In-Service STEM Teachers' AI Conceptual Change through Hardware-based Edge AI Activities (Fundamentals)

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Abstract

Enhancing access to educational and computational resources is critical to fostering innovations in Artificial Intelligence (AI). However, teachers' misconceptions and limited access to hardware resources, especially in rural or under-resourced areas, often impede effective AI education. Common misconceptions include viewing AI solely as ChatGPT, assuming AI requires cloud computing, believing AI devices are prohibitively expensive, overestimating financial motivations of AI engineers, and perceiving AI as inherently unethical due to potential job loss. Addressing these barriers benefits from hands-on engagement with AI in ways that are accessible, low-cost, and pedagogically meaningful.

To address common teacher misconceptions about AI, this qualitative study investigates how hands-on activities with low-cost, hardware-based Edge AI boards can support conceptual change in K-12 STEM teachers. Grounded in conceptual change theory and postphenomenology, the research analyzes the experiences of nineteen in-service teachers during a six-hour professional development workshop, with a specific focus on seven selected participants. During the process in which teachers interact with an Edge AI learning board with an ESP32 microcontroller, breadboard, a battery, five sensors, and an OLED monitor, data was collected through pre-surveys to identify their initial conception about AI, researcher observations, and the teachers' curriculum implementation plans. Hands-on activities included comparing both non-AI and AI-integrated learning board using Arduino Integrated Development Environment (IDE) and Edge Impulse. Teachers reviewed the AI workflows including data collection, model training, and on-device inference, connecting embedded microelectronics to AI decision-making.
The findings indicate that direct interaction with the hardware engaged teachers in cycles of alterity, seeing the technology as a quasi-other, and hermeneutic relations.

The analysis of their implementation plans revealed clear evidence of multistability, where teachers adapted the single Edge AI board for diverse and context-specific purposes within their own teaching subjects. This may indicate a shift from their initial, narrower conceptions of AI to a broader, more applied understanding in terms of AI's role. The study suggests that experiential, hardware-based professional development may deepen teachers' conceptual understanding and support meaningful classroom integration of AI.

Introduction

Enhancing access to educational and computational resources is critical to fostering innovations in Artificial Intelligence (AI). However, teachers' misconceptions and limited access to hardware resources, especially in rural or under-resourced areas, often impede effective AI education. Common misconceptions include viewing AI solely as ChatGPT, assuming AI requires cloud computing, believing AI devices are prohibitively expensive, overestimating financial motivations of AI engineers, and perceiving AI as inherently unethical due to potential job loss [1],[2],[3]. Addressing these barriers benefits from hands-on engagement with AI in ways that are accessible, low-cost, and pedagogically meaningful [4].

Leveraging conceptual change theory [4] and postphenomenology [5], this study investigates how hardware-based, hands-on Edge AI activities support conceptual change in K–12 STEM teachers' understanding of AI. Specifically, the focus of this research was on the process in which teachers interact with an Edge AI learning board with an ESP32 microcontroller, breadboard, a battery, five sensors, and an OLED monitor. That interaction is expected to shape their own understanding and perspectives about AI by allowing the tool to be used as a tool for thinking.

Nineteen in-service high school STEM teachers participated in a six-hour professional development workshop, engaging in hands-on activities comparing both non-AI and AI-integrated learning board along with Arduino™ IDE (Integrated Development Environment) and Edge Impulse™. Teachers reviewed the AI workflows including data collection, model training, and on-device inference, connecting embedded microelectronics to AI decision-making.
This study specifically focused on seven teachers among them, who represented low, mid, and high conception groups. Before their workshop involvement, an AI conceptions survey was administered to all nineteen participants to document their initial understandings of AI and to provide contextual information about the participant group. Survey responses were analyzed and used to inform purposeful selection of focal participants for in-depth qualitative analysis [6]. This survey results also served descriptive analysis of their early conceptions.

This study employed a qualitative, theory-driven analytic approach grounded in conceptual change theory and postphenomenology. The evidence was collected through researchers' observation to capture their learning process vividly during the workshop. The findings in the observation highlighted the role of the board for hermeneutic medication and alterity. Additionally, the teachers' implementation plan for their classroom teaching shows the multi-stability, and technology mediation that involves teachers' perceptions and experiences in response to direct interaction with the board.

Keywords: AI conception, Conceptual Change, In-service Teachers, Professional Development, Postphenomenology

Purpose of Study

Leveraging conceptual change theory and postphenomenology, the research aims to provide a qualitative explanation of how teachers' interactions with the hardware-based Edge AI boards mediate their understanding.

