoyability of the experience increase user satisfaction and motivation.

In conclusion, the survey and its analysis will help demonstrate it as a thorough approach for evaluating the CSCL application. This detailed assessment of micro level is valuable for understanding the application's strengths. Also, identifying potential areas where improvement can be made in supporting collaborative learning at individual level and creating an engaging application and environment.

3.7.3. Tests

Quantitative research frequently uses tests to evaluate various participant characteristics, such as attitudes, personalities, self-perceptions, aptitudes, and learning outcomes (Johnson & Turner, 2003). A popular method in this field is the pre-test and post-test design, which measures changes in knowledge creation, performance and retention (Kurniawan et al., 2024). This approach first creates a baseline before an engaging in the learning activity and evaluates the results afterward to determine the effect of activity on learning thus calculating learning performance. The pre-test and post-test design has shown potential evaluating effectiveness in studying mobile learning environments. Researchers have utilized this method to examine student performance and assess the influence of learning tools on their learning (Batdı & Jibril, 2024; Abdulrahman et al., 2024). These designs helps educators and researchers in identifying the advantages of these learning platforms. It also includes increasing knowledge retention, critical thinking in applying acquired knowledge and improved problem-solving skills.

Performance evaluation scores are often utilized alongside pre- and post-tests during learning activities. These scores offer real-time understandings into learners' engagement and progress as they participate in specific tasks and how the engage with the application and its affect on learning process for instance, Güneş et al. (2015) illustrated how performance evaluations can enhance understanding by providing immediate feedback and promoting active participation. Also by monitoring performance throughout an activity, educators can make timely adjustments to their teaching methods. This will ensuring any problems will not effect the achievement of learning objectives. The combination of pre-test and post-test designs with performance evaluations provides a complete approach to understanding learner progress and response to learning activity. These methods offer valuable insights into the learning process, also facilitating the development of more effective educational strategies along with measuring outcomes (Pre and post tests are shown in Appendix V).

3.7.4. Time Logs

System logs are utilization to provided another aspect for data collection. It offers another valuable dimension beyond the self-reported questionnaire responses to measure learners engagement and facilitation provided by the application. These logs allow us to objectively measure various aspects of user interaction with the system, including task completion time and student engagement levels. The analysis of nature and quality of student interactions within the learning environment can be obtained by chat logs to evaluate deeper understanding of their engagement (Shahjad & Mustafa, 2022). This comprehensive data collection strategy not only enhanced the reliability of the questionnaire but also offered different perspective on the overall user experience and system performance. Time taken to complete a task can be analyzed in different ways to either evaluated if the longer time is due to the difficulty of platform or less time indicate loss of students engagement

The combination of different analysis data gathered from varying methods such as questionnaires and objective data from system logs can create a robust framework for evaluating the practicality off application and potential challenges of the main study. This comprehensive approach may allows us to cross-validate findings, identify discrepancies between perceived and actual user behavior. It may also uncover potential areas for improvement in system design. Moreover, the real-time nature of log data provided researchers with the ability to track changes in user behavior and system performance over time,. Thus offering valuable insights into the learning process and the effectiveness of educational technology.

3.8. Summary

This chapter discusses the ScrumBan Ubiquitous Inquiry Framework (SBUIF), an innovative framework that integrates agile project management with inquiry-based learning using digital technologies. Building on existing frameworks, such as Design Science Research Methodology (DSRM) and Scrum-based Research, SBUIF seeks to facilitate collaborative learning pedagogy by providing a three phase approach: (1) Pre-Scrum is when teachers create desired learning outcomes and develop digital resources; (2) Scrum is made up of cycles of iterative learning where learners co-learn through meaningful inquiry, exploration, observation, and reflection; and (3) Post-Scrum is focused on sharing the final results and reflections and prompts to assess the student's progress and capabilities. The uASK application is designed to frame projects through SBUIF while providing different interfaces for teachers and learners. Beyond SBUIF's learning cycle, the uASK application includes additional features like Kanban boards for the team organization, real-time feedback to impact engagement, and the option for learning activities relevant to learners' surroundings using beacon technology. To assess effectiveness, this research utilizes the M3 Evaluation Framework and affordances of computer-supported collaborative learning. The experiments that compare the uASK with the other tool Trello examine learners' engagement and learning outcomes in a middle school science class in the topic of plant biology.

CHAPTER 4

RESULTS & DISCUSSIONS

This chapter discusses the results and discussion on the effectiveness of ScrumBan Ubiquitous Inquiry Framework (SBUIF). This is done by comparing the developed uASK application with Trello. It is done by observing collaborative learning by evaluating collaborative affordances. The research involved 205 seventh-grade students, divided in two experiments which were conducted on two different local schools. Experiment 1 involved 127 students and Experiment 2 had 78 students. The applications are assessed through the method defined in chapter 3 by evaluating collaborative affordances and M3 evaluation method for both experiments. For experimental groups micro-level and meso-level analyses were performed to evaluate individual experience and group level performance.

This experimental design allows us to conduct an evaluation between these applications in order to understand how each application performed in enhancing students' learning experiences through agile-based inquiry learning for the evaluation purposes, seven collaborative affordances (Jeong & Hmelo-Silver, 2016). are used to evaluate the effectiveness of both applications; uASK and Trello. These affordances are mapped with Micro and Meso level of the M3 evaluation framework (Fatima et al., 2024) as mentioned in the Table 3.5.

CSCL affordances defined by Jeong & Hmelo-Silver (2016) defined 7 affordances C1- establishing a joint task, C2- facilitating communication, C3- sharing resources, C4- engaging in productive processes, C5- co-constructing knowledge, C6- monitoring and regulating learning & C7- building groups and communities (Jeong & Hmelo-Silver, 2016).

Computer-Supported Collaborative Learning (CSCL) affordances can be grouped by characteristics that fit Communication, Learning Performance, and Technological Usability, each being an important factor in enriching the learning experience and in the analysis of results. The affordances of Communication include "setting up a joint task" (C1) that allows learners to set a shared goal and therefore align the objectives of the learning activities, "facilitation of communication" (C2) with elaborated discussions, peer interactions, and knowledge exchange, and "building groups and communities" (C7) as this will enhance social bonding, collaboration, and teamwork where learning becomes more interactive and engaging. Performance of learning through Cognitive activities by being "engaged in productive processes" (C4) to promote problem-solving and critical thinking and "co-constructing knowledge" (C5) to support collaborative meaning-making. These can be supported by Technological Usability that can provide the basic platform and tool support to carry out this process, which includes "sharing resources" (C3) for the purpose that students can be mutually partaking in knowledge construction. Kanban boards are in place for "monitoring and regulating learning" (C6), where learners can actually watch what they are up to.

4.1.Experiment 1 results and analysis

A quasi-experimental research design was employed. Sample size is 127 seventh-grade students (76 boys and 51 girls) of a local school which is a substantial sample size. These participants were divided into two experimental groups. Experimental group 1 has 64 students and Experimental group 2 has 63 students. The first experimental group utilized Trello that is a mobile application based on Kanban principles. While the second experimental group employed uASK, the custom-designed application (uASK) developed to implement the SBUIF. Seven collaborative affordances were evaluated at both micro and meso levels. Several different evaluation methods were employed, such as learners perspective evaluation, pre-test, post-test, Sprint assessment and time analysis. Micro and meso level analysis of these activities is given below.

4.2.Micro Level results and analysis

The micro level evaluation for collaborative affordances was conducted through learner's perspective evaluation as explained in evaluation methodology. For micro level all affordances C1 to C7 were mapped to questions of evaluation survey as previously discussed.

A Likert scale was applied ranging from 1 for 'strongly disagree' and 5 for 'strongly agree'. Figure 4.1 shows the results of both Trello and uASK for experiment 1. Overall results for both Trello and uASK were encouraging except for C7 (Application helped working in group) where uASK outperformed Trello by a considerable margin.

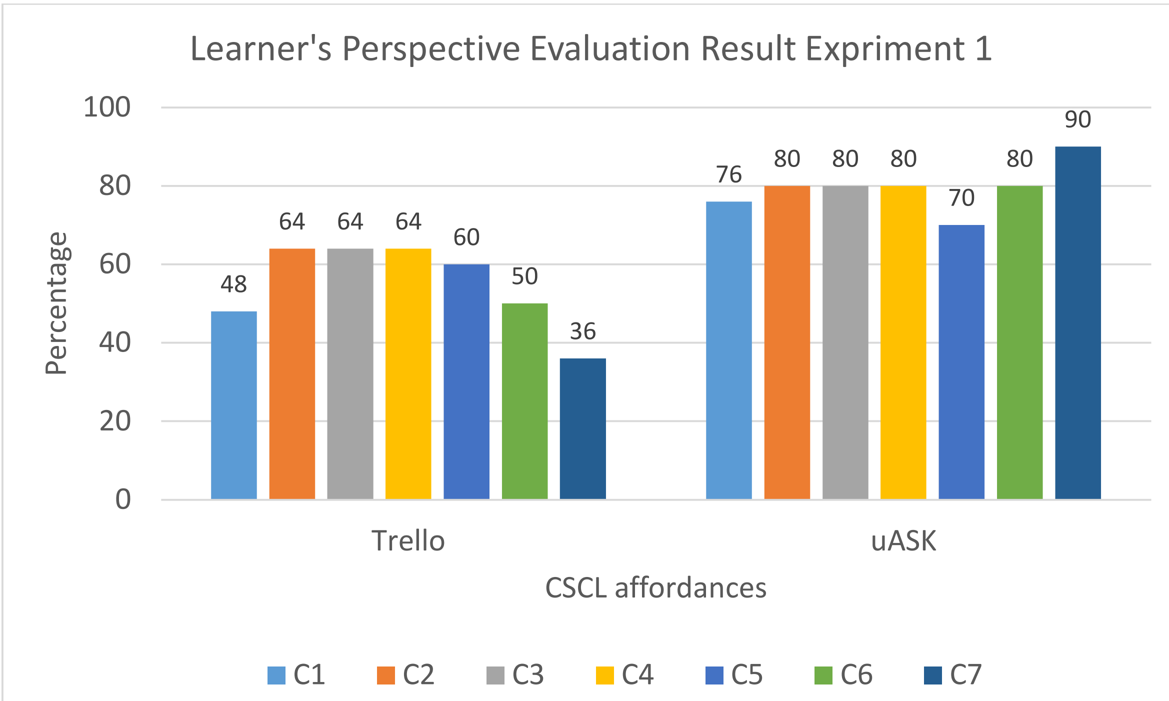

Figure 4.1: Analysis of Learner's Perspective Evaluation Experiment 1

Micro level analysis of learner's perspective results in figure 4.1 distinguish Trello from uASK regarding how well they supported collaborative learning through CSCL affordances. Affordance-based aspects are used to highlighted uASK's effectiveness in all respects. Especially in Technological Usability (C6, C7), along with Learning Performance (C4, C5). Communication affordances C1 (Establishing a Joint Task) and C2 (Facilitating Communication) conferred a major benefit to uASK, wherein Trello did poorly in assisting its users with task setting and enhancing their discussion. The uASK application was also able to offer more efficient resource sharing tools in support of C3 affordance Sharing Resources to allow users to access materials easily. C4 -Engaging in productive processes and C5 - Co-constructing Knowledge are two affordances that also showed better results by uASK thus shows its effectiveness in collaboration and developing problem solving skills. The most prominent difference is in C7 (Building Groups and Communities), where uASK scores 90% compared to Trello's 36%, highlighting its ability to strengthen collaboration and teamwork through advanced networking features. Similarly, affordance C6 that is related to monitoring and regulation of learning also showed better score for uASK than Trello demonstrating uASK improvement in regard.

Table 4.1 shows the comparison of responses given by students for both Trello and uASK. A two-Sample t-test assuming unequal variances against the neutral value 3.00 confirmed these interpretations ($t_{127} = 9.22$, $p < .01$ for C1; $t_{127} = 5.53$, $p < .01$ for C2; $t_{127} = 6.05$, $p < .01$ for C3; $t_{127} = 4.03$, $p < .01$ for C4; $t_{127} = 2.76$, $p < .01$ for C5; $t_{127} = 7.97$, $p < .01$ for C6; $t_{127} = 20.31$, $p < .01$ for C7). The statistical analysis with C7 showing the most significant gap (t127 = 20.31, p < .01). P values shows there for affordances form C1 to C7 all are highly significant. Confidence Intervals show all differences are positive, meaning uASK consistently outperformed Trello. **Effect sizes (Cohen's d)** are substantial for every affordance very large effects ($d > 1.4$) for C1, C6 & C7, large effects ($d \approx 1$) for C2 & C3 and moderate–large ($d \approx 0.77$) for C4 & C5.

