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# Applying the 6E learning by design model to support student teachers to integrate artificial intelligence applications in their classroom

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**Abstract**

The 6E Learning by Design (LbD) model can enhance student teachers' development of competence for integrating technologies in the classrooms including Artificial Intelligence (AI). However, teacher educators rarely use the 6E LbD model in supporting and encouraging student teachers to integrate AI applications in their classrooms effectively. To attract teacher educators to use the 6E LbD model, in the present study, we modeled learning activities for each phase. We also examined the impact of the 6E LbD model in supporting student teachers to integrate AI in the classroom. We adopted a Participatory Action Research approach implemented in two cycles. We collected data from 35 student teachers who were selected purposively. We collected data through observation, reflective journals and document analysis. We observed student teachers during the classroom activities and analysed their lesson plans and reflective journals, and interpreted data based on a thematic analysis. Findings show that there are various activities facilitating learning in different phases of the 6E LbD model. Also, findings show that the 6E LbD enables student teachers to develop skills and competence for integrating AI in their classrooms. The findings show that an evidence-based approach will motivate teacher educators to use the 6E LbD model.

**Keywords** Artificial intelligence · 6E learning by desing model · Student teachers · Teacher educators

Extended author information available on the last page of the article

## 1 Introduction

Artificial intelligence (AI) technology has the potential to transform the education industry. Automated Scoring, Tutoring Systems, Adaptive Learning and Automatic Writing Systems are just a few examples of forms of AI that can enhance assessment, and personalized learning opportunities among others (Celik, 2023; Zhai et al., 2021). Al Darayseh (2023, p. 1) posits,

> It is necessary to emphasize the great potential offered by AI for use in education through the Internet and the accompanying vast developments that have created ease of access for students and teachers to the information they need and want to obtain.

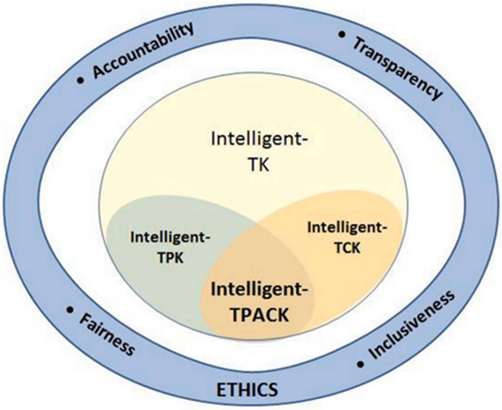
This indicates the extent to which integrating AI in the teaching and learning process is unavoidably necessary.

Despite the potential of AI to transform the teaching and learning process, previous studies have shown that education, so far, is one of the fields that most negligible benefit from AI (Celik, 2023; Salas-Pilco et al., 2022; Shum & Luckin, 2019). For instance, Salas-Pilco et al. (2022) argue that the application of AI in data analytics in education is very low compared to finance, industry and medicine. Lack of teachers' skills to integrate AI in education is cited to be among the causes of failure to harness the potential of AI in education (Franzoni et al., 2020; Kim et al., 2022; Kohnke et al., 2023; Lee & Perret, 2022; Nazaretsky et al., 2022; Utterberg Modén et al., 2021). For instance, Kohnke et al. (2023) observed that the majority of language teachers are unconsciously familiar with AI applications and they lack confidence to integrate AI int their classroom. These authors observed that teachers embrace AI only if they are capable of resolving challenges related to AI technology. Therefore, this shows how important it is for teacher educators to train teachers to integrate AI in their classrooms. It should be noted that training teachers to integrate technology in the classroom is a complex task that requires teacher educators to be informed of what specific aspects should be addressed to help teachers develop the needed competences. The Technological Pedagogical Content Knowledge (TPCK) framework shows that teachers can effectively integrate technology in the classroom only if they have developed Technological Knowledge TK, Pedagogical Knowledge (PK) and Content Knowledge (CK) (Mishra & Koehler, 2006). This framework indicates that skills for integrating technology are beyond teachers' ability to operate technological tools. As Mishra and Koehra (2005, p.94–95) underscore,

> There is more to teacher preparation than training teachers how to use tools—it requires appreciation of the complex set of interrelationships between artifacts, users, tools, and practices. What is needed, we argue, is an approach that helps teachers develop deeper understandings of the nuances and complexities of technology integration.