The study did not intend to provide whether the professional development workshop was effective or not, rather to offer a descriptive account of the teachers' experiences. Specifically, the study analyzes the human-technology relations that emerge during the teachers' professional development workshop and how these relations contribute to a shift in the teachers' conception about AI.

Theoretical Background

Conceptual Change

Conception is defined as the collection of beliefs an individual associates with one concept, content or context [7]. For example, one conception around the concept, penguins, may include that all penguins are friendly to humans. Conceptual change theories suggest that prior conceptions, whether accurate or not, fundamentally shape how new information is interpreted [4]. While there are multiple definitions and viewpoints around the definitions of conceptions and conceptual change process, conceptual change means the process of altering these foundational beliefs.

Early theories viewed conceptual change as a rational, cognitive paradigm shift. In this model, a person replaces a misconception when they become unsatisfactory with it and are presented with a new idea that is intelligible and plausible. However, later perspectives argued that purely cognitive "cold" models were insufficient. They highlighted the importance of warm, affective, or motivational factors, such as a student's interests and motivations in driving conceptual change.

More recent literature characterizes conceptual change as a slow, gradual, and domain-specific restructuring process [8]. Rather than quick replacement, learners restructure their naïve conceptions over time. Their conceptions may be internally coherent but incorrect frameworks, and this can lead to a difficult shift in ontological beliefs. To sum up, conceptual change is now understood as a complex process involving both cognitive and affective elements, which can be influenced and guided by instructional strategies.

Based on this collective knowledge about conceptual change, the professional development program was designed to foster teachers' AI conception by engaging them with Edge AI-based microelectronics boards. Studies around AI conceptions have identified several common myths and misunderstandings, even among STEM teachers [3]. These often stem from media portrayals, social biases, and vague definitions of intelligence, such as anthropomorphism, oversimplification, or narrow scope [1]. Specifically, people see AI systems having human-like characteristics, feelings, memory, or consciousness. They sometimes overestimate the capabilities of a single tool like ChatGPT. Many people also have a narrow scope in their understanding, viewing AI only through the lens of specific applications like robotics or Generative AI. Additionally, many hold vague existential fears about AI, particularly concerning immediate and widespread job loss.

Postphenomenology

Humans' relationship with technologies have been evaluated by different philosophical perspectives. Ihde [9] was one of the philosopher. Ihde contrasted Heidegger's philosophy on technologies to define the elements of the technology relations for being intensely romanticism and assigning the "good" or "bad" roles to technology [pp. 107-109] Ihde introduced the concept of embodiment relations to establish the humanistic approach related to technology where the experience of seeing the world through technology creates a transformation in perceptions and in the senses. This concept is expressed as "(I - technology) - world".

Continuing the relations, the hermeneutic concept addresses the interpretation that connects the perception with the world around. That connector represents the tension in the relationship between technology and the world, expressed as "I - (technology-world)". In this process of translations and retranslations, perception transforms phenomena into transmissions that can be re-translated into our perceptual gestalts. Embodiment relations differ from hermeneutics as the first refers more to the senses impacted by the connection of human-technology, while hermeneutics span the whole spectrum.

The third relation, alterity, is related positively and with fascination to a specific technology, such as a child playing with a toy. In this relation, technical characteristics become relevant, and the fusion of physical and material properties is crucial, as well as the personalization of the artifacts. The interaction with the phenomenon and the creation of varied patterns is key in this relation, where the quasi-otherness positively relates to technologies; thus, the interaction occurs with the technology as quasi-other, determined as "I - technology -(-world)" where the relationship to the world may remain as context and background.

The fourth relation, background, compiles the technology used in the environment. Some can affect the positioning of the "enigma" during interaction; others may remain irrelevant yet present. In sum, the general structure for these intentional relations is: Human-technology-world with different emphasis on the interaction held between humans and technology in a specific context, given the wide variety of technologies.

Even if Ihde were against a unified theory of technology, claiming that its role varies depending on cultural contexts, A key implication is that technology actively shapes human experience. A strategy to analyze this technology-culture connection is called multistability. Within the phenomenology perspective, this multistability can range from the microperception focusing on sensory to a macroperception driven by the culture [9].

In this era of AI and digital technology, educational researchers have suggested the need to explore how the relations between human and world are enacted through technologies [10] so that we can analyze the diverse relations between learners, technology including AI, and the class/school. From this viewpoint, Wellner and Levin [11] sought to bridge Ihde's postphenomenology and constructivists' ideas in their paper, where some educational concepts are correlated with postphenomenological concepts. Specifically, they saw embodiment relations as personalization of the learning environment, hermeneutic relations as computational thinking, alterity relations as microworld, and background relations as democratization.