Table 4.1: Micro level Quantitative responses for Trello and uASK for CSCL affordances for Experiment 1

CLCL Affordances	Trello Responses Mean Response ± S.E (Standard Error)	uASK Responses Mean Response ± S.E (Standard Error)	95% Confidence Interval	Cohen's d (Effect Size)
C1	2.33± 0.12	3.79 ±0.11	[1.14 , 1.78]	1.58
C2	3 .17± 0.10	4.07 ±0.11	[0.61 , 1.19]	1.07
C3	3.16± 0.12	4.04 ±0.1	[0.57 , 1.19]	0.99
C4	3.27± 0.12	4.04 ±0.13	[0.42 , 1.12]	0.77
C5	3.00± 0.10	3.62 ±0.11	[0.21 , 0.83]	0.59
C6	2.55± 0.12	4.02 ±0.13	[1.12 , 1.82]	1.46
C7	1.78± 0.08	4.46 ±0.1	[2.43 , 2.93]	3.68

To evaluate the reliability of the questionnaire Cronbach's coefficient alpha, a statistical method was used widely in the education context to check the internal consistency and reliability of the questionnaire. Alpha coefficient ranges from 0 to 1 where value greater than 0.70 is considered good reliability (Taber, 2018). In case of our study the Coefficient alpha equals 0.83 for Trello and 0.84 for uASK showing results are reliable. The high Cronbach's alpha (0.84) further validates the reliability of the survey. These findings suggest that the technological aspect of uASK's significantly improve collaborative learning, group cohesion, and individual engagement, making it a more effective platform for CSCL compared to Trello.

4.3.Meso Level results and analysis

At the meso level, some evaluation into CSCL (Computer-Supported Collaborative Learning) affordances was provided through a combination of pre-tests, post-tests, and Sprint performance evaluations. This included measures of the various skill levels pertaining to student engagement, learning performance, and collaborative knowledge construction. Figure 4.2 & 4.3 shows the evaluation results of pre-test, post-test and Sprint performance for Sprint 1 for experiment 1 that evaluate C4, C5 & C6 of CSCL affordances. Figure 4.2 shows that for the pre and post-test, there is significant improvement in learning performance by students in both the Trello and uASK groups. Trello users improve by from 27.5% to 60.5%, and uASK users showed a statistically significant increase from 24.5% to 70.5%. This suggests that both tools positively impacted learning outcomes, with uASK proving to be more effective.

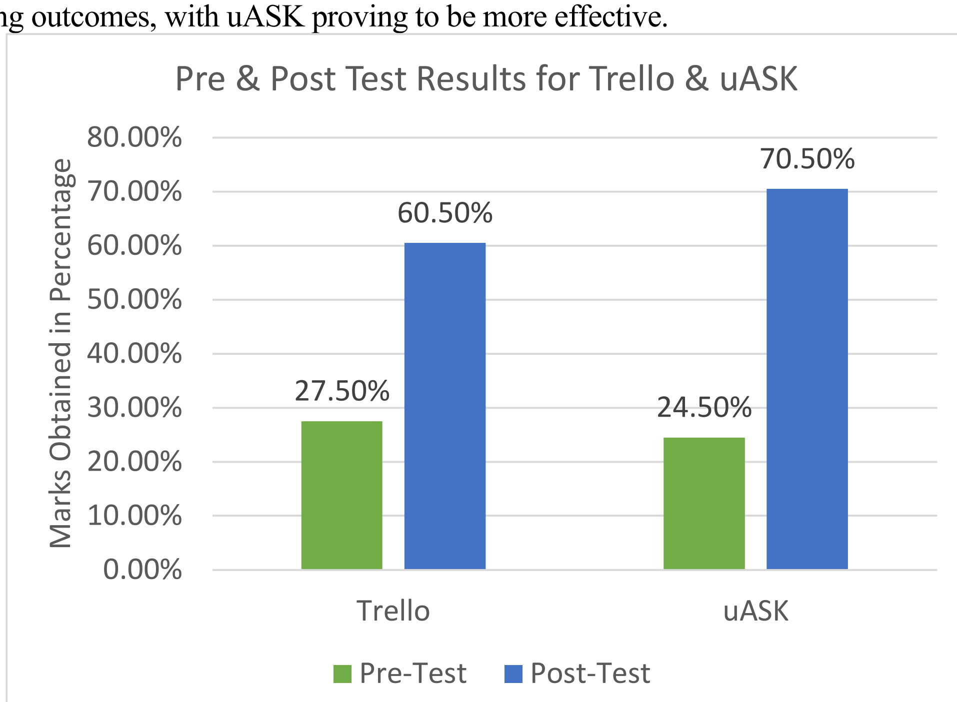

Figure 4.2: Results of pre-test and post-test results for Trello and uASK of experiment 1 Sprint 1

Figure 4.3 presents the performance evaluation for sprint 1. It shows assessment scores from worksheets and hypothesis generation exercises indicate a stronger performance in the uASK group compared to Trello. This is mapped with CSCL affordances related to engaging in productive processes (C4), co-constructing knowledge (C5), and monitoring and regulating learning (C6). The structured nature of uASK in which both Scrum and Kanban approaches are integrated. Also guidance is provided through beacon tags which appears to enhance students' collaborative learning experience. Improvement in both pre-test and post-test is shown in Figure 4.2 demonstrates effectiveness of designed approach. The Trello group's increase from 27.5% to 60.5%. This indicates that the use of Trello as a learning tool had a positive impact on students' understanding and retention of the material. Similarly, there is a 46-percentage point increase from 24.5% to 70.5% in uASK group. Which indicates both groups gained considerable increase learning performance but uASK showed better results.

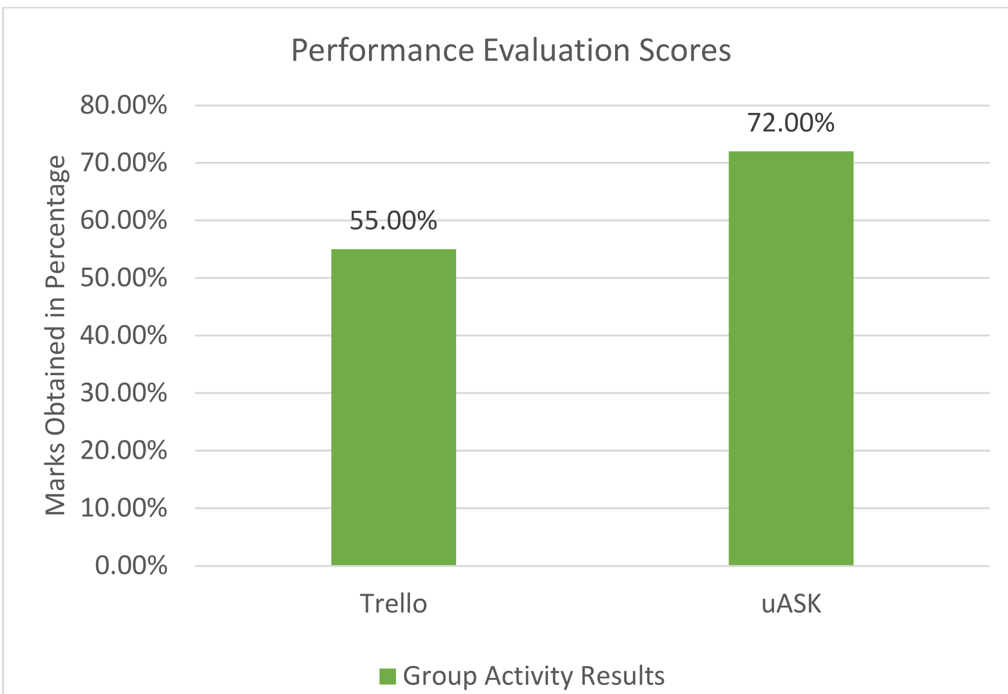

Figure 4.3: Experiment 1 Sprint Performance evaluation results for Sprint 1

Comparison of assessment results of the work done during the activity such as filled work sheet and hypothesis generation is presented in Figure 4.3. It shows uASK group marked improvement over Trello. These results are mapped "Engaging in productive processes", “Co-constructing knowledge” i.e. hypothesis generation & “Monitoring and regulating learning”. The significant improvement in the results of uASK in comparison to Trello shows that by incorporating scrum and kanban approaches along with inclusion of guidance via beacon tags and application support contributed to deeper understanding. Also Figure 4.4 illustrates similar trends in sprint 2, reinforcing the effectiveness of uASK over Trello. For the Trello group, the pre-test score was 20%, which increased to 55% in the post-test, reflecting a 35% improvement.

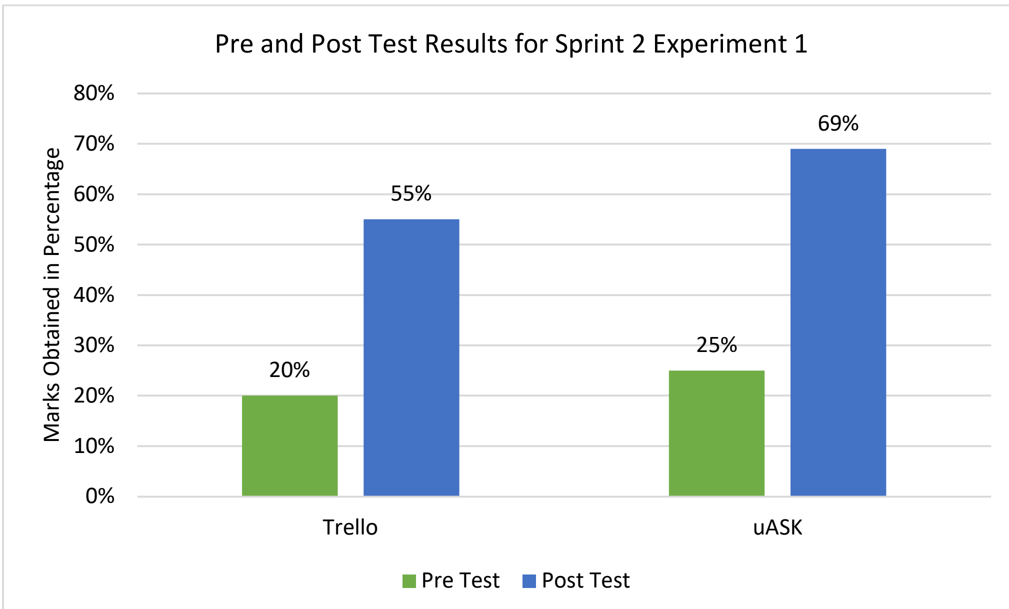

Figure 4.4: Results of Pre & post test results of Trello and uASK for Sprint 2 Experiment 1

Table 4.2 shows the Pre & Post-test responses given by students for both Trello and uASK applications. A two-sample t-test assuming unequal variances against the neutral value 3.00 confirmed these interpretations as for Pre-test the difference is not significant as ($p>0.05$) but for significant difference of ($p<0.01$) for both sprints. The quantitative data in Table 4.2 confirms these improvements, as post-test scores show statistically significant differences ($p < 0.01$), whereas pre-test differences were not significant ($p > 0.05$). Cronbach’s coefficient alpha value of 0.801 further validates the reliability of these results. These findings suggest that CSCL affordances for learning performance C4, C5 and C6 uASK have significant improvement over Trello. Both Trello and uASK produced very large learning gains within each sprint ($d > 2.5$) in per and post-test.