Furthermore, Celik (2023) developed Intelligent-TPACK by adding the four ethical aspects, namely Transparency, accountability, inclusiveness and fairness, to the

**Fig. 1** *Intelligent-TPACK*
Source: (Cellik, 2023, p.8)




TPACK framework as shown in Fig. 1. The transparency aspect requires the teacher to justify AI-based decisions. Accountability entails the awareness of the teacher of who are the AI developers. Inclusiveness means the ability of teachers to consider AI accessibility to all students. Fairness means the teachers' ability to enhance equity in the AI-based learning environment. The Intelligent-TPACK offers insights into how training teachers to integrate AI could be more complex compared to preparing them for integrating other technologies. Yet the framework does not answer the question of how successfully teacher educators can prepare teachers to cope with this complex task.

Literature shows that Learning by Design is one of the best approaches to training teachers to use technology in the classroom (An et al., 2022; Celik, 2023; Koehler & Mishra, 2005). Learning by design allows teachers to practice what they learn and thus internalize skills and knowledge (Koehler & Mishra, 2005). Furthermore, it helps them develop real-life problem-solving skills (An et al., 2022; Koehler & Mishra, 2005; Utterberg Modén et al., 2021). This implies the potential of this learning approach to help teachers customize solutions they develop in the classroom for any problem they may encounter. Therefore, there is a need for teacher education to adopt LbD models in preparing teachers to integrate AI in the classroom.

The 6E Learning by Design (LbD) is one of the models used in coping with complex teaching learning demands in various contexts including in teacher education (Gholam, 2019; Khaeroningtyas et al., 2016; Lin et al., 2020).[1] However, there is a lack of evidence on the application of this model in preparing teachers to integrate AI in their classrooms. Teacher educators may not be convinced of the impact of this model and/or are not conversant with the application of the model in preparing teachers to integrate AI in their classrooms. We believe that hesitation to apply this model in teacher preparation courses may exacerbate the existing gap in harnessing the potential of AI in the education industry. Therefore, to rescue the situation, the present study shows how the 6E LbD model can be applied in preparing teach-

[1] As LbD is a project-based inquiry in learning, there is a family resemblance to other design-based teaching and research approaches such as, for example, that of The Design-based Research Collective (2003).

ers to integrate AI in the classroom. Specifically, the present study intends to: (a) model learning activities for each phase of the 6E LbD model in preparing teachers to integrate AI in their classroom; (b) examine the impact of the model on teachers' preparedness to integrate AI in their classroom.

The paper is organized as follows. Section 2 covers a theoretical framework. In Sect. 3, we conceptualize the 6E LbD model. In Sect. 4, we discuss empirical studies related to adopting the 6E LbD model in teacher preparations. In Sect. 5, we present the methodology for the study. We present findings in Sect. 6. In Sect. 7, we discuss the study's findings, and in Sect. 8 we present conclusions and recommendations for the further development of teacher training.

## 2 Theoretical framework

The proposed study is informed by the social theory of Community of Practice (CoP) as advocated by Wenger (2008). The main assumption of the learning theory of community practice is that whether in a formal context or informal human beings tend to develop similar interests to pursue certain goals from which they learn from each other collaboratively to meet such a goal. As Farnsworth et al. (2016) restate, "In other words, learning takes place through our participation in multiple social practices, practices which are formed through pursuing any kind of enterprise overtime." (p. 2) According to Wenger (2008), the participation of an individual in a particular activity as a member of the group that engages in such activity creates the sense of belonging to the group in a way that it motivates him or her to invest his/her effort to maintain the bond regardless of the experienced obstacles. This means that learning in this perspective involves attaching the value of gaining potential competence as a social contract for one to remain a respected member of the learning community.

Since the present study aims at sharing successful practices for using the 6E LbD model to prepare teachers to integrate AI in the classroom, it fits in the framework of CoP. We believe that sharing the successful practices for the 6E LbD model will help other educators in implementing teacher preparation courses using the model. Hence, this will improve teacher educators' community skills and knowledge for adopting the 6E LbD model to prepare teachers to integrate AI into education.

## 3 6E learning by design model

The 6E LbD model was developed by the International Technology and Engineering Educators Association (ITEEA) (Lin et al., 2020; Yazıcı et al., 2022). This model is an extension of the 5E instructional model that was developed by the Biological Science Curriculum Study (BSCS) (Lin et al., 2020). The 6E model comprises six components including engineering which do not exist in the 5E model. According to Burke (2014), the 6E LbD model is comprehensive in the sense that it combines the elements of engineering and inquiry, which makes them integrate various disciplines (Technology and Engineering). As Burke (2014, n.p) posits, "6E model provides a student-centred framework that deliberately and purposefully uses the Technology

(T) and Engineering (E) dimensions of STEM." To make it clearer, Burke (2014) described the six components of the 6E LbD model alongside Engineering process as shown in Table 1.