This study integrates postphenomenology and conceptual change theory to form a conceptual framework for exploring teachers' relationships with Edge AI-based boards. Presented in Figure 1, this framework guides our analysis of participating STEM teachers' experiences during a professional development program on AI and microelectronics.

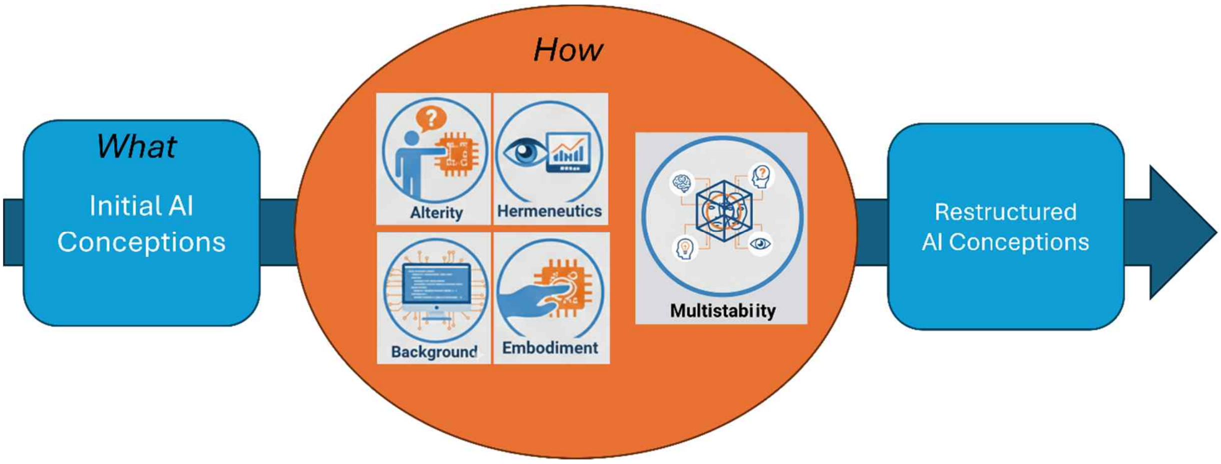

Figure 1. Conceptual framework of this study

Context

This research is situated within a hands-on professional development workshop designed for high school STEM educators, focusing on the integration of AI and microelectronics into classroom practice. As part of an NSF-funded project, the program aims to enhance teachers' expertise and provide instructional scaffolding through ready-to-use lesson plans that bridge AI technologies with K–12 education, with a particular emphasis on high school contexts.

Participating teachers were recruited through online advertisements as well as through the internal network of a large institution's center for precollegiate education and training. All participants were in-service high school teachers in the southeastern United States. They teach STEM subjects including computer science, engineering and robotics, physics, and environmental science. The professional development workshop consisted of a six-hour, one-day session held in September 2025. The workshop featured hands-on activities in which participants built both non-AI and AI-integrated IoT devices using a microelectronics-based platform (the AHA board; see Figure 2), leveraging Arduino™ and Edge Impulse™.