Table 4.2: Meso level Quantitative responses for Trello and uASK for CSCL affordances for Experiment 1

Sprints	Groups	Tests	Participants (N)	Mean (M)	Standard Deviation (SD)	Standard Error (SE)
Sprint 1	Experimental Group 1 (Trello)	Pre-Test	64	2.38	1.27	0.17
		Post-Test	64	5.75	1.31	0.667
	Experimental Group 2 (uASK)	Pre-Test	63	2.48	1.33	0.71
		Post-Test	63	7.04	1.31	0.118
Sprint 2	Experimental Group 1 (Trello)	Pre-Test	64	1.98	1.22	0.17
		Post-Test	64	5.5	1.14	0.667
	Experimental Group 2 (uASK)	Pre-Test	63	2.52	1.45	0.71
		Post-Test	63	6.87	1.12	0.118

Confidence interval for post-test is with the difference of 1.29 points (95% CI =[0.87, 1.71]) corresponds to a large effect size ($d \approx 0.99$), confirming that uASK produced stronger learning outcomes than Trello in Sprint 1. Simirarly for Sprint 2, the 95% Confidence Interval for difference of 1.37 is approximately [0.96, 1.78] and effect size (Cohen's d) for this comparison is about 1.21, which is considered a very large effect confirming that the advantage of uASK is statistically significant.

The evaluation of affordances C1, C2, C3 & C7 is done through time log observation to determine students' engagement thus evaluating communication and technological usability aspects. Figure 4.5 gives the result of average time spent on individual tasks in Sprint 1. The graph shows Trello taking more time to complete the tasks than uASK especially Task 1 & 6, which corresponds to initial knowledge generation. Also Task 2 botanical garden sample collection which required interaction with environment uASK took much lesser time with the help of beacon tags. Task 4 (filling the worksheet) & Task 5 & 7 hypothesis generation also show better time trend in uASK as compared to Trello as shown in Figure 4.5. Thus, it indicates that only kanban approach is not as effective as combined Scrum-Kanban structure in uASK and the decreased time suggests enhanced Monitoring and Regulation of Learning. Trello does not provide any additional guidance to either navigate or help students therefore the students take more time in contrast with uASK.

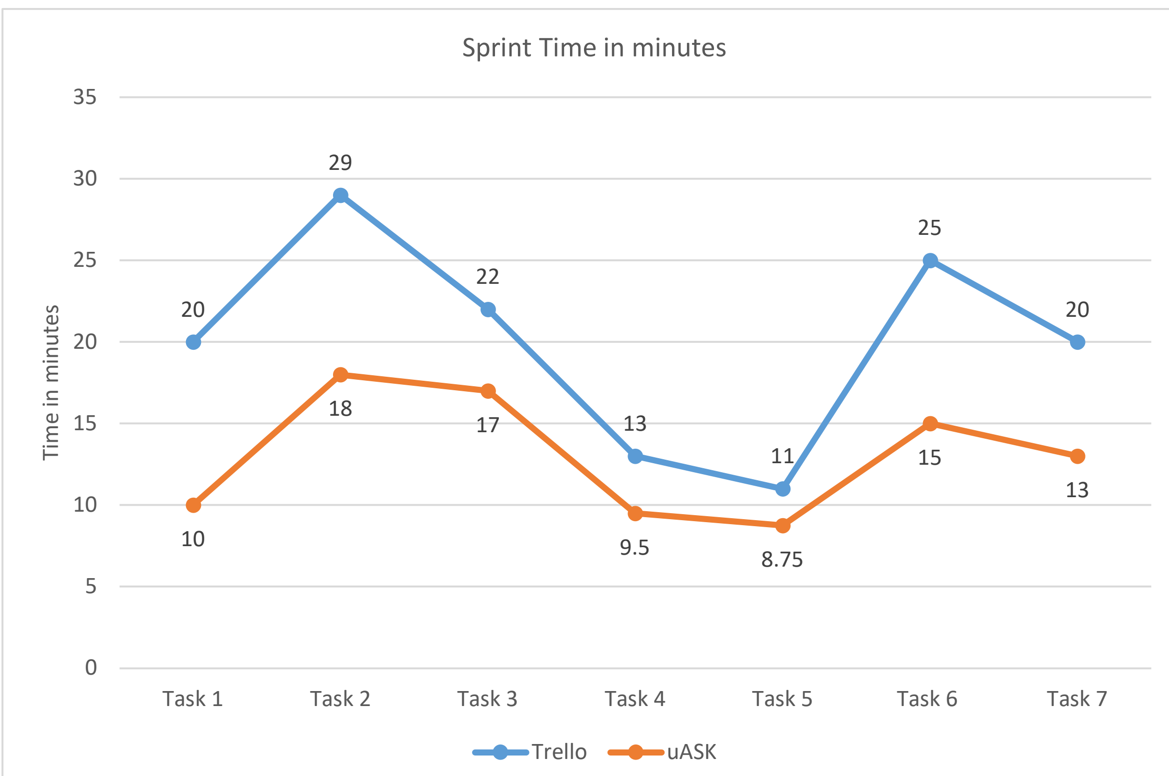

Figure 4.5: Time analysis of individual task in Sprint for Experiment 1

Similarly Figure 4.6 shows result of average time of complete sprint that is 34.70%-time efficiency in uASK. The shortened time period shows improved communication and technological usability, as learners gained swifter access to assignment guidelines and peer input, thus promoting more productive collaborative interaction.

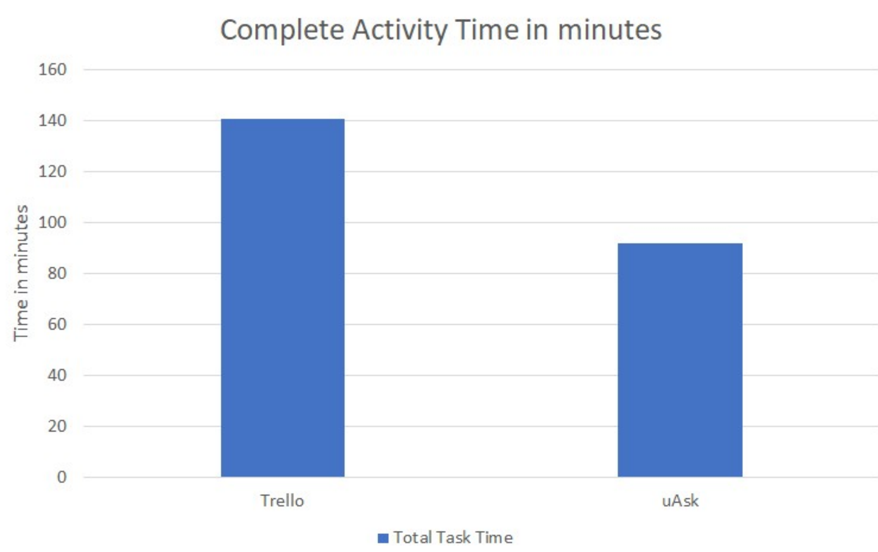

Figure 4.6: Time analysis of entire sprint 1 for Experiment 1

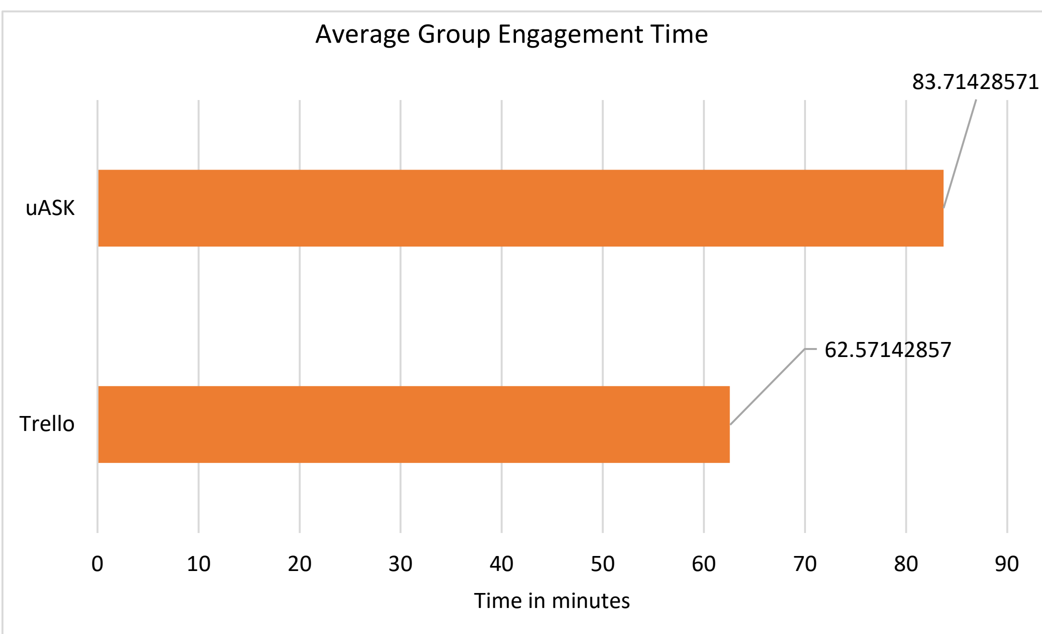

Figure 4.7: Result of average chat time for uASK and Trello in Sprint 2 experiment 1

Learners' engagement in sprint 2 is measured by how long students engage with each other using application as they need to engage for prolonged period of time i.e. multiple days but few minutes a day to share and discuss their progress with peers. In Figure 4.6 & 4.7 it shows that uASK group spent more time actively engaging in collaboration compared to Trello group. Hence fostering the concept that affordances C1, C2, C3, C6 and C7 involved in communication and technological usability gives better result for uASK. Thus indicating uASK is easy to use and navigate therefore students prefer to engage were as in case of Trello they engage less as time passes and there is not active teacher monitoring and support.

The first experiment showed that the uASK groups did much better than the Trello groups, with better success across a number of metrics. An additional round of data collection was conducted to confirm the reliability and generalizability of results. Thus by repeating the first experiment's activities to collect additional data from a different local school, thereby validating the outcomes of experiment 1.

4.4.Experiment 2 results and analysis

A year after Experiment 1 a follow-up experiment was conducted in a different school. In this experiment the sample size was of 78 students out of which 42 boys and 36 girls. This research aimed to validate the findings from the first experiment and further explore the effectiveness of different collaborative tools in supporting student learning. The research design for this second experiment employed same as experiment 1-quasi-experimental approach. The participants were divided into two experimental groups, with 38 students assigned to the first group and 40 to the second. Both experimental groups engaged in the same activities as those conducted in the first experiment. This is kept to ensure direct comparison between the two collaborative tools and their impact on student learning outcomes. Using similar approach to experiment 1 micro and meso level evaluation of C1 to C7 affordances was performed.

4.4.1. Micro level results and analysis

The micro level evaluation was performed using the same strategy as experiment 1 by employing learners' perspective evaluation for all seven affordances. Figure 4.8 shows the survey results where uASK performed better than Trello for all affordances. But this difference is less than that was found in experiment 1. However, like experiment1 technological usability especially monitoring and regulating learning (C6), building groups and communities (C7) shows significant increase in uASK in comparison to Trello. Also (C4, C5, C6) learning performance gives better results in uASK than Trello. Thus over all uASK performed better on all three aspects communication, learning performance and technological usability than Trello.