Table 1 shows that various phases of this model provide learners with opportunities to understand the problem, find the solution and evaluate it. Based on this, one may argue that the model helps learners to learn about how to solve problems rather than what is the solution to the specific problem, something that enhances learners' ability to deal with any problem that they may face in the future. Conceiving the 6E LbD model through the lens of Burke (2014), Yazici et al. (2022, para. 5) posit,

> Students are provided with opportunities to realize a deeper understanding of the core problem through the application of concepts during the engineering phase students question and integrate inquiry with engineering concepts to make design decisions in problem solving. While they apply what they have learned to new situations and new problems in the enrichment phase, they understand and use the concepts of design, modelling, resources, systems and ethical values.

In addition, Gholam (2019) cautions that the elements of the 6E LbD model should be viewed as interactive. This shows how 6E Learning by Design model is relevant

**Table 1** Components of 6E Learning by Design Model as Linked to Engineering Design Process

| Engineering process | 6E learning model by Burke (2014) |
|---|---|
| Determining the scope of the problem | *Engage* Attention is drawn to real-life situation, preliminary information is revealed, and context is created for what is to be learned at this stage.<br>Students encounter teaching task and describe it.<br>Students are encouraged to put forward different ideas and ask questions. |
| Doing necessary to develop possible solutions | *Explore* Students look for solutions to questions by using inquiry processes. This process includes guessing, hypothesizing, experimenting with alternative solutions and discussing the results.<br>As the students work together as a team, they perform collaborative experiment that involve sharing and communicating. Inquiry, data analysis, and critical thinking are emphasized at this stage. |
| Developing possible solutions and selecting the most suitable solution | *Explanation* Students explain results of their discovery process using data and observation. They can reach generalization from the explanation. The teacher offers feedback, offer alternative explanations, asks questions, expands and evaluates explanations. |
| Building, testing, evaluating and developing prototype | *Engineering* Students integrate inquiry with engineering design to make design decision appropriate to the solution of the problem. Solution-oriented design development, prototyping, improvement, evaluation, and redesign processes are carried out. |
| Sharing the solution, evaluation and improving | Enrich Students are provided with the opportunity to explore what they have learned in greater depth and to transfer concept to complex problems. Students apply their knowledge to new situations, new problems and daily life.<br>*Evaluate* Students are encouraged to assess their understanding and abilities. Students' progress towards achieving educational goals is evaluated. The evaluation covers the whole teaching process. Rubrics, teacher observation, student interviews, portfolios and products can be used in this context. |

Adopted from (Burke, 2014)

to preparing teachers to integrate AI as AI integration is a complex task that requires one to engage in solving problems day by day.

## 4 The application of learning by design models in technological related teacher preparations

Findings from previous studies show that LbD models enable both pre-service and in-service teachers to develop needed knowledge skills and knowledge for integrating technology in the classroom. Lee and Perret (2022) worked collaboratively with teachers in the US to design a curriculum for STEM learning. They report that teachers highly rated the project as valuable to their learning. Also, Anabousy and Daher (2022) observed an improvement in skills for designing STEM learning units among preservice teachers who were involved in LbD training in Israel. In addition, Haas et al. (2021) reported that hands-on activities helped pre-service teachers develop skills for facilitating Outdoor STEAM activities in the classroom. Although these studies are not focused on training about employing technology, they partly show the usefulness of Learning by Design in preparing teachers to use technology because technology is part of the STEM classroom. In addition, these studies show how the Learning by Desing approach enhances the development of interdisciplinary skills. This is because the ability to facilitate STEM learning implies teachers' competence in transdisciplinary/interdisciplinary teaching approaches. However, evidence on how the specific model of Learning by Design in the context of preparing teachers to integrate AI is missing. This implies the need for more studies that can fill this gap.

In contrast, Lu (2014), Makri et al. (2014) and Lu et al. (2011) observed positive impacts of Learning by Design in teacher preparation courses based on specific models of Learning by Design. For instance, Lu (2014) adopted Kolodnen (2003)'s model of Learning by Design in training pre-service teachers. Lu (2014) reports that the training approach led to improved teachers' skills in using technology in the classroom. Some of the learning tasks reported in this class include reflection, designing and solving real-life problems. Besides, Lu et al. (2011) reported that the application of Kolodner (2003)'s model of Learning by Design improved technological-pedagogical knowledge and pedagogical knowledge more than content knowledge among teachers who were being trained in using Microsoft Word, Excel and PowerPoint. On the other hand, Makri et al. (2014) revealed that the application of Kalantizis and Cope (2012)'s framework in teacher training courses in Greece impacted teachers positively. The activities that were used in this study include exploration and discussions. Despite providing insights into the impacts of specific models of the LbD approach, these studies report on limited models excluding the 6E LbD model. Also, the application of the mentioned model was not on training teachers in the context of integrating. Therefore, since the present study focuses on the 6E LbD model in the context of preparing teachers to embrace AIs in their classrooms, there is no way we can rely on the findings from these studies.