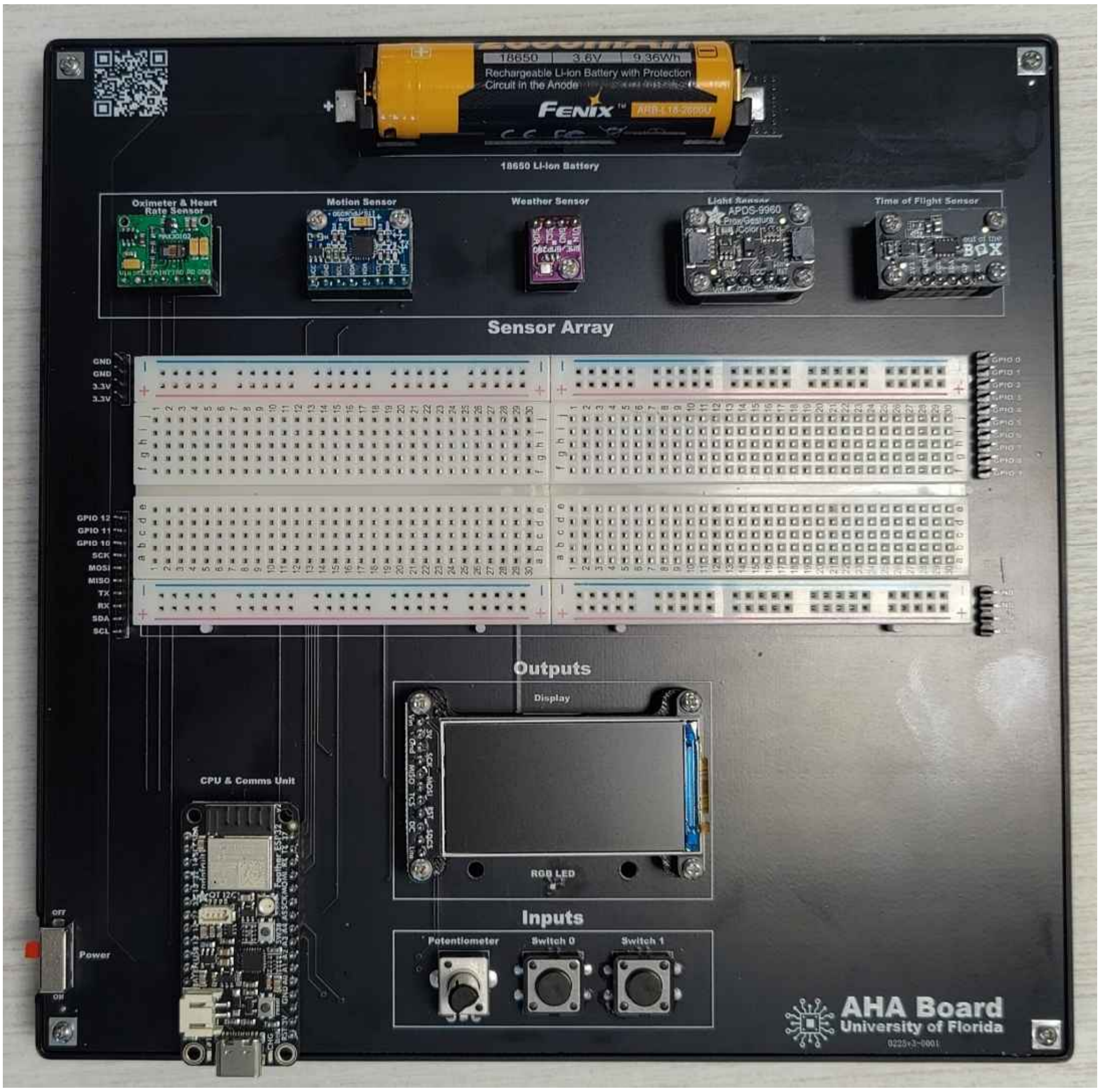

Figure 2. AHA board

In terms of technological perspective, engaging with the AHA board involved two interrelated components: hardware (the AHA board) and software (Arduino™ IDE and Edge Impulse™). While it is not intense, deploying preconfigured files to the board requires a basic understanding of computer software. In addition, although the board's subcomponents are physically integrated, effective use of the system requires foundational knowledge of computer hardware concepts, including input, processing, storage, and output.

Professional Development Workshop Overview

The professional development workshop provides a structured, six-hour one day participation in September 2025. It was designed to move educators from foundational theory to practical classroom integration. The session structure is organized as introduction to the project, introduction to the core conceptions, technical integration and exploration, and implementation plan as outlined in the Table 1.

Table 1. Overview of professional development workshop

Sessions	Topic
Session A: Intro to Embedded Systems and AIoT	Key Concepts Activity 1: AHA board exploration
Session B: AI Integration	Activity 2: Fruit Ripeness Activity 3: Water leak detection
Session C: AHA Board Exploration	Activity 4: Sensor Stations
Session D: Project Ideas	Activity 5: Implementation Planning

Session A introduced key concepts related to embedded systems, IoT (Internet of Things), AIoT (AI and Internet of Things), and Edge AI. Teachers then engaged in Activity 1, exploring various sensors in AHA board to grasp both the hardware (the AHA board) and the software tools used in this context (Arduino™ IDE and Edge Impulse™).

Session B focused on technical integration and more hands-on exploration. Activities 2 and 3 were designed to support the application of AI concepts through the use of a light sensor for fruit ripeness detection and water leak detection, using Arduino™ software and the web-based Edge Impulse™ platform.

In Session C, teachers were encouraged to explore additional sensor applications using the AHA board. They compared non-AI and AI-integrated versions of each sensor activity to deepen their understanding of how AI alters data interpretation and system behavior.

In the final session of project ideas, teachers shifted from exploration to design, focusing on developing context-specific curriculum implementation plans for their own classrooms.

The focus of this research was on the process in which teachers interact with an Edge AI learning board with an ESP32 microcontroller with different components such as a breadboard, a battery, five different types of sensors (time of flight, oximeter/heart rate, weather, light sensor, and motion), and an OLED monitor. That interaction is expected to shape their own understanding and perspectives about AI.

