

A Design Study of Problem-Centered Instruction (PCI) for Private Artificial Intelligence (AI) Curriculum Development

Abstract: This design study examines a pilot test that implemented PCI for private AI curriculum in Computer Science (CS) education to identify the strengths and weaknesses of the curricular activities. The results indicated the feedback received from both the instructor and the students was generally positive. However, the study identified several areas of concern that indicate the need for further improvement. The study concludes by presenting the lessons learned and recommendations for enhancing the curriculum.

Introduction

Problem-centered instruction (PCI) is a learner-centered approach that leverages real-world problems to develop problem-solving, communication, and collaboration skills necessary for the 21st-century workforce (Kaufman, 2013). PCI is highly regarded in clinical education disciplines (Abdelkarim et al., 2018; Aslan, 2021; Niwa et al., 2016) and has been extended to manifold educational contexts including CS (Yew & Goh, 2016).

Studies in CS have deployed PCI models in various topics including foundational CS, programming, computer networks, and Artificial Intelligence (AI) (Bosica et al., 2021; Chen et al., 2017; Kwon et al., 2021; Sáez-López et al., 2016). As the use of AI technologies gains prevalence in fields like healthcare, finance, and education, ensuring personal data privacy is crucial, warranting the expansion of pedagogical approaches that expose students to genuine open-ended, real-world AI privacy challenges and problem scenarios. In this regard, PCI has proved to help promoting students' engagement in authentic, rich problem-solving environments (Hmelo-Silver et al., 2015; Kim et al., 2020).

Despite this, there is a dearth of investigations regarding the application and evaluation of PCI in the context of Private AI. To address this gap, we have conducted a private AI curriculum development project funded by National Science Foundation. The current pilot study aims to evaluate the initial design outcomes to further improve the instructional strategies employed. Thus, the following research questions were investigated:

- (1) What are the strengths and weaknesses of the curricular activities implemented in the pilot test?
- (2) What areas require further refinement or development?

Private AI Curriculum Development

Scholars have studied PCI models extensively (Abdelkarim et al., 2018, Jaganathan et al., 2020, Orfan et al., 2021, Sattarov & Arsenijevic, 2021). PCI models were effective in fostering students' knowledge to transfer skills to real situations (Kim, 2015), and promoting learners' involvement, motivation, and interest (Tseng et al., 2008), self-directed learning (Jaganathan et al., 2020), communication (Tseng et al., 2008), and confidence (Dube et al., 2014). However, the literature also revealed PCI's challenges

and limitations including lack of explicit learning goals and resources, unfair student evaluation, and time constraints (Dube et al., 2014; Kim, 2015).

Building upon the literature on PCI (Chauhan, 2017; Chernikova et al., 2020; Chi & Wylie, 2014; Clark et al., 2006; Dostál, 2015; Garrison et al., 2001; Hmelo-Silver & Barrows, 2015; Jonassen, 2011; Kim & Hannafin, 2016; Kim & Kim, 2020; Wittwer, & Renkl, 2010), we have developed a new course consisting of ten modules on private AI. The course includes instructional materials and hands-on labs to educate the next generation of cybersecurity, privacy, and AI professionals. Each module follows the PCI process, including (a) problem-posing, where problems are presented before the learning process begins, (b) instructor-led instruction, where students gain content knowledge through instruction from their teacher, connecting what they have learned to the given problems, (c) exploration and integration, where students build on their initial understanding of the problems and conduct experiments to assess the applicability of ideas and analyze the outcomes, and (d) articulation and resolution, where students implement the proposed solution and reflect on their problem-solving process and the knowledge acquired.

Pilot Test

We conducted a 2-hour workshop on Private AI, using a downscaled module focused on Differential Privacy and TensorFlow. The workshop began with an introduction to the problem, followed by lectures and pairwise collaboration on a hands-on lab designed to explore and manipulate solutions to the problem. We concluded with a debriefing session to discuss problem-solving strategies. A total of 25 students participated in the pilot test, including 68% male and 32% female students from both graduate (60%) and undergraduate (40%) levels. The instructor was a graduate teaching assistant with four years of experience teaching Private AI. We collected data using a 22-item survey that assessed the quality of the curricular activities (content and lecture, problem scenario, hands-on lab, collaboration value, and evaluation) on a Likert scale ranging from 1 to 5. We also conducted in-class debriefings with the students and semi-structured interviews with both the students and the instructor. To analyze the qualitative data collected, we used a dual deductive/inductive thematic analysis model (Bingham & Witkowsky, 2022).

Results and Discussion

Based on the survey results, it was found that the participants had highly positive perceptions of the quality of the curricular activities. The mean scores ranged from 4.62 for the relevance and quality of the problem scenario to 4.47 for the overall module evaluation, which included module organization and content balance, ranked in order of highest to lowest.

Thematic analysis was used to categorize the results into four themes: knowledge and application aspects (17%), learning-related aspects (44%), instructor-related aspects (22%), and instructional and implementation challenges (17%). For example, the learning-related aspect with the highest occurrence indicated that the PCI design encouraged learners' participation, motivation, and interest, communication and interaction skills, and self-directed learning, ranked in order of highest to lowest. Additionally, some students reported that the lesson was supportive of their learning

styles, saying *"I'm a person that has more of a tactile learning style. So, I'm actually doing the task while learning, it helps me learn it better"*.

The instances of instructional and implementation challenges revealed the need for advanced planning, managing overwhelming content, time constraints, and a more user-friendly technology environment. The participants needed more explicit instruction on the module expectations and objectives, as well as the PCI-based activities in advance. They also sought more accessible resources for the hands-on labs. Time constraints hindered students from keeping up with the content, which was supported by the instructor's comment emphasizing the importance of allocating enough time to optimize comprehension.

Finally, the findings suggest that teaching presence played a significant role in facilitating smooth and effective implementation of the hands-on lab to cater to diverse learning needs.

In conclusion, this study suggests that while the participants had positive attitudes towards the quality of the curricular activities, there were still areas that could be improved upon for future courses.