Above all, An et al. (2022) employed the Learning by Design approach to training teachers to use Robotics AI in the US where they noted improved teachers' skills in teaching with robotics AI. They reported that teachers developed knowledge and skills related to the content knowledge about robotics technology, constraints of using robotics AI and teaching with robotics. They also reported that their project was accompanied by various learning activities such as Robotics building, Reflective essays, open-ended questions and presentations. In another study from the field of engineering education, Guzmán-Ramírez et al. (2019, p.1237) developed a "field programmable gate array-based educational system" focused on the modeling, implementation, and evaluation of hardware architectures in artificial neural networks based on a LbD approach. The authors conclude that encouraging students and academics to expand their capabilities through designing new modules, especially a flexible course structure supports the effectiveness of learning at the undergraduate level through a learning-by-design approach applied to real-world problems like the iris-plant issue.

These studies show that Learning by Design leads to the successful training of teachers on integrating AI technology in the classroom. However, the study focused on a limited number of AI technologies and said nothing about the 6E LbD model. This implies the need for more studies that focus on 6E LbD in the context of a large number of AIs. Hence the present study is significant in filling this gap.

## 5 Methodology

### 5.1 Study context

The study was conducted at one of the higher learning institutions in East Africa involving student teachers who were pursuing master's degrees in Education specializing in mathematics, Language and Literacy, Education Leadership and Management, Early Childhood Education and Science. The student teachers in this class come from the three East Africa countries namely Uganda, Kenya and Tanzania. These teachers are teaching pre-primary, primary and secondary school. One of the admission requirements in this master's degree was a minimum of three years of teaching experience. Therefore, all the student teachers regardless of their counry of origin and specialization, they had worked as teachers for at least three years. Furthermore, there is low technology integration in the classroom contexts (Uganda, Kenya and Tanzania) where these student teachers work, despite having educational policies for integrating technology in teaching. Aga Khan university offers the ICT in Education course as a way to support student teachers who join master program to develop competence to integrate technology in their respective countries. This study was part of the intervention in the ICT in education course that these students take in their second semester. The intervention project aimed familiarizing student teachers with AI and developing competence for integrating AI in their classroom. The project covered the whole semester in which there were three contact hours per week.

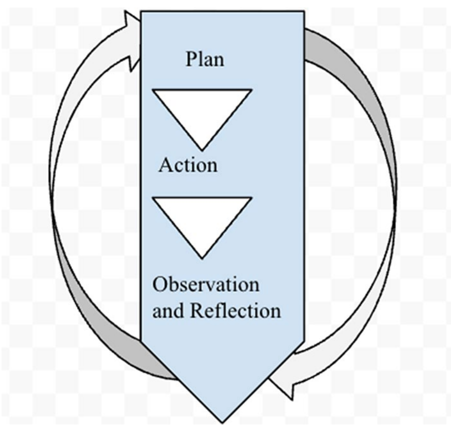
### 5.2 Research approach

We adopted the qualitative Participatory Action Research (PAR) approach. Action research intends to modify existing satisfying situations through collaborative initiatives with the community in the relevant setting (Berg & Lune, 2017; Burns, 2009; James et al., 2008; Kemmis et al., 2014; Koshy, 2005). Laurillard (2008) argue that teachers as researchers have the responsibility to assess their classroom situation and collaborate with students to improve the teaching and learning process. Our approach aligns with the principles of the PAR since one of the researchers is responsible for facilitating the ICT in Education Course at this university. In this regard, he took the role of 'the teacher as a researcher' and collaborated with other researchers and students to improve the teaching and learning process. During the implementation of PAR, we adopted the spiral model of PAR as presented by Kemmis et al. (2014). This model has four phases, namely planning/reconnaissance, action/intervention, observation, and reflection. The planning stage involve identification of major concerns and developing possible solutions. Intervention phase involves implementing the solution developed from the reconnaissance phase. The observation and reflection phase involves assessing the intervention to draw lessons for possible improvement of the next cycles. These phases are interactive in a way that it allows the researcher to go back and forth within a certain cycle setting. Figure 2 illustrates the interactive nature of these phases. Moreover, PAR can go through several cycles; however, given the limited time, we implemented PAR with two cycles only.

