Fostering Youth's Critical Thinking Competency About AI through Exhibition

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Figure 1: AI-related exhibition <AI with Weird Wonderland> poster and exhibition experience of the youth.

ABSTRACT

Today's youth lives in a world deeply intertwined with AI, which has become an integral part of everyday life. For this reason, it is important for youth to critically think about and examine AI to become responsible users in the future. Although recent attempts have educated youth on AI with focus on delivering critical perspectives within a structured curriculum, opportunities to develop critical thinking competencies that can be reflected in their lives must be provided. With this background, we designed an informal learning experience through an AI-related exhibition to cultivate critical thinking competency. To explore changes before and after the exhibition, 23 participants were invited to experience the exhibition. We found that the exhibition can support the youth in relating AI to their lives through critical thinking processes. Our findings suggest implications for designing learning experiences to foster critical thinking competency for better coexistence with AI.

CCS CONCEPTS

• **Applied computing** → **Interactive learning environments**; • **Social and professional topics** → **Informal education**; • **Human-centered computing** → *User studies.*

KEYWORDS

AI education, Informal learning, AI-related exhibition, Critical thinking, Youth learning

ACM Reference Format:
Sunok Lee, Dasom Choi, Minha Lee, Jonghak Choi, and Sangsu Lee. 2023. Fostering Youth's Critical Thinking Competency About AI through Exhibition. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23), April 23–28, 2023, Hamburg, Germany.* ACM, New York, NY, USA, 22 pages. https://doi.org/10.1145/3544548.3581159

CHI '23, April 23–28, 2023, Hamburg, Germany

ACM ISBN 978-1-4503-9421-5/23/04…$15.00
https://doi.org/10.1145/3544548.3581159

1 INTRODUCTION

With the rapid development of artificial intelligence (AI)-related technologies, today's youth has been naturally exposed to AI technology from an early age and encounter various forms of AI-embedded devices and services. Youth is characterized by the age range of 15–24; that is, in the transitional stage from childhood to adulthood [83]. While AI can provide youth with entertainment and educational opportunities, it can also have potentially negative impacts [2, 3, 69]. For instance, TikTok provides educational content to youth through the in-app tool "The Youth Portal" [102]. However, owing to its feature of endless streams and lack of restrictions, addiction and ethical concerns coexist [88]. Specifically, youth consume AI-generated recommended content indiscriminately, thus leading to a narrowed perspective; further, they unconditionally prefer personalized AI, thus allowing AI to access all their personal data without considering the importance of privacy.

Accordingly, human-computer interaction (HCI) researchers have emphasized that youth needs to cultivate AI literacy competencies that allow individuals to evaluate AI technology and utilize AI as an online tool [25, 26, 61, 76, 82, 103]. Among various AI literacy competencies, it is important to educate youth on critical thinking competency, which is defined as critically examining AI to communicate and collaborate effectively with AI [3, 37, 68]. As youth can combine and classify items in a more sophisticated manner and for higher-order reasoning [39], the youth age group is considered for effective learning of critical thinking competency among younger age groups. Moreover, when youth enter the workforce, they will have to build a closer relationship with AI as a collaborator, and decide the direction of their effective collaboration with AI by themselves.

In this regard, recent studies, which are still in the early stages, have attempted to provide critical perspectives through AI education [3, 37, 67, 91]. These attempts have focused on delivering AI-related ethical knowledge through a structured classroom curriculum. In particular, by developing AI ethics curricula or applying AI ethics subjects to existing computer science classes, these studies have attempted to instill a critical perspective in youth [14, 24, 40, 68, 90]. Although these attempts have imparted knowledge regarding existing AI issues within the boundaries of the curriculum, whether they support the youth's individual development of critical thinking competency is not guaranteed. Although class-based formal education aims to effectively deliver consistent and structured content to several students simultaneously, there is a limit to developing critical thinking competency for individuals; because each individual possesses different ways of thinking. Therefore, attempts to overcome these limitations are necessary.