Research Design

This qualitative study employed an interpretive case study approach [12], theoretically grounded in conceptual change theory and postphenomenology. To meet the methodological rigor of triangulation, this study collected three different data sources: survey, observation, and document analysis.

First, a pre-survey about AI conceptions was administered through Qualtrics form. While we asked all nineteen participants to provide the survey, contextual insight into teachers' prior understandings and shifts in conceptions of AI. This survey's results were not intended to provide statistical generalization. Instead, the survey served as a tool for purposeful sampling [6] and for understanding the teachers' initial conception about AI. The survey includes twenty items identifying the belief on certain statements, such as "AI is a technology like ChatGPT." "AI is dangerous." "AI can function independently of humans," and so on. The respondents will mark their belief in the statements from "strongly agree" to "strongly disagree". fifteen out of nineteen teachers completed the survey, and the results were divided into three groups: low, med, and high (Min: 59 – Max: 86). Based on the survey data, seven teachers were selected based on the participants' total scores. The selected seven teachers whose responses reflected each group: high, mid, or low in terms of AI conception. This selection was for more focused qualitative analysis of observational data and artifacts to capture a wide range of perspectives. Their demographic information is illustrated in Table 2. The survey was not used to measure outcomes or changes over time but rather to support participant profiling and analytic focus. This approach allowed the researchers to examine in greater depth how human–technology relations unfolded for participants who exhibited meaningful conceptual change.

Table 2. Selected participants

ID	Total Score (out of 100)	Score Category	Teaching Subject
T2	77	High	Chemistry/Environmental Science/Physics
T4	79	High	Environmental Science/Physics
T6	83	High	STEM
T11	75	Mid	Environmental Science
T5	67	Low	Computer Science
T8	53	Low	Biology, Environmental Science
T13	70	Low	Computer Science

Second, two researchers observed the seven selected participants during the workshop to capture their experience of the human-technology interaction process based on the deductive coding framework (Table 3) related to postphenomenology. Specifically, two main researchers – trained graduate students for qualitative research - wrote the observation notes separately based on the coding framework. They later discussed whether their observation meaningfully supports the concepts around postphenomenology.

Third, the selected teachers' implementation plans served as artifacts revealing how teachers synthesized the experience and how they planned to mediate their own students' learning, which later represents the multistability of technology.

Table 3. Deductive coding framework

Relationship with Technology		Definition (Adapted from [13])
Embodiment relations	(I – technology) → world	Users treat technology as though it was a part of their body.

Hermeneutic relations	I → (technology – world)	A situation wherein a kind of reading or interpreting a sign is at stake. For example, an x-ray photo of an internal organ is a representation of the respective organ. For humans to make sense of the condition of the internal organ the photo has to be read first by a physician. The diagram of such a relationship may be sketched as this.
Alterity relations	I → technology (– world)	Taking technology as a quasi-human existence. A vending machine, for instance, is treated as if it was an intentional agent, that is, it is being directly communicated.
Background relations	I (– technology – world)	A background relationship is meant to refer to kinds of technologies which do not engage the user's attention, rather in the background they are just preparing the stage. An air conditioner, for instance, is a technology to provide a pleasure environment for human beings, but it does the task in silence. That is, here users are not directly in contact with the technology.

In sum, these sources together provide a holistic narrative of the teachers' journey from their initial understanding, through their direct interaction with the technology, to their intended application of that experience in their professional context.

Data Analysis

The analysis on AI Conception surveys was conducted through Goolge Colab using python language, generating a heatmap or ranking groups. For the observation note, the two main researchers combined their observations in the Google Spreadsheet according to the coding framework in Table 1. The four categories of the relationship with the technology from postphenomenology guided the data analysis. After collecting the data, the researchers discussed each observation point to analyze the results and see if each observation represents the notion of relations. The multistability analysis was mostly done with the implementation plans written by the teachers. This was based on the definition of postphenomenology, where technology has 'multistability' rather than 'stability' [9] Technologies offer different characters, different meanings, in different usages. In other words, they never reduce to a single nature considering their world. Two researchers uploaded the implementation plans on the internally shared file repository where the annotation is available. Two researchers separately commented on the implementation where the multistability is noticed. Then the researchers discussed each observation point to analyze the results and see if each observation represents the notion of multisabtility.

Results and Discussion

The following part illustrates the key findings observed and discussed the interpretation of the findings.

Background to Alterity and Beyond

Session A was designed to draw the teachers' attention to the background technology, such as wifi and hardware in AI. In the workshop setting, shifting that technology from background relations to alterity were constantly at play, shaping the teachers' experience with requiring their direct attention.