### 5.3 Participants, data collection methods, and analysis

We collected data through observation, document analysis and reflective journals from students. Data collection was conducted within 12 weeks of the second semester starting from May, 2023 to July 2023. We observed students when they were working in the classroom. We analyzed student teachers' lesson plans and reflections. Only students who took part qualified to be part of the study. Thus, we used a purposive sampling technique based on the involvement criteria. The class has a total number of 69 student teachers. However, we collected data for this study from 35 student teachers only. The number of student teachers to participate in this study was determined by the data saturation point. The data saturation point is when the researcher finds no new emerging themes from the respondents (Hennink & Kaiser, 2022). We renamed the participants as STUDENT TEACHERS I-XXXV to hide their identity.

**Fig. 2** Phases of PAR



Finally, we analyzed data thematically based on the framework proposed by Auerbach and Silverstein (2003), Miles et al. (2014) and Miles and Huberman (1994). Based on this framework, we coded, sorted, consolidated data and developed themes. Finally, these themes were verified through relating them to theories and views of participants. In the coding stage, we coded data collected through document analysis, and reflective journals manually by assigning different labels to data. In contrast, data from observation of student teachers' interaction with peers and Ais were coded separately because we used a checklist, which enabled us to collect and code them simultaneously throughout the project course. We classified the coded data from document analysis, observation, and reflective journals based on their relationship by using tables. We finally developed themes for each of the classifications of the data and related these themes to theories that informed the study. To ensure the rigor of the data analysis, we analysed data in two separate groups and later exchanged the analysis results for peer review. In case of differences, we discussed until we found consensus.

### 5.4 The PAR implementation

The implementation of the PAR is presented in the Tables 2 and 3 for the two cycles.

## 6 Findings

The present study was guided by two research objectives: (a) modeling the teaching-learning activities for each phase of the 6E LbD model and (b) examining the impact of the 6E LbD model in supporting student teachers to integrate AI in their classrooms. In this section, we present findings thematically based on the research objectives.

### 6.1 Activities for each phase of the 6E LbD

Sharing real-life narratives about the impacts of embracing or neglecting AI attracts the interest of student teachers. The narrative about the researcher's personal experience with the introduction of cryptocurrency, and the experience of the Italian government on ChatGPT (McCallum, 2023) control made student teachers curious to learn about the integration of AI in the classroom. This was evident from their reflections as STUDENT TEACHER I reflected, *"In summary, the session was an eye opener since from it, it was discovered that the use of AI in education cannot be ignored. If the educationists will, other sectors will use it alongside other digital hardware and software."* This shows the extent to which such narratives awakened student teachers. In addition, providing opportunities for student teachers to practice technologies in contexts where they use traditional means was identified as a catalyst for student teachers' interest in the lesson. It was observed during the exercise that student teachers developed more questions and they looked excited to learn more practices with technologies, especially in their classroom. It was also evident from their reflections, as STUDENT TEACHER V reflected, *"The transition from writ-*

**Table 2** Cycle 1

| PAR Phase | Activities |
|---|---|
| Planning/Reconnaissance | We planned the teaching and learning activities based on the lessons we learned from the literature related to framework for integrating AI in the classroom. We also considered the context in which our student teachers work and their competence in using AI in teaching. Furthermore, the plan integrated the components of 6E learning by Design model. |
| Action/Intervention | *Facilitating Engagement*: we introduced students to evidence-based reports on the inevitability of embracing AI. The banning and lifting of the ChatGPT ban in Italy (McCallum, 2023) were used as one of the examples.<br>We also shared with student teachers some of the scenarios that the researchers had once benefited and/or cost from because they either embraced technology or rejected it at one point. Ignoring investing in cryptocurrency was used as one of the scenarios that cost one of the researchers.<br>*Facilitating student teachers' Exploration*: we Exposed student teachers to ChatGPT. We provided time for students to explore how ChatGPT works with less focus on pedagogical issues. Then we shifted their focus to explore how ChatGPT works with more focus on pedagogical responsible use and ethical issues<br>*Facilitating Explanation, Engineering, Enriching and evaluation*: We allowed student teachers to share their views about the potential challenges and opportunities of integrating. This involved sharing and receiving feedback from facilitators and peers. |
| Observation and Reflection | *Assessing the intervention*: we identified the need to introduce more AIs to meet student teachers' needs to use AI for different purposes such as creating diagrams.<br>We also learned that extending time for practices was necessary to accommodate all student teachers.<br>We realized that unguided exploration of how AI works was a catalyst to expanding student teachers' insights. We learned that student teachers can find better pdeagogical approach if they work in groups created based on their specialization. We observed that student teachers needed extended time for out-of-class consultation to cater to challenges that student teachers faced outside of the classroom. We noted that peer learning sessions could be an alternative solution to close knowledge and skill gaps that we observed among student teachers. |

*ten responses to audio or video submissions was a significant shift for many of us. It required embracing new technologies and overcoming the initial discomfort of speaking or appearing on camera."* This shows that the exercise enhanced student teachers' change in attitude towards using technologies.