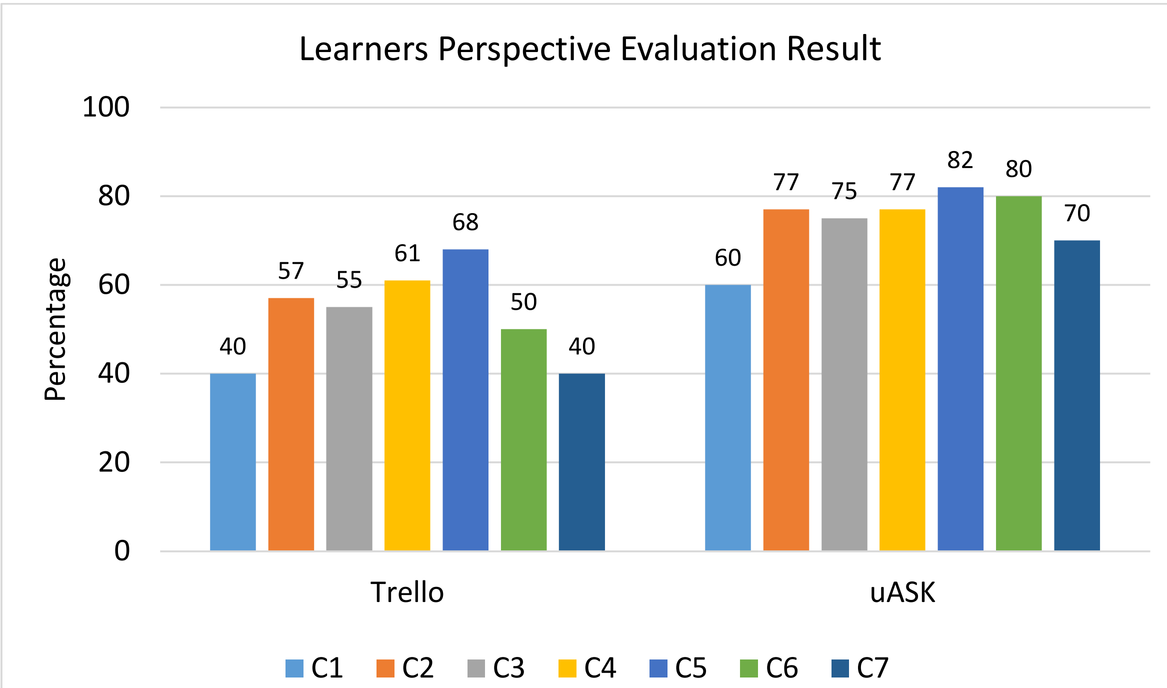

Figure 4.8: Analysis of Learners Perspective Evaluation Results for Experiment 2

Table 4.3 shows the comparison of responses given by students for both Trello and uASK. In terms of communication, uASK was much better in C1, C2, and C7, suggesting it provides better support for discussions, peer interactions, and teamwork. Regarding learning performance, uASK was rated higher for C3, C4, and C5, indicating that it more effectively supports problem-solving, critical thinking, and collaborative knowledge-building. For technological usability, uASK significantly outperformed Trello in C6 and C7. A two-sample t-test assuming unequal variances against the neutral value 3.00 confirmed these interpretations ($t_{77} = 5.57$, $p< .01$ for C1; $t_{77} = 2.93$, $p< .01$ for C2; $t_{77} =2.65$, $p< .01$ for C3; $t_{77} = 2.99$, $p< .01$ for C4; $t_{77} = 2.91$, $p< .01$ for C5; $t_{77} = 7.68$, $p< .01$ for C6; $t_{77} = 9.21$, $p< .01$ for C7). Statistical analysis ($p < .01$) confirmed all affordances show statistically significant difference, reinforcing that uASK provides a more effective and supportive environment for CSCL. C1, C2, and C3 demonstrated large effects ($d \approx 0.85–0.93$), C4 reflected a moderate-to-large effect ($d \approx 0.72$), C5 showed a moderate effect ($d \approx 0.59$), while C6 and C7 yielded very large effects ($d \geq 1.3$). Reliability analysis using Cronbach's coefficient alpha for uASK is 0.89 and 0.82 for Trello which further validated the consistency of the results.

Table 4.3 Micro level Quantitative responses for Trello and uASK for CSCL affordances for Experiment 2

CLCL Affordances	Trello Responses Mean Response ± S.E (Standard Error)	uASK Responses Mean Response ± S.E (Standard Error)	95% Confidence Interval	Cohen's d (Effect Size)
C1	2.08 ± 0.13	3.05 ± 0.11	[0.64 , 1.30]	1.22
C2	2.85 ± 0.1	3.85 ± 0.14	[0.65 , 1.35]	1.05
C3	2.75 ± 0.15	3.75 ± 0.11	[0.61 , 1.39]	0.93
C4	3.05 ± 0.11	3.85 ± 0.13	[0.47 , 1.13]	0.77
C5	3.4 ± 0.12	4.1 ± 0.12	[0.40 , 1.00]	0.60
C6	2.5 ± 0.14	3.98 ± 0.13	[1.12 , 1.84]	1.40
C7	2 ± 0.11	3.48 ± 0.11	[1.17 , 1.79]	1.42

4.4.2. Meso level results and analysis

Evaluation of meso level was achieved through similar process as experiment1. Figure 4.9, 4.10 & 4.11 shows the comparative analysis of Trello and uASK giving post-test, pre-test, and Sprint performance assessment for sprint 1 & 2. For all three results uASK gives better performance than Trello thus indicating affordances C4, C5 and C6 corresponding learning performance experiment 2 validates the findings of experiment1.

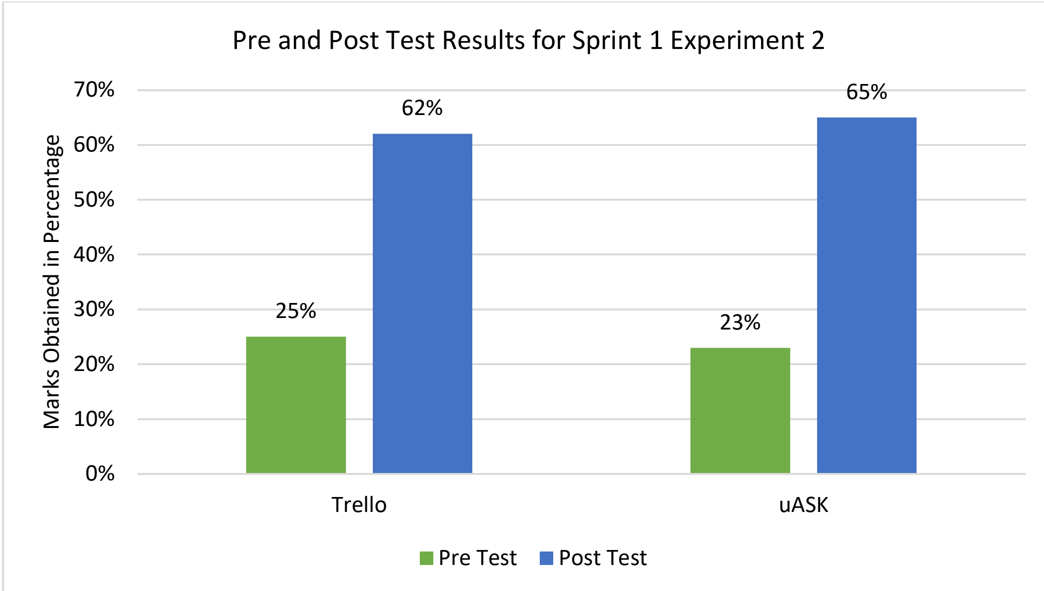

Figure 4.9: Results of Pre and Post Test Results for Sprint 1 Experiment 2

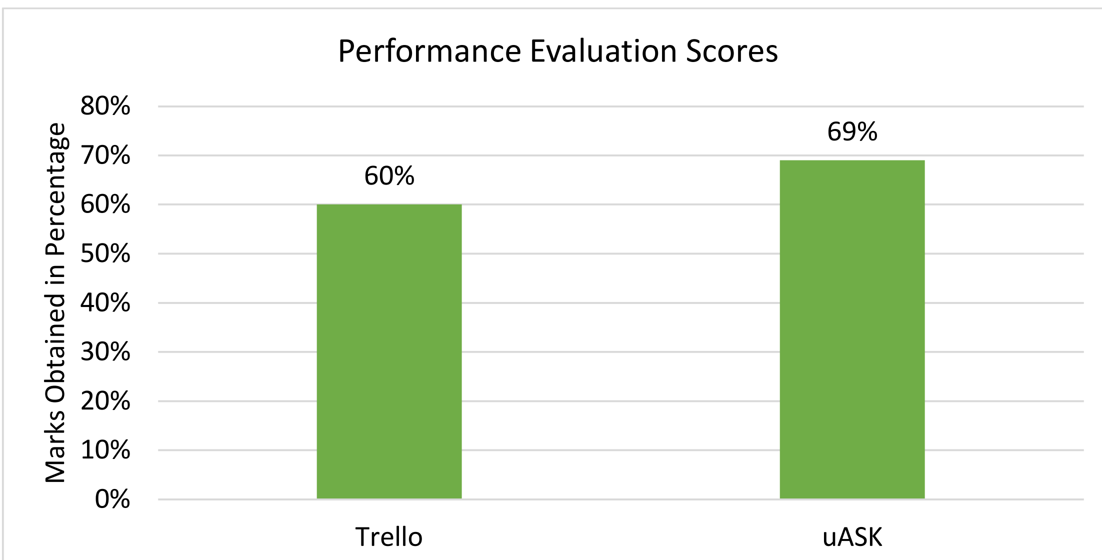

Figure 4.10: Sprint Performance evaluation results Sprint 1 Experiment 2

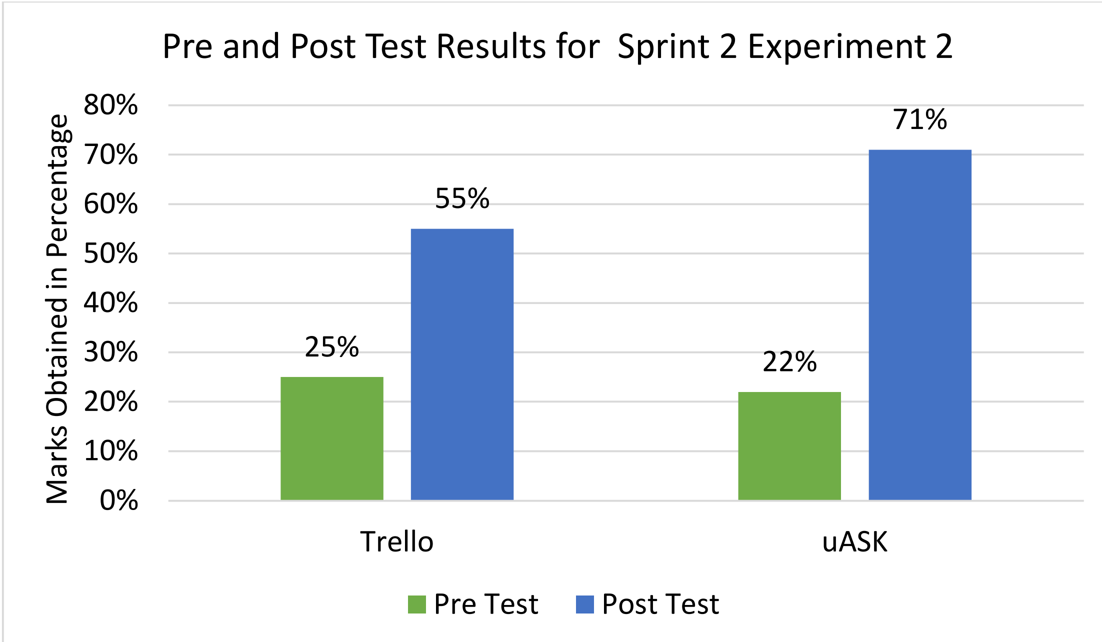

Figure 4.11: Results of Pre and Post Test Results for Sprint 2 Experiment 2

For both sprints the score for learning performance have better score for uASK 45.5% than Trello 33.5% for both sprint 1 and 2. Thus giving 12% improvement in learning. Table 4.4 shows the Pre & Post-test and Sprint performance of responses given by students for both Trello and uASK. A two-Sample t-test assuming unequal variances against the neutral value 3.00 confirmed these interpretations as for Post-test the difference is not significant as ($p>0.05$) for sprint 1 but for significant difference of ($p<0.01$) for sprint 2. Also, for Sprint 2 performance there is significant difference between Trello and uASK ($p<0.01$). Performance results further emphasized that uASK's has advantage over Trello. The post-test scores showing higher improvements and significant differences in Sprint 2 performance and p value ($p < 0.01$) showing significant difference. For Sprint 1, 95% Confidence Interval CI = [–0.17 , 0.65], that is not statistically significant with Cohen's $d \approx 0.27$ which shows small effect. However, for Sprint 2 Confidence interval, 95% CI = [1.22 , 2.08] with difference of 1.65 is statistically significant ($p < 0.01$) and Cohen's $d \approx 1.79$ showing very large effect. Cronbach's alpha values indicate high reliability which is 0.82 for Trello and 0.89 for uASK. Overall, uASK results shows that it outperforms Trello in affordances relating to communication, supporting learning performance, and providing superior technological usability, leading to better student outcomes.