The session required the teachers differentiate the keywords such as Internet of Things (IoT), AIoT, and Edge AI, where they have to questions the necessity of high-bandwidth Wi-Fi, and the role of hardware in operating AI-models. They also need to define general computers and embedded systems focusing on one specific tasks so they can realize the role of computers used in the real-world.

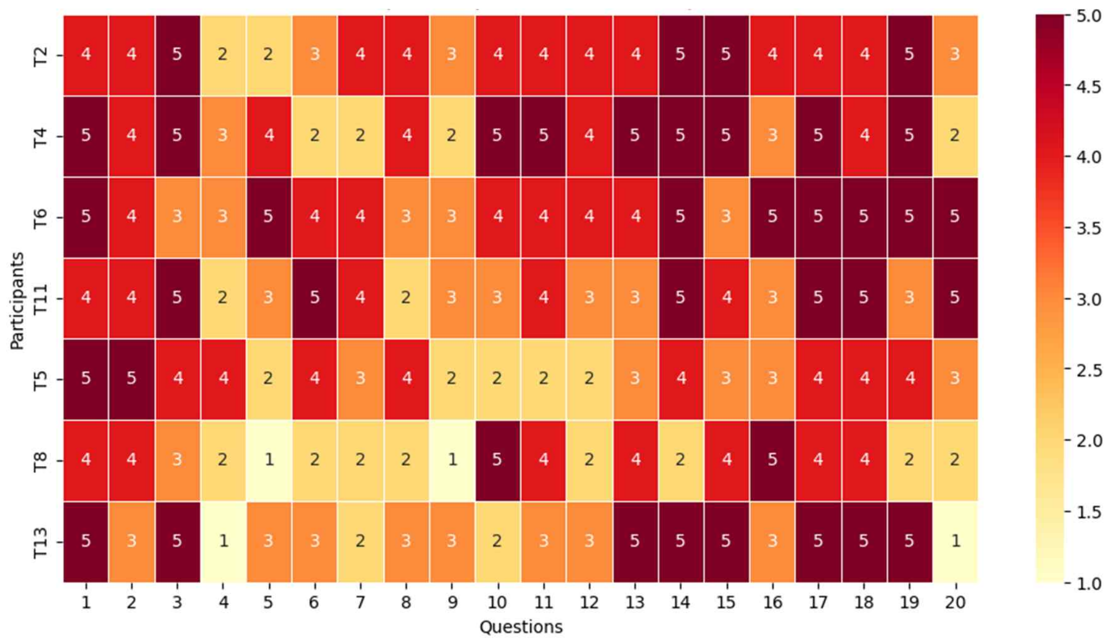

Figure 2. AI conception map for the selected teachers

The lack of awareness around the key words were evident in their AI conception survey (Figure 2). For example, T5 and T8 agreed with "12. AI is expensive." The session's exploration of different hardware types, such as general computers vs. specialized embedded systems, directly relates to the cost of implementing AI solutions. While most of the teachers agree that "13. AI can function without an Internet connection." the session's focus on differentiating Edge AI which operates locally on hardware from cloud-based AI and questioning when and where the high-bandwidth Wi-Fi is necessary, is precisely what this question assesses. A teacher who understood the session would be able to answer this question with the knowledge that not all AI requires constant connectivity.

Beyond the institutional infrastructure, teachers also carried with them personal technologies that extended background relations into everyday life. Smart devices such as laptops, watches, and even the embedded technologies in their cars formed part of the technological horizon that co-shaped their workshop experience. In postphenomenological terms, these background relations came to alterity relations when the technologies have to play in the curriculum implementation in terms of Edge AI.

This understanding was noted in their implementation plan. T13 in his computer science classroom implementation, the teacher wanted the students to provide “justification for Edge AI” in the formative assessment, where the teacher cited speed/latency, privacy, or reliability/internet connection as the benefits of using Edge AI.

T5 also moved from a general view of expensive AI to understanding embedded systems as specialized, cost-effective computers designed for one specific task. In T5’s implementation plan, the learning objective was clearly mentioning that students should identify the "differences between embedded systems with and without AI," showing an understanding that AI can be a specialized feature added to low-cost hardware rather than cloud-based massive computers.

Alterity During Deployment

Most of the teachers faced alterity relations when they were introduced to the deploying stage of AHA board in Session B. The first hurdle was understanding the basic libraries that should be installed in the computer along with the hardware. In Session A of AHA board exploration stage, the teachers were required to flash the board with Non-AI version file for the light sensor in AHA board. For connecting the software part from Arduino™ IDE with the hardware board, the teachers were required to install driver software as well as the relevant libraries. Most teachers were able to successfully open the ready-made ino. file but downloading the driver for the ESP 32 microcontroller required the next hurdle in that some teachers had to face the technical restrictions in their computers. It was especially evident with T8, who has the lowest AI conceptions. T8 drew the attention of other teachers asking for help and realized that the computer set the limit in downloading new software. None of this process requires coding from the teachers, but the Arduino™ itself took all attention from T8.