Moreover, allowing student teachers to interact with AI for their interests, and exposing student teachers to various AI are useful activities for the Exploration phase. Data analysis indicates that these activities allow student teachers to experiment with AIs. As STUDENT TEACHER XX reflected, "*I learned how a variety of AIs can be utilized in the spheres of academic and research writing. The use of ChatGPT, perplexity, Elicit, and Connected papers to search and consolidate relevant data was amazing"* Based on this reflection, it is evident that these activities were helpful for student teachers to determine the strengths and weaknesses of each AI appropriately.

**Table 3** *Cycle 2*

| PAR Phase | Activities |
|---|---|
| Planning/Reconnaissance | We improved the plan used in cycle 1 by incorporating the lessons we learned from the reflection phase of the cycle 1. |
| Action/Intervention | Facilitating Engagement and Exploration: We exposed student teachers to more AIs (perplexity™, You.com™, TinyWow™, Elicit™ and Connected Papers™) with free access. We extended the time for student teachers to explore how various AI works<br>*Facilitating Explanation, Engineering, Enriching and evaluation*: The individual with unique observations was given time to present their observations in the course of exploring how various AI works. Student teachers volunteered and led peer learning sessions on AIs such as Gamma. Student teachers formed groups based on their specialization to develop lesson plans. Student teachers presented their lesson plans and received instant feedback from faculty and students. Each student teacher was assigned to develop hypothetical lesson plan for teaching his/her topic of choice. All students submitted their lesson plans in the moodle and presented their lesson plan in the last sessions of the course. Student teachers received feedback from faculty and peers during the presentation of their lesson plans. Individual reflections for each session were posted to Moodle |
| Observation and Reflection | Assessing the intervention: We learned that student teachers have developed interest and confidence to integrate AI in their classroom. We also learned the need to provide opportunities for teachers to experiment their lesson plans in the actual classroom contexts to gain more insights for dealing with diverse contextual needs. |

On the other hand, providing face-to-face and online opportunities for student teachers to share their reflections is useful for the Explaining phase. Data analysis indicates that both face-to-face and online channels allow student teachers to explain their questions, discoveries and answers to questions they developed before. For instance, from the online channel, STUDENT TEACHER XXV explained,

> *In my presentation, I discussed how I integrated ChatGPT into my lesson preparation, coupled with the use of Tome AI—an application also built upon ChatGPT—to generate accompanying slides…. As an educator, the input we provide to these AI systems plays a pivotal role in shaping the outcomes they produce. It's important to recognize that these AI tools are not infallible. Hence, the responsibility rests with the teacher to customize and tailor the materials to best suit the needs of their learners.*

Therefore, this shows how the provision of a reflection channel enhances learning in the Explain phase where student teachers are required to share their discoveries.

Besides, providing micro-teaching sessions and peer learning sessions among student teachers enhances learning among teachers in the Engineering phase. Data analysis indicates that these activities engage student teachers in solving problems through engineering processes such as planning, designing and evaluating. It was observed that students had to go through various stages such as decision-making and evaluation to develop the AI-integrated lesson for the micro-teaching sessions. Similarly, peer teaching requires engaging in various engineering-related aspects before producing the lesson plan for the session. The influence of micro-teaching sessions was evident from student teachers' reflections. As STUDENT TEACHER XXI reflected,

> *One experiencing moment was an assignment where we went off as a group, because of not understanding it clearly. It was a reflecting moment whereby any teacher who wants to integrate technology into his/her teaching, has to ask himself/herself several questions before integration to enhance the teaching and learning practices.*

Therefore, this reflection shows how valuable the micro-teaching exercise challenged student teachers in a way that they needed to make informed judgments about the choice of their AI.

Furthermore, data analysis indicates that developing lesson plans is useful for the Enriching phase. Through this exercise student teachers deepen their understanding of integrating AI in the classroom. The lesson development was enriching to student teachers because it required them to synthesize theoretical knowledge from teaching and technological frameworks. The lesson plans developed showed the coherence between the choice of AI, learning content, pedagogy and expected competence. Also, student teachers' reflections showed that the exercise influenced student teachers to deepen their knowledge. For instance, STUDENT TEACHER II reflected, "*It was found out that pedagogical considerations should be taken into account when using the AIs in education since their wrong use can be detrimental.*" Therefore, it is clear that the development of lesson plans enables student teachers to recognise issues that one should consider to ensure the successful integration of AI in the classroom.