Table 4.4: Meso level Quantitative responses for Trello and uASK for CSCL affordances for Experiment 2

Sprints	Group	Test	Participants (N)	Mean (M)	Standard Deviation (SD)	Standard Error (SE)
Sprint 1	Experimental Group 1 (Trello)	Pre-Test	38	2.51	0.82	0.13
		Post-Test	38	6.23	0.93	0.15
	Experimental Group 2 (uASK)	Pre-Test	40	2.021	0.71	0.11
		Post-Test	40	6.469	0.88	0.14
Sprint 2	Experimental Group 1 (Trello)	Pre-Test	38	2.48	1.2	0.13
		Post-Test	38	5.47	0.83	0.15
	Experimental Group 2 (uASK)	Pre-Test	40	2.21	1.28	0.11
		Post-Test	40	7.12	0.98	0.14

Second matrix of evaluation for assessing learning engagement is by time log observation as previously done in experiment1 for affordances C1, C2, C3 & C7. Figure 4.12 shows similar pattern of time engagement with uASK group taking less time but the difference in significantly large for all tasks. Only task 1, 2, 6 & 7 shows elevated time values demonstrating when students engage with the environment or support is not provided through the application uASK produces better results.

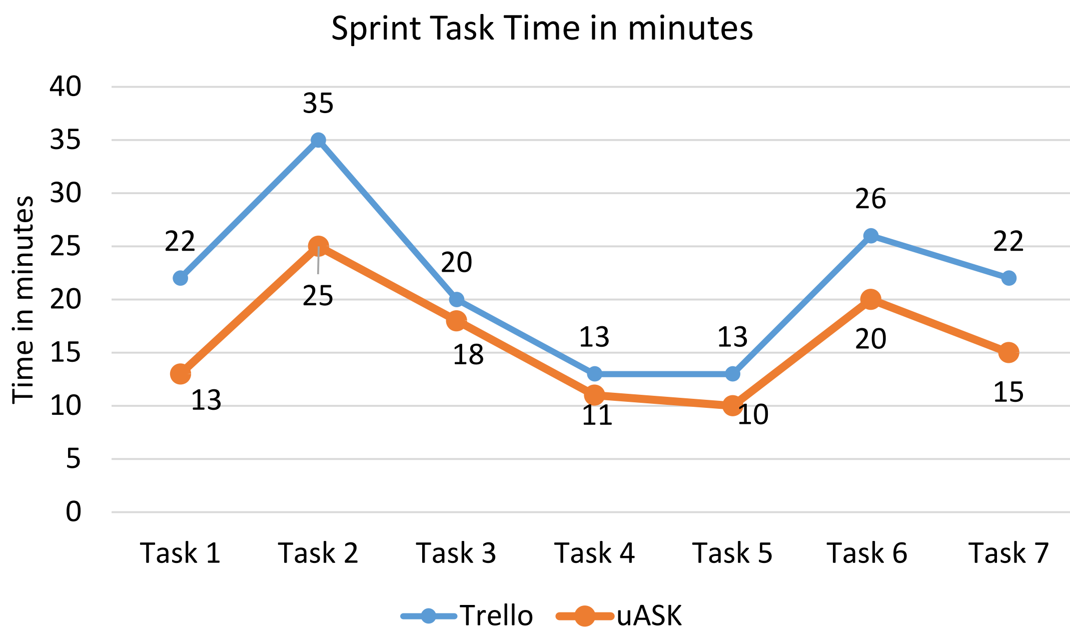

Figure 4.12: Time analysis of individual task in Sprint1 for Experiment 2

Where Figure 4.13 shows that uASK had higher task efficiency then Trello group. Also, Figure 4.14Similar to findings of Experiment 1 Students better engaged in the germination reporting activity through uASK as compared thus generating higher learners' engagement.

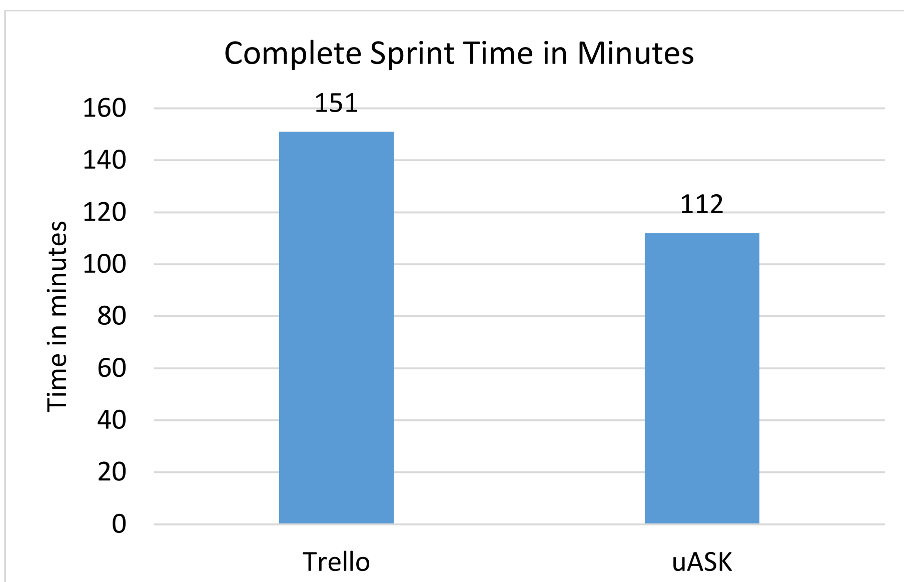

Figure 4.13: Complete time for Sprint1 in Experiment 2

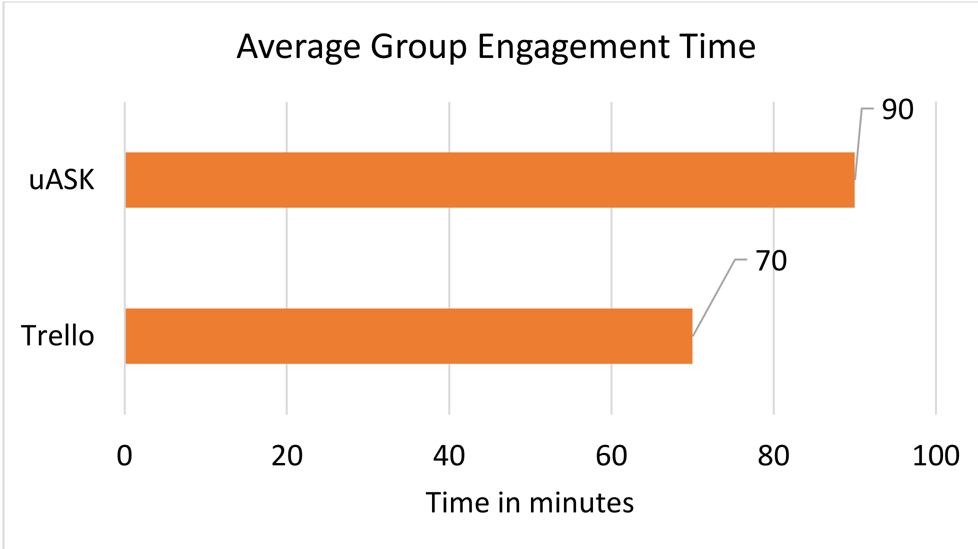

Figure 4.14: Engagement Time for Sprint 2 in Experiment 2

4.5.Integrated analysis of both results and discussion

To get a better understanding of the effectiveness of proposed framework, evaluation of analysis of results of both experiments 1 and 2 is discussed in this section. Total sample size is of 205 participants out of which Group 1 had 103 and Group 2 102). A power analysis using T-test for independent means indicates a statistical power of 95% which exceeding the conventional 80% threshold required to detect true effect. The minimum detectable effect size (Cohen's d) is 0.39 that means the study is well-suited for identifying moderate effects. This sample size is sufficient for detecting medium to large effects at a significance level (α) of 0.05. Overall, sample size is suited and well-powered for moderate or stronger effects, making it statistically robust for this research scenario.

4.5.1. Micro level integrated results and discussion

By combining the results of both experiments at micro level as shown in Figure 4.15, it was found that for every CSCL level from C1 to C7 uASK results are better than Trello. Especially for C6 gives 30% and C7 gives 32% better results uASK in comparison to Trello. Overall, there is a significant increase in the results of uASK for every CSCL affordance C1 shows 24% increase, for C2 is 13%, C3 shows 8% difference, C4 13% and for C5 20% marked improvement of uASK over Trello. Therefore, the results show marked improvement in the results of technology usability (C2, C3 C6 & C7) and communication, C1, C2 and C7.

Also learning performance also shows a marked increase in results of learners' perspective in micro analysis.

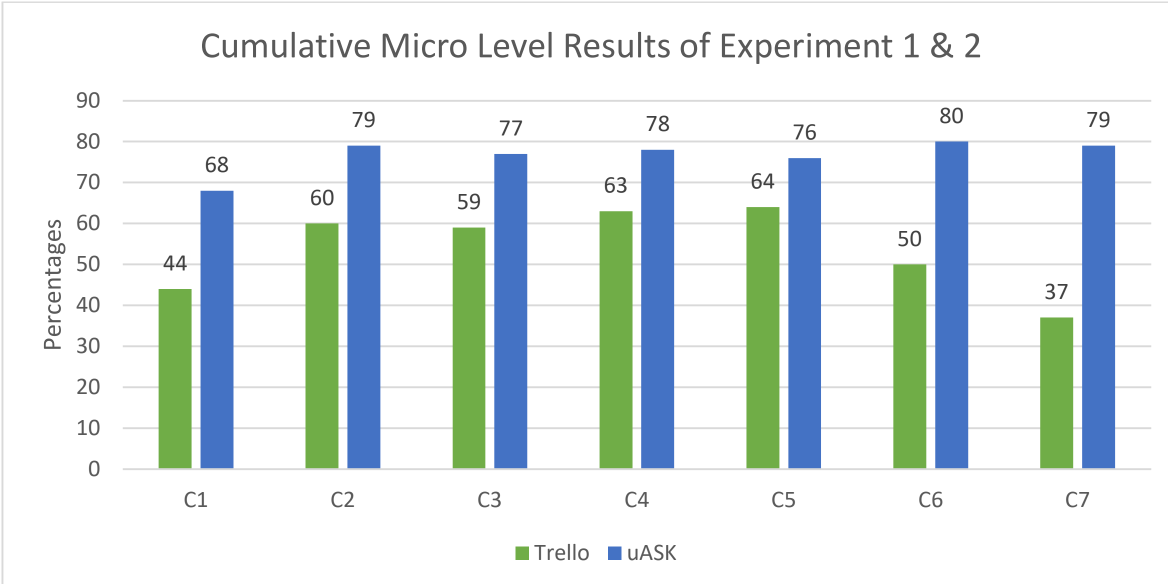

Figure 4.15: Cumulative Micro levels Results for Experiment 1 & 2

Table 4.5 shows the comparison of responses given by students for both Trello and uASK. A two-Sample t-test assuming unequal variances against the neutral value 3.00 confirmed these interpretations ($t_{204} = 10.23$, $p < .01$ for C1; $t_{204} = 5.67$, $p < .01$ for C2; $t_{204} = 6.98$, $p < .01$ for C3; $t_{204} = 4.83$, $p < .01$ for C4; $t_{204} = 2.03$, $p < .05$ for C5; $t_{204} = 9.44$, $p < .01$ for C6; $t_{204} = 19.26$, $p < .01$ for C7). Table 4.5 detailed the mean scores for each affordance based on student feedback. To evaluate the reliability of the questionnaire Cronbach's coefficient alpha for combined results is the Coefficient alpha equals 0.81 for Trello and 0.83 for uASK.The mean score for Trello across all affordances was approximately 2.7, which is equal to 54.12% when converted. Conversely, uASK had a higher mean score of 3.85, which is equivalent to 77.14%. These results were statistically significant and reliable in demonstrating the effectiveness of uASK, especially in regard to technology usability (i.e., C2, C4, C6 and C7: uASK ~ 4.0 vs. Trello ~ 2.5). The instrument was reliable (Cronbach's alpha > 0.8) and statistically significant ($p < 0.01$) at measuring support of learner satisfaction with uASK's organized collaborative features. Therefore, for sample size of 205 (103 group 1 and 102 group 2) shows high significant differences in results.