During the similar phase, however, the computer science teachers showed their skillful reaction in navigating this alterity relation. While they were introduced to the AHA board for the first time on that day, their familiarity with computers and coding allowed the computer science teachers to treat the board. When a coding library produced an error, T13, one of the computer science teachers carefully examined the boards and checked if there was anything wrong with the hardware boards. Confirming that the board was working properly, T13 analyzed the problem in the software fixing the mismatch in the name of the file. This teacher later consulted the other teachers to fix the problem. While T13 was one of the lower AI conception groups, the teacher’s background relation with the software technology allowed entering a sophisticated dialogue with the technology, knowing what questions to ask of it, how to test its components, and how to distinguish between its hardware and software. This shows how technology became part of their perceptual and cognitive field. Considering that flashing (i.e. deploying) the boards and installing the necessary software were preparatory steps, the teachers' familiarity with software enabled the alterity of relations with the hardware part of AHA boards.

These two examples clearly showed us that technological knowledge, especially about the software-related competency, provided the teachers to overcome the hurdle during the moment of alterity relations with physical technology.

Facilitating Hermeneutic Relations with AHA! boards

This hermeneutic relation was revealed throughout Session B and Session C, when the teachers explored the sensors, especially with heart rate/oximeter sensors, time-of-flight sensors, and motion detectors. In this session, teachers were encouraged to explore various uses of sensors in AHA board, where they were able to compare the non-AI version and AI version of each sensor's use designed to provide deeper understanding with the specific hardware kits. Within the workshop design, two distinct settings facilitated these hermeneutic relations during the sessions. First, when microcontrollers operated *without* AI, the sensors – such as weather, time-of-flight, and light detectors – provided raw data that teachers interpreted directly as readings of the world. In this case, the technology served as a transparent mediator, allowing the physical environment to be read through its signals. Second, with Edge AI, the data was re-interpreted and shaped by the configurations set by researchers and teachers. Here, technology did not simply present the world but actively transformed its significance by adding another value. The use of items like RGB color cards, fruit ripeness indicators, and water leak detection strips further reinforced environmental impulses, helping the teachers understand how technologies mediate interpretation between human perception to coded signals.

When working with the boards for fruit ripeness detection in Session B, teachers were asked to see Arduino™'s serial monitor on the computer along with the OLED monitor of AHA board. They read the ambient light along with the constantly changing the values from the three channels – red, blue, and green. And when the teachers noticed the low accuracy in detecting the color like brown, teachers including T8 and T5 constantly wrote down interpreting the meaning of the rather inaccurate value. Especially, T5 and T6 were seated in a pair and actively discussed the readings in OLED monitors. They questioned why the reading's accuracy is so low, and how to make the accuracy better. This shows a sophisticated level of hermeneutic engagement.

When working with sensors other than the light sensor in Session C, the teachers' interactions with the AHA board primarily revealed hermeneutic relations. For instance, the heart rate sensor required participants to cover it with their fingers, which would then classify their body status as 'excited,' 'resting,' or 'active.' The teachers performed physical exercises and discovered how the boards mediated bodily signals and other biological cues not visible to the naked eye.

When interpreting the raw distance values from the Time-of-Flight sensor, teachers T2 and T4, who had a more advanced understanding of AI, applied their background knowledge. They realized the sensor uses light reflection and demonstrated a clear understanding of its underlying principles by explaining it to the other teachers. They then expanded this thought into how to divide up the classification.

When some teachers explored the AI-integrated motion sensor, they were puzzled, While the non-AI version only detected basic movement, the AI version provided more detailed classifications. The teachers were introduced to this basic difference, but they did not know how to affect the readings on its OLED monitor. When T2 picked up and shook the board, the reading changed, classifying the movement into value-added interpretations such as 'snake,' 'up-down,' or 'stationary.' In that moment, T2 noticed and said, “This board uses a gyroscope and accelerometer to detect these motions, right?”

In this case, while the initial confusion with the sensors demonstrates an alterity relation, it then transitions to a hermeneutic relation after the teachers understand the principle behind each sensor and its display.
During the session, the workshop became a site where technology reshaped human-technology relations: the boards were not passive instruments but active mediators that allowed teachers to perceive and interpret both their bodies and surroundings in new ways.