Above all, providing channels for peer feedback is identified as one of the most valuable activities for enhancing learning in the Evaluation phase. Data analysis indicates that peer feedback enabled student teachers to evaluate their lesson plans. During the feedback session, we observed student teachers taking notes and others requesting more clarifications for feedback given by their peers that they can use for improving their lesson plans. Also, this was evident from the reflections, as STUDENT TEACHER XXXII reflected, "*This message [the peer feedback] led to personal reflection, prompting me to utilize AIs more effectively in future teaching scenarios for enhanced learner engagement and ethical use.*" Therefore, this shows that providing student teachers with access to peer feedback enables them to evaluate their approaches to integrating AIs in their classrooms.

### 6.2 The impact of the 6E LbD model on Student teachers to integrate AI in the classrooms

Data analysis indicates that the 6E LbD model facilitates student teachers to develop competence for integrating AI in their classrooms. It was noted that student teachers developed lesson plans that align with theoretical frameworks for integrating AI in the classrooms. Also, some student teachers' reflections showed they have developed the competence to integrate AI in the classrooms. For instance, STUDENT TEACHER IX stated,

> *While AI tools can be useful, there are some potential ethical concerns. AI models can have issues with fairness, bias, and transparency which could impact the information they provide. As with any information source, it is important to verify AI output and exercise good judgment.*

STUDENT TEACHER XVIII also reflected, "*Overall, the use of all these applications must be tailored to the teacher's pedagogical content.*" This shows how competent these student teachers are in integrating AIs into the classrooms. Therefore, one of the impacts of the 6E LbD model is to develop competence for integrating AI in the classroom.

Another impact of the 6E LbD model in supporting student teachers to integrate AI in the classroom was the familiarization with various AI. Data analysis indicates that the use of this model enabled student teachers to be familiar with various AIs. It was observed during preparations for micro-teaching that student teachers used a variety of AIs. Also, this was alluded to in their reflections as STUDENT TEACHER XIX posted,

> *I learned about the AI tools: ChatGPT, Perplexity, Elicit, and Connected papers. What I learned is that every AI has specific functions and that AI tools give answers to the right questions, sometimes AI tools may provide mismatch responses. What we have to do is to monitor the AI tools, for example, ChatGPT.*

This shows that the student teacher is familiar with various AIs and knows how each of them functions.

The development of skills to use AIs among student teachers is another impact of employing the 6E LbD model in supporting student teachers to integrate AI in the classroom. Data analysis indicates that student teachers developed skills on how to interact to optimize its output. Analysis of lesson plans shows that student teachers used AI to achieve different purposes such as creating images and accessing notes and they have a good plan for how to use it to engage learners. Therefore, it is evident that student teachers developed skills to interact with AIs successfully.

In addition, the 6E LbD model impacted student teachers by motivating them to employ AIs in their classrooms. Reflections from student teachers showed that they developed a curiosity to adopt AIs in their working stations. For instance, STUDENT TEACHER XXIII stated,

> *And I reflected deeply about it and found that I had been underutilizing the AIs. I shall use the AIs in future for learner engagement in activities that I would not have done without the AI. For example, in the absence of a resource for teaching and the AI can generate it.*

This shows the determination of the student teacher to integrate AI in his/her workplace as a result of learning through the 6E LbD model.

The development of problem-solving skills such as critical thinking, communication and collaboration is one of the impacts of learning through the 6E LbD model. Data analysis indicates that student teachers developed problem-solving skills as they engaged in various learning activities and applied the information gathering and exploration methods previously acquired to the AI-related topics in the course. It was observed during the presentation that student teachers were able to share feedback constructively. This indicates the development of collaboration and communication skills. Apart from that, data from lesson plans and reflections show that student teachers were making informed decisions on the types of AI to integrate to serve specific purposes. STUDENT TEACHER XXXI stated, "*As I pondered these matters, I realized that the incorporation of AI into education should be guided by a strong ethical framework.*" This shows that student teachers employed critical thinking in determining the solution for integrating AI in the classroom successfully.

## 7 Discussion

The findings show that the modelled activities can enhance learning in various phases of the 6E LbD model among student teachers and that this model provides an effective guideline to the integration of AI into the classroom. This implies the possibility of attracting other teacher educators to use the model, especially those who had been hesitant to use it because of unfamiliarity with the relevant activities to employ in the phases of the model. Based on the theory of CoP, people will always strive to participate in certain activities to maintain a bond with the community they belong to (Wenger, 2008; Farnsworth et al., 2016). Therefore, the modeled activities may act as the catalyst for teacher educators who wish to use the 6E LbD model in supporting student teachers' integrated AI in their classrooms.