Furthermore, the results show that uASK consistently outperformed Trello across all CSCL affordances. The strongest improvements were observed in C7 and C6 with very large effect size with Cohen's d value of 2.73 and 1.60 respectively. Both of which are critical for sustaining collaborative inquiry learning. Large effects were also observed in C1, C2, and C3 with effect sizes around Cohen's d value 1.0 to1.3. A moderate-to-large effect was found for C4 and C5 showed a moderate effect. Overall, these findings highlight that uASK not only enhances general collaborative processes but also provides particularly strong support in areas essential for learner autonomy and effective inquiry.

Table 4.5 Cumulative Micro level Quantitative responses for Trello and uASK for CSCL affordances for Experiment 1 & 2

CLCL Affordances	Trello Responses Mean Response ± S.E (Standard Error)	uASK Responses Mean Response ± S.E (Standard Error)	95% Confidence Interval	Cohen's d (Effect Size)
C1	2.205± 0.09	3.42 ± 0.09	[0.96, 1.47]	1.33
C2	3.01 ± 0.07	3.96 ± 0.09	[0.73, 1.17]	1.17
C3	2.95± 0.1	3.89 ± 0.08	[0.69, 1.19]	1.02
C4	3.16± 0.08	3.94 ± 0.1	[0.53, 1.03]	0.85
C5	3.2± 0.08	3.8± 0.09	[0.36, 0.84]	0.70
C6	2.52± 0.09	3.98 ± 0.09	[1.21, 1.71]	1.60
C7	1.89 ± 0.07	3.97 ± 0.08	[1.87, 2.29]	2.73

4.5.2. Meso Level integrated results and discussion

For Meso level combined leaning performance results for both experiments 1 and 2 and also combining results of both activities. Figure 4.16 shows combined the pre and post test performance for both experiment 1 & 2, also combining the results for both activities. It was found that uASK (68.88%) also performed significantly better in learners' performance as compared to Trello (58.13%) at Meso-level evaluation.

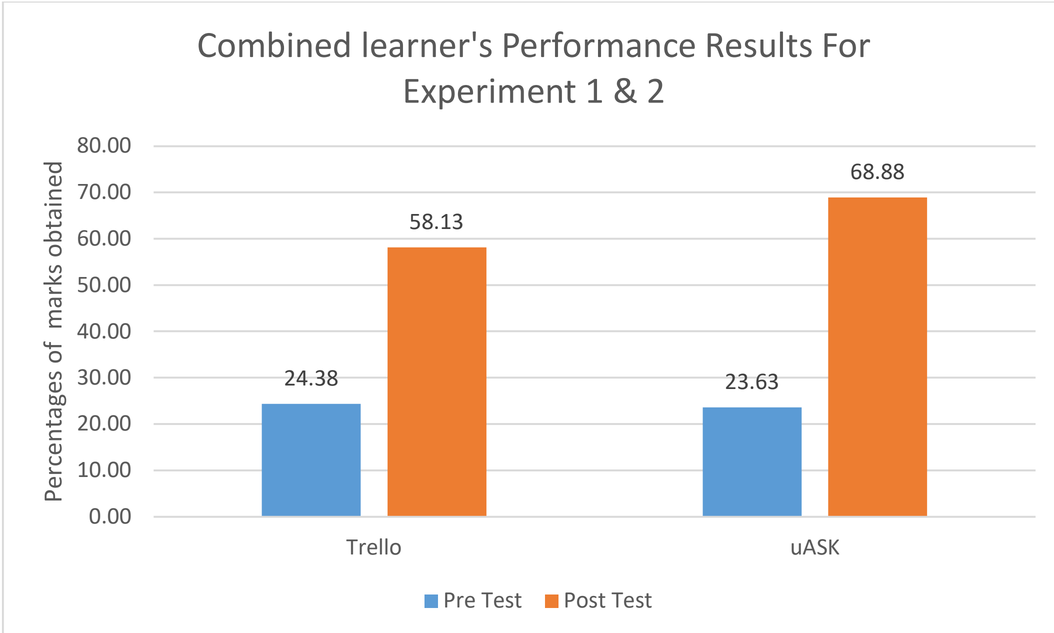

Figure 4.16: Combined learner's Performance Results for Experiment 1 & 2

Table 4.6 shows the meso level combine results for Pre & Post test Trello and uASK. A two-Sample t-test assuming unequal variances against the neutral value 3.00 was used to confirmed these interpretations. For Pre-test the difference is not significant as p value is less than 0.05 but for significant difference of p value of less than 0.01. uASK shows that it assist school students better in understanding the content and material as it integrates hints and guided learning that Trello does not. Which helps in better comprehension of the material which is clear in post-test scores as well. 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 and reducing time spent on each activity. In this research beacon tags helped students navigate the botanical garden and locate specific samples more efficiently. Both Trello and uASK groups showed marked learning improvements from pre- to post-test. But, uASK learners gained almost one full point more from +4.46 vs. +3.55. At post-test, evaluation uASK results shows that it significantly outperformed Trello with a mean difference of 0.72 points of confidence interval of 95% CI = [0.49, 0.95] and to a large effect size with Cohen's d ≈ 0.89.

Table 4.6: Meso level Quantitative responses for Trello and uASK for CSCL affordances for Experiment 2

Group	Test	Participants (N)	Mean (M)	Standard Deviation (SD)	Standard Error (SE)
Experimental Group 1 (Trello)	Pre-Test	102	2.44	0.97	0.11
	Post-Test	102	5.99	0.85	0.10
Experimental Group 2 (uASK)	Pre-Test	103	2.25	0.89	0.11
	Post-Test	103	6.71	0.76	0.09

As Trello lacks the structured guidance found in uASK, it makes it harder for students to stay on track or find specific information without teacher intervention. In the study, it took Trello group more time to complete each task. This lack of support might have made it challenging for younger students to perform with complex learning tasks. Additionally, uASK's features, such as hints and prompts, guidance of students through discussions to complete worksheet. This structured support helps in achieve the affordances relating to Engaging in Productive Processes and Monitoring and Regulation of Learning. The students could focus on what to do rather than getting stuck in task or needing frequent teacher intervention. Trello's Kanban approach is good for organizing tasks but may not provide enough guidance for inquiry-based learning. It does not support features like hypothesis generation, hints, or guidance in navigation. This limitation could result in hindering understanding if students struggle to access deeper content on their own.

The findings from both micro- and meso-level analyses provide strong evidence that uASK outperforms Trello in supporting collaborative student learning which was analysed using

CSCL affordances. The data from quantitative responses, pre- and post-test scores, shown in Figures 4.15 and 4.16, shows support that it can be implemented as pedagogical frameworks. At the micro-level, uASK consistently shows that higher mean scores across all seven affordances from C1 to C7, with improvements ranging from modest gains C3 = 8% to substantial gain of C6 = 30% and C7 = 32%. This uniform growth in performance suggests that uASK does not simply enhance a single dimension of collaboration, but rather provides comprehensive support across communication, technology usability, and collaborative processes.

4.6.Summary

In summary, the 'uASK' platform integrated more collaborative learning tools as developed and identified by Jeong and Hmelo-Silver whereas the Scrum-Kanban inquiry framework assisted better in visualization and integration of collaborative learning structures. uASK makes collaborative learning more impactful and effective to school students. With its findings of incorporating flexible and structured methodologies to streamline learning process.

The research studied the effectiveness of two collaborative learning tools, uASK and Trello. The experiments were conducted on a cohort of 205 seventh-grade students. The findings indicated that uASK performed better than Trello on all aspects of evaluation criteria. In the micro-level analysis, it was found that uASK had significantly higher learner satisfaction 72.36% than Trello 54.5%. As well as significantly higher reliability for the affordances of technological usability 30 to 32% higher scores for monitoring learning and group building, communication 8 to 24% improvement, and for learning performance 8% improvement over Trello. The meso-level approach showed that uASK students had improved learning outcomes from post-test score improvement of 68.88% uASK versus 58.13% Trello and were time-efficient 34.7% faster at completing the same task due to the integration of a variety of features such as the beacon tags and the Scrum-Kanban methodology. Overall, the relationship between uASK's collaborative learning affordances and agile framework established an effective learning environment that improved student engagement, understanding, and productivity in contrast to Trello. The overall evidence indicates that the uASK design offers better support for the process of collaborative learning and meets the outcomes in educational contexts relative to Trello.

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1. Conclusion

In this thesis, the ScrumBan Ubiquitous Inquiry Framework (SBUIF) has been proposed as a framework to support collaborative learning in ubiquitous environments. An agile approach for learning is developed for this framework. The framework developed to address the research questions that were defined in chapter 1. The focus of this framework is on improving collaboration, knowledge construction, and inquiry learning through structured sprints and providing real-time support for learning. Experiments shows the effectiveness of SBUIF in creating better collaboration and deeper learning outcomes compared to traditional tools.

In conclusion, this research shows that the uASK application developed on the ScrumBan Ubiquitous Inquiry Framework (SBUIF), offers substantial advantages over Trello in development collaborative learning among students using agile approach. In comparison of uASK applications with Trello it indicates that uASK application outperformed Trello by 72.36% vs 54.5% in user satisfaction at Micro-level evaluation. Similarly, uASK also performed significantly better in learners' performance as compared to Trello by 68.88% vs 58.13% at Meso-level evaluation.

5.1.1. Revisiting the Research Objectives

This section revisits the research objectives considering findings of this research.

a) *To design a framework for IBL in a ubiquitous environment using an agile approach.*

In chapter 3 a detailed discussion was done on the development of SBUIF framework. This discussion centred around the how seamless inquiry-based learning components are integrated with agile principles to create a learning framework. This integrated concept ensured that for the education purposed an effective and flexible framework is developed that respond to students' need by combing the elements of both agile and inquiry.

b) *To develop an agile-based application for inquiry-based ubiquitous environment.*

Also, in chapter 3 an application based on SBUIF is created uASK that corresponds to the stages and phases of designed framework. Along with creation of experiment scenario in form of lesson activity to test the effectiveness of the framework. For comparative analysis, Trello, is also used to validate the results. For evaluation a method is adapted by integrating elements of CSCL affordances and ME evaluation model. This is done to achieve the second research objective and validate the application of the agile-based framework.

c) *To evaluate the effectiveness of developed learning environment.*

For achieving this objective in chapter 4 all results of experiments on both uASK and Trello group are shared. These are thoroughly analysed and both the micro and meso level analysis shows marked improvement post results thus showing effectiveness of SBUIF framework. Along with better results for uASK show that a tailored application is more effective

5.2.Revisiting Research Contributions

There contribution this research makes is threefold i.e. in theoretical, practical, and methodological levels.

- On theoretical level this study adds a new theoretical framework based of inquiry learning by integrating agile principles ScrumBan Ubiquitous Inquiry Framework (SBUIF) is proposed. This framework is developed by merging the components of scrum, kanban and the inquiry-based 5E instructional model. This contribution opens a new opportunity to understand the effects of agile practices as a pedagogy approach and how it enhances collaborative inquiry in technology-supported school settings.
- This research also gives a practical contribution in form of innovative learning application named uASK. This application was developed to be used in real classrooms. The purpose of this application is to support teacher and students in implementing inquiry-based learning activates in a structured way

- Methodological contribution is that inform of student feedback inform of learners perspective and performance evaluation. This id done by adapting CSCL affordances with M3 evaluation framework and employing it for ubiquitous environment.

Along with these contributions the added benefit that the study brings to the table is its contribution to curriculum planning and overall organizational educational policies. Moreover, curriculum reforms can be helped by evidence provide by the successful integration of agile-inspired inquiry learning at middle school level as shown by this study. The results show evidence of effectiveness of these methods to improve problem solving skills and they can be used to improve collaboration between peers. By introducing it at institutional level it can be used in to include technology enhanced learning and support policy makers.

5.3.Limitations of the Study

Some of the limitations of this research are discussed in this section. One of the limitations is that the study did not address macro-level, such as effects of applying it at institutional level and for policy making. This was due to resource and time constraints. Due to this limitation, it restricts the genializing of the findings to larger educational systems and institutional contexts. Furthermore, the application of the study across multiple grades and linking it to the overall school system to give a comprehensive analysis. Also, a continues feedback for the improvement at institutional level needs to be done.