Informal education in museums or exhibitions, which is distinct from formal learning in classrooms, is regarded as an important context for AI literacy education because it has the potential to impart critical thinking competency [74, 81, 92]. Several exhibitions have delivered critical perspectives on technology to audience. Although exhibitions have long served as an intrinsic motivation for critical thinking and have pushed learners to reflect on their lives [7, 17, 35, 45, 113], previous attempts have focused on delivering the creator's critical perspectives, with slight regard for the educational aspect. However, for better coexistence with AI, in addition to delivering critical messages regarding AI, it is necessary to provide opportunities for youth to develop critical thoughts and apply critical thinking to AI in their lives. Therefore, numerous aspects in the AI-related exhibition context need to be explored to cultivate critical thinking competency in youth.

In this background, our study aims to explore how youth can obtain critical thinking competency about AI that can be reflected in their lives through the exhibition. Through collaboration with AI developers, designers, and artists, an exhibition and four exhibits aiming to foster critical thinking competency in youth were designed. To explore thought changes in the youth and the critical thinking process associated with AI and their lives, 23 participants were invited to experience the exhibition and fill out surveys before and after the exhibition. We also conducted a debriefing interview after the exhibition. Our findings show that it is possible that the youth relate AI technology to their lives through critical thinking processes supported by the exhibition; they discover connections with their future hopes, increasing their desire to learn to use AI effectively; and they establish their own standards regarding the ethical direction of AI. Building on our findings, we discuss how to encourage the youth to relate their critical thinking competency toward AI to their own lives and become sustainable, responsible, and critical users of AI.

The contributions of this study are three-fold: we 1) design an evidence-based AI-related exhibition that fosters critical thinking competency in the youth and supports their use of this competency in their lives, 2) identify the types of thought changes that occur before and after the exhibition experience and the way in which the youth relate their learning experiences to their lives, and 3) propose implications for designing the exhibition as informal learning experiences to foster critical thinking competencies for youth to better coexist with AI.

2 RELATED WORKS

2.1 AI education for the youth

With the development of AI technology, AI users leverage AI-embedded systems but, simultaneously, face various ethical concerns related to AI. For instance, people cannot be sure that they can control the significant impact of AI in their lives, including the personal data breaches and discriminatory content generated by algorithms [4, 6, 23, 33, 69, 88, 116]. Accordingly, considerable HCI research has emphasized the importance of cultivating AI literacy, the competency needed for the non-AI-expert public to understand the driving principles of AI, critically evaluate AI, and effectively collaborate with it. Previous studies have defined AI literacy from different perspectives [69, 76, 84, 85, 114]; nonetheless, they have been defined as a set of competencies for people without technical expertise to understand, critically examine, and collaborate with AI technology, thus enabling wise coexistence.

In particular, fostering AI literacy is considered important for youth among the diverse public without AI expertise [1, 26, 29, 43, 56, 60, 61, 69, 76, 82]. Youth is characterized by the age range of 15-24 years by the United Nations [83]. As today's youth is growing up with AI, they are naturally exposed to AI-embedded services and devices every day, without even recognizing it. Therefore, although AI-powered services can provide various opportunities, possible

adverse effects of indiscriminate use cannot be ignored [69, 77, 88]. Further, when the youth enters adulthood, our society will be highly integrated with AI. Thus, it is crucial as responsible users to learn AI literacy for wise coexistence with AI. To this end, recent studies have proposed guidelines for youth AI literacy education curricula [103, 113]. Touretzky et al. suggested five big ideas for K-12 AI education and created a detailed educational goal framework based on the following: 1) Computers perceive the world using sensors; 2) agents maintain models and representations of the world and use them for reasoning; 3) computers can learn from data; 4) making agents interact comfortably with humans is a substantial challenge for AI developers; 5) AI applications can impact society in both positive and negative ways [103].

Based on these guides, several studies have attempted to educate youth on AI literacy in classrooms, the formal learning space. Particularly, curriculum and tools were developed for youth Al literacy learning experiences focused on technical aspects such as the driving principles of AI and building AI algorithms [22, 25, 66, 97, 106, 115]. Some studies have revealed the need to foster AI literacy competency beyond technology-oriented education by developing and verifying the effectiveness of AI education [3, 73, 104]. To educate students on AI literacy, Van Brummelen et al. designed a classroom curriculum by applying AI literacy design considerations; they verified the effects of the developed curriculum through interactive AI workshops and discovered that although the youth's overall understanding of AI increased through the workshop, they found that youth still thought the concept of AI ethics difficult [73].