However, the modeled activities should be regarded as interactive in a way that one cannot draw the line between them. The interactivity of the phases (Gholam, 2019) might be the main reason for the inseparability of the activities. The interactive nature of the activities makes it possible for one activity to be influential in more than one phase. For instance, allowing student teachers to share their reflections can influence the exploration, explanation and evaluation phases. This is because student teachers are likely to make some exploration from which their reflection will come. In addition, once student teachers share their reflection (Explaining phase) they may get some feedback from colleagues that can help them refine their previous understanding, which brings in the aspects of the Evaluation phase. Therefore, this indicates the extent to which the activities for various phases are inseparable.

The findings on the modeled activities for the phases of the 6E LbD model make the present study slightly similar to the previous studies such as (Lu, 2014; Makri et al.,2014, An, 2022). The learning activities reported in the previous studies such as exploration and discussion (Makri et al., 2014), robotics building and reflections (An et al., 2022), and reflection and designing (Lu, 2014) correspond to learning activities reported in the present study. This similarity may be caused by the fact that both studies come from student teachers' learning contexts that adopted LbD models.

On the other hand, these findings differentiate the present study from the previous ones due to the fact that previous studies involved only models of LbD that are different from the 6E LbD model. For instance, the study conducted by Lu (2014) reported learning activities related to Kolodnen (2003)'s model and the one conducted by

Makri et al. (2014) adopted the Kalantizis and Cope (2012)'s framework. This difference is attributed to the difference in focus of the studies on models of LbD, especially regarding the various dimensions of the student teacher learning process.

Apart from the findings on the modeled activities for phases of the 6E LbD model, this study also shows that the impacts of the 6E LbD model include the development of competence for integrating AI, problem-solving skills and skills for interacting with AI among student teachers. This means that the model is useful for supporting student teachers to integrate AI in the classrooms. This aligns with the consensus among various scholars (Koehler & Mishra, 2005; An et al., 2022; Utterberg Modern, 202) that LbD is the most useful for developing teachers' competence to integrate technology in the classroom. LbD models are useful because they enable teachers to deal with complex teaching contexts (Khaeroningtyas et al., 2016; Lin, 2020; Gholam, 2019). Therefore, teacher educators should consider employing the 6E LbD model to cater to the complexities that student teachers may face in integrating AI in their classrooms.

These findings are similar to those from previous studies (Lee & Perret, 2022; Anabousy & Daher, 2022) in that they all report LbD as helpful in training teachers to integrate technology in the classrooms. However, unlike the previous studies, the present studies focused on the 6E LbD model for supporting teachers to integrate AI in the classrooms. The difference could be attributed to the difference in the focus of the studies. While the previous studies focused on developing teachers' competence in integrating technologies through LbD models, the present studies were confined to the specific model (6E). Therefore, the findings from the present study are similar and different to the previous study in various aspects.

Overall, we argue that the present study aligns with previous studies in the sense that it also shows the significant contribution of LbD models in training teachers to integrate technologies in the classrooms. However, its uniqueness lies in the fact that the study focused on the impact of the 6E LbD model on Artificial Intelligence in Education (AIED), which to our knowledge has not yet thoroughly been addressed in the previous research. In addition, despite 6E LbD being reported in the previous studies, none of the previous studies modeled the learning activities in each phase of the model, especially concerning training teachers to integrate AI in the classrooms. Therefore, the unique contribution of the present study is not only advocating the use LbD model but also showing the specific LbD model (the 6E model) and the potential tools (modeled activities) for using the model in supporting the integration of AI in teaching and learning.

## 8 Conclusions and recommendations

The present study modeled activities for each phase of the 6E LbD model and examined the impact of the model in supporting teachers to integrate AI in the classroom. Sharing real-life narratives, providing reflection opportunities and practising microteaching are some of the modeled activities for the different phases of the model. It has also been observed that the model enables student teachers to develop competence for integrating AI, familiarity with AIs, problem-solving skills and skills to interact with AIs. Based on these findings, teacher educators may use modeled activities as their starting point to adopt the 6E LbD model in supporting their student teachers in integrating AIs in the classrooms. Additionally, these findings are potential evidence for the usefulness of the 6E LbD model in supporting student teachers to integrate AIs in their classrooms. Therefore, we urge teacher educators to employ the model in their training to support student teachers in developing desirable competence for integrating AI in their classrooms. Further, we call for further research on the use of LbD models to support teachers in integrating AI in the classrooms to broaden teacher educators' chances to support student teachers such as based on comparisons to other models, longitudinal studies, or adaptations to other learning and teaching contexts.

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## Declarations

**Conflict of interest** The authors have no competing interests to declare that are relevant to the content of this article.



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