The framework was tested using small number of sprint iterations. Because of this limitation might have affected to fully show the impact of the study on how framework perform over longer learning periods. Testing framework with longer and repeated sprints across different learning settings is necessary for complete evaluation. The research lacked a longitudinal perspective to assess the long-term effect of SBUIF on learning outcomes and collaborative dynamics over time. Thus, it limits study of the long-term effects of the framework on student learning and collaboration skills.

5.4.Future Work

Building on the findings of this study, future research should pursue applications that expand the scope and practical application of the ScrumBan Ubiquitous Inquiry Framework

(SBUIF). One way is the implementation of SBUIF in rural and under-resourced schools, where problems such as limited internet connectivity and access to smart devices present challenges. Testing the framework in such environment would prove of its adaptability across different learning environments. Similarly, the framework should be extended to additional subject areas beyond science, such as mathematics, social studies etc, to evaluate its effectiveness in domains that require different forms of inquiry and collaboration.

Another area that can be explored in future is integration with AI and other analytical tools to improve adaptability and support by improving personalized learning experience. AI can improve different aspect from activity design to sprint flows and real time support. Whereas advanced data analytics can help create personalized experience by adapting customizing learning style most suited for the students needs. Which in turn helps educators to create refined instructional policies.

Along with that teacher's perspective is an important aspect that can be explored in future study. This will provide a unique opportunity to study the challenges the teacher may face in implementing such studies in their day-to-day classrooms practices such as lesson planning with integration with digital tools. Also, the study of SBUIF adaption at broader organization level and its possible contribution in policy making can also be studied. Besides that more comprehensive longitudinal research having multiple sprints at multiple grade levels to study its long-term impact on collaboration, knowledge retention, and critical thinking

So, by studying its impart in multiple targeted directions such as different subject domains and educational context on teacher practices, and institutional policies. This will further validate and refine SBUIF strengthen its role in future educational environment.

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Appendix I: Ethical Review Forms

Bahria University
Discovering Knowledge

PhD-12

Ethical Review Form

Part-I

This Form is designed to ensure that the departmental research operates an ethical review process that falls within the University guidelines. Any scholar undertaking research on live human subjects needs to fill this Form. If all questions in this Form are answered 'No', ethical approval shall automatically be granted. In such case Part-II of this Form shall not be filled by the scholar. If any of the questions is answered 'Yes', the scholar shall be required to fill Part-II of this Form. This part of the Form shall be reviewed by the Ethical Review Committee (ERC). Scholars shall be informed of the decision of the ERC as soon as possible. If needed, the scholar may be asked to submit further information and appear before the ERC for discussion meeting.

Scholar's Name:	BUSHRA FAZAL
Reg. No:	6244
Faculty/Department	SOFTWARE ENGINEERING
Programme:	PhD SE
Title of the Thesis:	AN AGILE APPROACH FOR INQUIRY-BASED LEARNING IN UBIQUITOUS ENVIRONMENT
Principal Supervisor:	DR SOHAIB AHMED

Name of Supervisor:	DR SOHAIB AHMED
Faculty/Department	SOFTWARE ENGINEERING
Designation:	SENIOR ASSOCIATE PROFESSOR

Name of Co-Supervisor:	
Faculty/Department	
Designation:	

Aim/purpose of study, source(s), Method(s) of Data Collection, benefits of study, duration of the study (*not more than one page, use extra sheet if required*).

To evaluate the effectiveness of agile ubiquitous learning inquiry framework. from middle school students. They will fill application evaluation survey, Pre-& post-test by using two applications Trello & our designed application. our framework & application will benefit learners in their learning.

Bahria University
Discovering Knowledge

Please answer all of the questions below by ticking (☒) 'Yes' or 'No' in the box provided

S No	Questionnaire	Yes	No
1.	Does the study involve participants who are particularly vulnerable or unable to give informed consent? (e.g. people under the age of 18, people with disabilities etc.)	✓	
2.	Will it be necessary for the participants to take part in the study without their knowledge and consent?		✓
3.	Does the study involve audio or visual recording of people in public places?		✓
4.	Will the study involve the discussion of sensitive topics? (e.g. sexual activity, drug use, illegal activities, death, whistle-blowing etc.)		✓
5.	Does the research involve the use of drugs, radiation agents experimental surgical / harmful procedures, blood or tissues samples		✓
6.	Is physical pain or psychological stress being part of this research work is likely to cause harm or negative consequences to the participants?		✓
7.	Will the study involve prolonged or repetitive testing on the participants?		✓
8.	Will financial inducements be involved in the study and (other than expenses) be offered to participants?		✓
9.	Will the study involve recruitment of patients or staff?		✓

Note:

If you have answered 'yes' to any of these questions, please fill in Part-II as well. Otherwise, simply submit Part-I of the form.

Scholar

Signature: ____________

Date: 16/3/2020

Verified by Principal Supervisor

Signature: ____________

Date: 17/03/2020

Bahria University
Discovering Knowledge

Part-II

A. In consultation with the supervisor, the scholar is required to give following information:

Scholar's Name:	BUSHRA FAZAL KHAN
Reg. No:	6244
Faculty/Department	SOFTWARE ENGINEERING
Programme:	PhD SE
Detail reason of answering 'yes' to one or more of the questions in Part-I of the Form, and the plan to address the ethical/financial issues. (*attach additional sheet if required*). **The ERC for Faculty of Health Sciences may ask further information if required.*	This research is for middle school student, aged under 18 (12-13 year old) for this purpose, the research consent will be taken from student's Parents. The experiment will be conducted in school premises during their class timing. Further the consent from school authorities will be taken.

Supervisor's Comments

All the ethical issues will be tackle according to research guidelines as per BU Rules & Regulations.

Principal Supervisor Signature: ______ **Date:** 17/03/2020

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B. Scholar is also required to do the following:

1. Prepare an information letter for their participants. The letter needs to introduce the scholar and provide a simple explanation of the research. It needs to make clear what the participants are asked to do, how long the research work will take. The letter shall also include whether it will be/not be anonymous and/or confidential and who will have access to the data.

2. Prepare a Consent Form containing the phrases "I agree to participate in the research work agile approach for ubiquitous learning and I understand my information will be/will not be treated as confidential, and/or anonymous."

Scholar

Name: Bushra Fazal Khan

Signature: ____

Date: 17/3/2020.

Appendix II: Approval from the Schools

Falconhouse Grammar School
We Excel in O/A Levels & Secondary Education

05 August 2023,

Bahria University Karachi Campus
13 National Stadium Road, Karachi,
Ph: 021 9924002-6

To whom it may concern,

As the Principal of Felconhouse Grammer School I am satisfied that the project at Felconhouse Grammer School can proceed and that it can be based on a low risk notification to the Bahria University Ethics Committee.

I am aware that in order to reach the low risk notification criteria, the University will be requesting written consent from both the students participating in the activity (because their identities will be known to the researchers) and from the parents (because some of the students will be under 16).

Thank you.

Yours faithfully,

Arjumand Ansari
Principal
arjumand.ansari@TES.edu.pk

Felconhouse Grammer School, Taurus Campus, Cambridge & Secondary System,
Address: E-24 & 25, Block - 4, Behind Regency Heights, Gulshan-e-Iqbal, Karachi Contact No.: 021-34988930

13 September 2024,

Bahria University Karachi Campus
13 National Stadium Road. Karachi,
Ph: 021 9924002-6

Subject: Approval for Project at Froebels Education Centre

Dear Ethics Committee,

As the Principal of Froebels Education Centre, I am pleased to confirm my support for the proposed project at our institution. I am satisfied that the study meets the necessary ethical and procedural standards and that it qualifies for a low-risk notification to the Bahria University Ethics Committee.

I acknowledge that, to comply with the low-risk notification criteria, the University will obtain written consent from both the participating students—whose identities will be known to the researchers—and their parents, particularly for students under the age of 16.

Thank you.

Yours faithfully,

madiha

Madiha Sheeraz
Vice Principal
Email: madihasheeraz@fec.edu.pk
Ph:03354722247
208-209 A, Khayaban-e-Iqbal,
Phase VIII DHA, Karachi

Appendix III: Participants Consent Form

Bahria University
Discovering knowledge

ScrumBan Ubiquitous Inquiry Framework Learning Activity

Participant and Parental Consent Form

We invite you to participate in a research study on ScrumBan Ubiquitous Inquiry Framework based activity on a mobile application designed to enhance science education. This study involves engaging in learning activities using mobile devices with internet connectivity. If available, students are encouraged to use their own devices; otherwise, alternative devices will be provided in the classroom. The study will include using a learning application that supports the educational experience. Participation is voluntary and will take place during regular class hours. No academic grades will be affected by participation.

Participants will be required to complete a questionnaire and take test based on content learned. Additionally, some participants may be interviewed. All responses will remain anonymous, and no personal data will be collected.

By participating, you will contribute to improving educational technology while also benefiting from the learning experience. The study focuses solely on evaluating the software and does not involve individual assessments.

Consent Agreement
I agree to participate in this study under the outlined conditions.

Student Name (Printed): ______________________

Student Signature: ________________ **Date:** __________

Parental Consent (For Participants Under 16 Years of Age)
I consent to my child's participation in this study.

Parent/Guardian Name (Printed): ______________________

Parent/Guardian Signature: ________________ **Date:** __________

Researcher: Bushra Fazal Khan (PhD Candidate), Department of Software Engineering, Bahria University, Karachi Campus, email: bushrafazal.bukc@bahria.edu.pk

Supervisor: Dr. Sohaib Ahmed, Department of Software Engineering, Bahria University, Karachi Campus, email: sohaib.bukc.@bahria.edu.pk

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Thank you for your participation!

Bahria University Karachi Campus, 13, National Stadium Road, Karachi-75260
UAN: +92-21-111-111-028 | Tel: +92-21-99240002-11 | Email: info.bukc@bahria.edu.pk | Web:bahria.edu.pk/bukc

Appendix IV: Learning Experience Questionnaire

Scrumban Ubiquitous Inquiry Framework Activity Questionnaire

This questionnaire is about your learning experience regarding the given mobile learning application.

Mark the application you are using

a) **Trello** ○ b) **uASK** ○

For answering the given questions, a five-option scale is given. Please follow the instructions below.

INSTRUCTIONS

Please read the questions carefully and tick one of the options beside each question. Please make sure that you have answered all the questions.

Questions	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
1. The task was well-defined and clear	○	○	○	○	○
2. There were no challenges in establishing a common understanding of tasks due to application	○	○	○	○	○
3. The application helped in learning	○	○	○	○	○
4. The learning experience was enjoyable	○	○	○	○	○
5. Navigation through the application was easy	○	○	○	○	○
6. The application helped working in group	○	○	○	○	○
7. It was easy to share information and files with our group	○	○	○	○	○

If you find any difficulty in understanding any questions, then please feel free to contact me.

Contact: Bushra Fazal (PhD candidate), Bahria University Karachi Campus
Email: bushrafazal.bukc@bahria.edu.pk

Appendix V: Pre & Post Tests

a) Reproductive Parts Of Plants Pre Test

Scrumban Ubiquitous Inquiry Framework Pre-Test

Topic: Reproductive Parts of Plants

Student Name: ________________

Instructions: Select the correct answer for each question.

1. **What is the male reproductive part of a flower?**
   - ○ Pistil
   - ○ Ovary
   - ○ Stamen
   - ○ Sepal
2. **Which part of the flower contains ovules?**
   - ○ Anther
   - ○ Filament
   - ○ Stigma
   - ○ Ovary
3. **Which of the following is NOT a part of the stamen?**
   - ○ Anther
   - ○ Filament
   - ○ Pollen
   - ○ Ovule
4. **What is the function of the stigma in a flower?**
   - ○ Produces pollen
   - ○ Catches and holds pollen
   - ○ Supports the petals
   - ○ Stores food
5. **Which part of the flower develops into a seed?**
   - ○ Petal
   - ○ Ovule
   - ○ Sepal
   - ○ Filament
6. **What role do pollinators play in plant reproduction?**
   - ○ Absorb water from the soil
   - ○ Help in the transfer of pollen
   - ○ Make food for the plant
   - ○ Protect the flower from insects

7. Which part of the flower turns into a fruit?
   - ○ Stigma
   - ○ Ovary
   - ○ Anther
   - ○ Sepal
8. What is the main function of petals in a flower?
   - ○ Protect the ovules
   - ○ Produce seeds
   - ○ Attract pollinators
   - ○ Store water
9. The order of the parts of a flower, from the outside inwards is:
   - ○ sepals carpels, stamens petals
   - ○ sepals, petals, stamens, carpels
   - ○ carpels, sepals, stamens, petals
   - ○ petals, carpels, stamens, sepals
10. The part of a flower to which pollen grains carried by insects stick is called the:
   - ○ anther
   - ○ stigma
   - ○ ovary
   - ○ moss

Submit

Clear form

b) Reproductive Parts Of Plants Post Test

Scrumban Ubiquitous Inquiry Framework Post-Test

Topic: Reproductive Parts of Plants

Student Name: ________________

Instructions: Select the correct answer for each question.