2.2 AI education to foster critical thinking competencies toward AI

Thus far, most AI education efforts for youth have focused on delivering technical knowledge. Education in competencies to consider and evaluate AI or to understand both the positive and negative impacts of AI on society is thus relatively lacking. However, among the various competencies of AI literacy for youth, the ability to think critically and evaluate AI, along with its computational learning, is crucial [3, 69]. This is because, although AI has significant educational potential for youth, these youth are exposed daily to various negative influences related to privacy, bias, and filter bubble issues [2]. As critical thinking is a self-directed thinking pattern that allows people to evaluate an issue from various perspectives to produce self-led conclusions [9, 80, 100], education in critical thinking about AI is necessary for youth to effectively collaborate with AI and grow into critical users.

Furthermore, the youth, a transition period from adolescence to adulthood, is particularly well suited to fostering critical thinking competency compared with other younger age groups. According to Piaget's theory of intellectual development, a formal operational stage, including adolescence to adulthood, can combine and classify items in a more sophisticated way and higher-order reasoning [39]. The youth in this stage can understand complex concepts such as ethics and politics and engage in scientific reasoning. Therefore, this study focused on youth between the ages of 15 and 24 as informal education learners, to effectively educate critical thinking competency.

Recent attempts have been made to educate and evaluate critical thinking competency, critical data literacy, and AI ethics in AI education [3, 14, 24, 40, 52, 55, 67, 68, 90, 101, 112]. Garrett et al. demonstrated that education on the ethical aspects of AI is in its early stages compared with the technical aspects of current AI education. Researchers analyzed 31 independent AI ethics classes at 22 U.S. universities and 20 AI/ML classes at 12 U.S. universities. They found that AI ethics classes focus primarily on the bias, automation and robots, policy, and the consequences of algorithms; relatively few classes focus on the impacts of AI technology. Accordingly, researchers have emphasized the importance of educating students to consider the potential ramifications of technology [37]. Referring to these attempts, we found that understanding the consequences of technology impacts will allow the youth to consider and use the technologies more critically. In addition, the role of ethics in AI education should be emphasized.

Based on this, to educate youth on critical data literacy, Tissenbaum et al. revealed the need to support youth to become self-motivated, innovative creators beyond simply teaching them how to code in computational thinking education. Subsequently, researchers used a critical computational literacy approach to engage youth in developing personally meaningful applications that impact the real world. These attempts have become a lens for youth to place their computational thinking in contexts that are relevant to their lives, through developing digital empowerment and computational identity [101]. Hautea et al. explored the critical perspectives of youth programming with public data about their learning and social interaction in the Scratch online community by observing discussions among these young users. Based on youth's critical perspectives on data literacy, they suggested strategies for designers and educators to engage youth in critically thinking about the role of data in their lives and world [43]. Furthermore, researchers have applied AI ethics classes to the computer science (CS) curriculum to provide a critical perspective and evaluation competencies in school. Ali et al. developed an AI education curriculum that enables students to engage in constructivist learning, design AI considering ethics and develop a creative mindset to answer research questions regarding preparing the youth to live in the AI era. This study aimed to educate youth on the skills needed when designing AI as developers, rather than from a user perspective [3]. DiPaola et al. presented design activities in an AI + Ethics curriculum. This curriculum was structured to understand the surrounding AI-related technology and the attendant ethical issues, and to explore future directions for ethical AI design [24]. Burton et al. included various types of science fiction content in the AI education curriculum to allow CS-major college students to participate in ethical issues directly and cultivate critical perspectives as developers. They suggested that science fiction could be an effective tool for educating students in ethical issues by immersing students in AI decisions and the consequences of those decisions [14]. These attempts were mostly aimed at educating critical perspectives in developing AI or handling data, rather than educating critical thinking competency when using AI from the perspective of non-AI expert users.