Multistability: Steps to Curriculum Implementation

Analysis of the teachers' final implementation plans reveals clear evidence of multistability, where the same Edge AI board was framed for different purposes depending on the teacher's specific subject and goals. This demonstrates a significant conceptual shift from their initial, narrower views of AI.

Initially, teachers’ misconception about AI were explicitly noted (Figure 2). The selected teachers, either with high or low AI conception, agreed with the statement like “AI is a technology like ChatGPT.” or they disagreed with “AI obeys humans”. This indicates that the teachers clearly had a narrow conception about AI perceiving Generative AI as the typical type of AI tool. In contrast, their post-workshop implementation plans showed a much broader and more applied understanding. Teachers consistently adapted the Edge AI technology to fit the unique contexts of their own disciplines. For example, T2 who teaches Physics planned a lesson where students would "detect” fruit ripeness using AI algorithms, demonstrating an understanding of AI as a tool for sensor-based classification, a concept beyond generative AI. Similar subject-specific applications were found in most of the teachers' plans.

While they all showed the agreed acknowledgement on the role of Edge AI technology both in their classroom and in the world, their implementation plan showed more direct examples of multistability. T8, teaching biology and environmental science, explicates in the content standard that “To define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science” For T2 who had a more nuanced AI conception than the others in the initial stage, Edge AI technology became a tool for deeper conceptual analysis, enabling students to “*Analyze* the motion of an object in terms of its position, velocity, and acceleration as a function of time.” In this latter case, T2 envisioned technology not only as an object of study itself, but also as a medium for achieving higher-order thinking in physics. This sophisticated pedagogical goal in their implementation plan shows their development of conception where the technology mediates a deeper engagement with their teaching subject.

Implications

Drawing on postphenomenology and the conceptual framework, this study aimed to illuminate how in-service teachers experienced Edge AI–based microcontroller boards as they developed their understanding of AI and microelectronics. The findings may suggest that workshops grounded in hands-on interaction with Edge AI technology actively engaged teachers in cycles of alterity and hermeneutic relations, enabling them to critically attend to the technology and reflect on how it shaped their understanding within their subject contexts. Through this process, teachers might have recognized AI as an embedded, real-world technology as indicated in their implementation plan. This experiential engagement with hardware and sensors may have deepened their conceptual understanding and increased their confidence in applying AI meaningfully across diverse disciplines. These results suggest that experiential, hardware-based AI professional development can more effectively support classroom integration than abstract or tool-focused approaches alone.

Doroudi's [14] notion of the "microworld" provides a useful lens for interpreting these findings. The AHA board functioned as a bounded exploratory environment in which teachers could experiment, reflect, and construct new meanings about AI through embodied interaction. Rather than simply transmitting knowledge, the workshop's hands-on environment supported teachers in transforming their experiences into pedagogically relevant understanding that could be transferred into their own classrooms and subject areas.

Furthermore, the findings indicate that moments of alterity, when the technology resisted smooth use or demanded attention, served as productive disruptions that pushed teachers to extend their understanding beyond isolated components such as sensors or software platforms (e.g., Arduino™, Edge Impulse™). Engaging with Edge AI-focused boards requires teachers to integrate knowledge of both hardware and software, reshaping how they conceptualized AI systems. In this way, technology functioned not merely as a neutral tool but as an active mediator shaping teachers' curricular thinking, task design, and evolving conceptions of AI and microcontroller-based learning.

Limitations and Future Steps

This guided workshop was designed to support teachers in exploring concepts, integrating them with practice, and experimenting with microcontroller devices and sensors, with the broader aim of envisioning the implementation of AHA microcontrollers in K-12 classrooms. However, several limitations emerged.

First, when it comes to the workshop structure, we offered only six-hour one day workshop for this experience. This time constraints prevented teachers from fully exploring the technology and thus inhibiting the breadth of information shared proved overwhelming for some teachers.

Additionally, different background knowledge from teachers allowed them uneven engagement limiting the depth of exploration and the consistency of experience across participants, highlighting the challenges of balancing breadth and depth within a constrained workshop format.

For the future steps, longer-term and scaffolded professional development is needed to allow teachers more time to build confidence with both the conceptual and technical aspects of Edge AI and hardware-based learning. Future workshops should be differentiated according to teachers' prior technological experience to better support equitable engagement. Ongoing support structures, such as follow-up sessions, classroom implementation coaching, and collaborative teacher communities, could further strengthen meaningful integration of AI into diverse subject areas. Additionally, future research should examine how teachers' evolving understandings translate into actual classroom practice and student learning outcomes.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 2142473. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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