1. **Which of the following is a function of the stamen?**
   - ○ Produces ovules
   - ○ Produces pollen
   - ○ Captures pollen
   - ○ Protects the flower

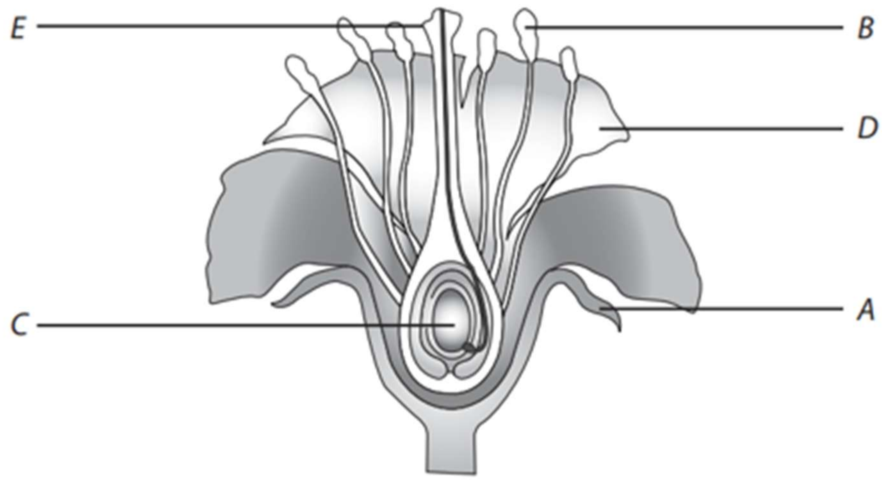
2. **Which of these is a female reproductive part of a flower?**
   - ○ Anther
   - ○ Filament
   - ○ Stigma
   - ○ Pollen

3. **What is the role of the anther in a flower?**
   - ○ It produces pollen
   - ○ It holds the stigma
   - ○ It captures pollen
   - ○ It supports the ovary

4. **What part of a flower receives pollen?**
   - ○ Anther
   - ○ Filament
   - ○ Stigma
   - ○ Sepal

5. **Which part of the flower is responsible for holding the ovules?**
   - ○ Stigma
   - ○ Ovary
   - ○ Anther
   - ○ Style

6. The diagram below shows a flower that has been cut in half to show its reproductive organs.



I. sepal	○ A	○ B	○ C	○ D	○ E
II. petal	○ A	○ B	○ C	○ D	○ E
III. stamen	○ A	○ B	○ C	○ D	○ E
IV. stigma	○ A	○ B	○ C	○ D	○ E
V. ovary	○ A	○ B	○ C	○ D	○ E

7. Write the letter of the flower part next to its job or function.

I. attracts insects to the flower
○ A ○ B ○ C ○ D ○ E

II. protects the flower when it is a bud
○ A ○ B ○ C ○ D ○ E

III. makes the seeds
○ A ○ B ○ C ○ D ○ E

IV. makes and stores pollen
○ A ○ B ○ C ○ D ○ E

V. has a sticky surface for the pollen to land on
○ A ○ B ○ C ○ D ○ E

Submit

Clear form

c) Pollination Pre-Test

Scrumban Ubiquitous Inquiry Framework Pre-Test

Topic: Pollination in Plants

Student Name: ________________

Instructions: Select the correct answer for each question.

1. **What is pollination?**
   - ○ The process of fertilizing soil
   - ○ The transfer of pollen from the anther to the stigma
   - ○ The movement of seeds from one plant to another
   - ○ The production of chlorophyll in leaves
2. **Which factor can help in pollination?**
   - ○ Water
   - ○ Wind
   - ○ Insects
   - ○ All of the above
3. **What is the result of fertilization in plants?**
   - ○ Formation of seeds
   - ○ Growth of roots
   - ○ Absorption of sunlight
   - ○ Production of oxygen
4. **Which type of pollination happens when pollen transfers from an anther to a stigma on the same flower?**
   - ○ Cross-pollination
   - ○ Wind pollination
   - ○ Self-pollination
   - ○ Insect pollination
5. **Which part of the plant produces pollen?**
   - ○ Stigma
   - ○ Anther
   - ○ Ovary
   - ○ Petal
6. **What are the two main types of pollination?**
   - ○ Internal and external
   - ○ Artificial and natural
   - ○ Self-pollination and cross-pollination
   - ○ Air and water pollination

7. In self-pollination, pollen is transferred:
   - ○ From the anther of one flower to the stigma of another flower on the same plant
   - ○ From the anther to the stigma of the same flower
   - ○ By wind from one plant to another
   - ○ By insects from one flower to another
8. What is the main function of pollination?
   - ○ To help plants produce oxygen
   - ○ To transport water to the leaves
   - ○ To enable plants to produce seeds
   - ○ To attract insects for food
9. Which of the following is an example of a pollinator?
   - ○ Earthworm
   - ○ Bee
   - ○ Mushroom
   - ○ Cactus
10. Why do flowers have bright colours and sweet scents?
   - ○ To scare away herbivores
   - ○ To attract pollinators
   - ○ To store energy
   - ○ To absorb sunlight

Submit

Clear form

d) Pollination Post-Test

Scrumban Ubiquitous Inquiry Framework Post-Test

Topic: Pollination in Plants

Student Name: ________________

Instructions: Select the correct answer for each question.

1. **Which type of pollination results in greater genetic diversity?**
   - ○ Self-pollination
   - ○ Cross-pollination
   - ○ Asexual pollination
   - ○ Artificial pollination

2. **What happens after successful pollination?**
   - ○ The flower wilts and dies
   - ○ The ovary develops into a fruit containing seeds
   - ○ The pollen grain turns into a new plant immediately
   - ○ The flower stops producing nectar

3. **The part of a flower to which pollen grains carried by insects stick is called the:**
   - ○ anther
   - ○ stigma
   - ○ ovary
   - ○ moss

4. **Which of the following is NOT a pollinating agent?**
   - ○ Wind
   - ○ Insects
   - ○ Water
   - ○ Roots

5. **Which of the following best describes pollination?**
   - ○ The process by which plants make their own food
   - ○ The process of transferring pollen to fertilize ovules
   - ○ The movement of water from roots to leaves
   - ○ The breaking down of dead plant matter

6. The male reproductive part of a flower that produces pollen is called:
   - ○ Stigma
   - ○ Ovule
   - ○ Anther
   - ○ Petal

7. What part of a flower receives pollen?
   - ○ Anther
   - ○ Filament
   - ○ Stigma
   - ○ Sepal

8. Which type of pollination happens when pollen transfers from an anther to a stigma on the same flower?
   - ○ Cross-pollination
   - ○ Wind pollination
   - ○ Self-pollination
   - ○ Insect pollination

9. What is the main function of petals in a flower?
   - ○ Protect the ovules
   - ○ Produce seeds
   - ○ Attract pollinators
   - ○ Store water

10. What role do bees play in pollination?
   - ○ They eat pollen and nectar, preventing pollination
   - ○ They transfer pollen from one flower to another while collecting nectar
   - ○ They break down plant waste to create fertilizer
   - ○ They act as natural pesticides for flowers

Submit　　　　Clear form

e) Germination Pre-Test

Scrumban Ubiquitous Inquiry Framework Pre-Test

Topic: Germination in Plants

Student Name: ________________

Instructions: Select the correct answer for each question.

1. **Which of these is NOT a method of seed dispersal?**
   - ◯ wind
   - ◯ animals
   - ◯ explosive mechanisms
   - ◯ fog

2. **What happens after pollination that leads to seed formation?**
   - ◯ Transpiration
   - ◯ Germination
   - ◯ Fertilization
   - ◯ Photosynthesis

3. **What is the result of fertilization in plants?**
   - ◯ Formation of seeds
   - ◯ Growth of roots
   - ◯ Absorption of sunlight
   - ◯ Production of oxygen

4. **What is fertilization in plants?**
   - ◯ The transfer of pollen from anther to stigma
   - ◯ The process where pollen unites with an ovule
   - ◯ The growth of a new plant from a seed
   - ◯ The release of oxygen from leaves

5. **Which part of the flower develops into a seed?**
   - ◯ Petal
   - ◯ Ovule
   - ◯ Sepal
   - ◯ Filament

6. **What are the necessary conditions for seed germination?**
   - ◯ Water, oxygen, and suitable temperature
   - ◯ Sunlight, soil, and fertilizer
   - ◯ Carbon dioxide, roots, and chlorophyll
   - ◯ Soil, insects, and wind

7. What happens to the seed coat during germination?
   - ◯ It becomes thicker
   - ◯ It breaks open to allow growth
   - ◯ It turns into a leaf
   - ◯ It absorbs sunlight

8. Which of the following best describes epigeal germination?
   - ◯ The seed remains underground
   - ◯ The cotyledons come above the soil
   - ◯ The seed does not need water
   - ◯ Germination occurs without oxygen

9. In which type of plant would you most likely find hypogeal germination?
   - ◯ Beans
   - ◯ Corn
   - ◯ Sunflowers
   - ◯ Peas

10. What role does water play in seed germination?
    - ◯ It helps the seed remain dormant
    - ◯ It activates enzymes for growth
    - ◯ It absorbs sunlight for photosynthesis
    - ◯ It prevents the seed from rotting

Submit | Clear form

f) Germination Post-Test

Scrumban Ubiquitous Inquiry Framework Post-Test

Topic: Germination in Plants

Student Name: ________________

Instructions: Select the correct answer for each question.

1. After germination, what helps the young plant make its own food?
   - ○ Cotyledons
   - ○ Roots
   - ○ Chlorophyll in leaves
   - ○ Seed coat
2. Which of the following is **NOT** necessary for seed germination?
   - ○ Water
   - ○ Oxygen
   - ○ Sunlight
   - ○ Suitable temperature
3. What is the first step in seed germination?
   - ○ The seed coat falls off
   - ○ The root emerges from the seed
   - ○ The leaves develop
   - ○ The stem elongates
4. Which factor is most important in breaking seed dormancy?
   - ○ Water
   - ○ Fertilizer
   - ○ Carbon dioxide
   - ○ Sunlight
5. What happens to the cotyledons after the seedling grows leaves?
   - ○ They grow larger
   - ○ They fall off as the plant starts photosynthesis
   - ○ They turn into flowers
   - ○ They become part of the root system
6. What is the function of oxygen in germination?
   - ○ It is not required for germination
   - ○ It helps break down stored food to release energy
   - ○ It makes the seed coat softer
   - ○ It turns the seed green

7. What happens if a seed does not receive enough water?
   - ○ It will germinate faster
   - ○ It will remain dormant
   - ○ It will grow without leaves
   - ○ It will skip the germination process
8. Why do some seeds need **scarification** before germination?
   - ○ To allow oxygen to enter
   - ○ To weaken the hard seed coat
   - ○ To increase water absorption
   - ○ All of the above
9. Identify the correct **sequence of events** in germination:
   - ○ Root emerges → Stem grows → Leaves develop
   - ○ Leaves develop → Root emerges → Stem grows
   - ○ Stem grows → Root emerges → Leaves develop
   - ○ Root emerges → Leaves develop → Stem grows
10. How does temperature affect seed germination?
   - ○ Very high or low temperatures can slow or stop germination
   - ○ Only cold temperatures help in germination
   - ○ Temperature has no effect on germination
   - ○ Seeds only germinate in direct sunlight

Submit

Clear form