In reviewing these previous studies, we found that it is the time for more attempts to educate youth in critical thinking competencies. Although several existing projects involve education for critical perspective, these attempts have focused predominantly on

a single way of delivering AI-related ethical knowledge, following a structured curriculum in the classroom. It should be noted that these attempts allow youth to acquire knowledge about AI problems and critically evaluate current AI systems within the boundaries of the curriculum covered. Furthermore, classroom education enables simultaneously delivering structured content to multiple students. However, youth still faces difficulty in actively relating their life to AI impacts, critically thinking about the potential influence of future AI, and individually developing critical thinking competencies, depending on their own different thoughts. Thus, this study focuses on educating critical thinking.

2.3 Informal learning for AI literacy

A growing body of HCI research has considered that informal learning is particularly important in contexts that foster AI literacy, as it can lead to youth-led learning and support reflective learner thinking [32, 71, 74, 75, 81]. Because informal learning is heavily influenced by the theory of constructivism, the informal learning approach is well-suited for critical thinking competencies and group learning. Whereas the formal education approach involves teachers unilaterally delivering objective knowledge, constructivism emphasizes the importance of an environment where learners can construct their learning [5, 71]. Therefore, the informal education approach is an effective way to increase learners' active learning, critical thinking, and problem-solving competencies while overcoming the limitations of formal education, which is focused only on knowledge delivery. Using the informal learning approach, previous studies have explored AI literacy education in environments such as museums, art galleries, and homes, as opposed to formal education taught in classrooms [74, 75, 77]. Among the various informal learning environments, museums can help students gain knowledge, develop interest, and attain critical thinking abilities, all of which can lead to intrinsic learner motivation [49, 92]. Long et al. co-designed exhibits with family audience, focusing on the effects of informal learning in museums to foster AI literacy via public interest development and introductory exploration. Subsequently, they suggested design considerations for AI-related exhibits to cultivate AI literacy [74]. Although this study provided us valuable insight, previous informal education attempts have mainly focused primarily on teaching the technical aspects of AI, rather than on educating students in critical thinking competencies, which are appropriate to learn in informal education context.

Further, a few recent AI-focused exhibition projects have evoked critical perspectives of AI for audience [19, 35, 45]. Ian Chang recently exhibited on the development of AI technology and human relations through artwork embedding AI technology [17]. Even though comparable concepts have been explored in science fiction and films, this art exhibit was a novel attempt to pose queries that might prompt discussion about AI. In addition, the exhibition "AI: More than Human" was curated in collaboration with artists, scientists, and researchers, and included digital media and immersive art installations. This exhibition provided opportunities for audience to experience AI directly and delivered messages by asking questions, such as: "how can humans and AI work together?" [7]. These projects have provided insight into the potential of art exhibitions in supporting the learning of AI literacy competencies, particularly relating to AI and human relationships, and critical perspectives on AI. However, these exhibits focused little on the educational aspect of helping learners develop critical thinking skills and providing an opportunity to apply critical thinking to reflect the lives of audience. Instead, they focused on delivering the creators' perspectives to the audience. Moreover, few attempts have been made to grasp the educational effects of audience's emerging understanding or change of thinking through AI-focused art exhibitions.

Given our focus on fostering youth-led critical thinking in informal learning contexts, the present study focuses on an emerging understanding of the youth's changing thoughts by fostering youth-led critical thinking competencies and relating AI to the youth's lives in exhibition contexts.

3 METHOD

We adopted a two-phase approach. First, we designed an AI-related exhibition by conducting a collaborative workshop. Second, we invited 23 youth audience to experience the exhibition to examine the changes in their perspectives by conducting pre- and post-exhibition surveys and a debriefing interview. This section, we detail the overall design intent of the AI-related exhibition and the workshop process and then describe the art exhibits; furthermore we describe the procedure for the participants' learning experience at the art exhibition. This study was approved by the Institutional Review Board (IRB).

3.1 Designing exhibition

3.1.1 Overall theme and educational goals. We designed the exhibition called "AI with Weird Wonderland" to allow youth to develop critical thinking competency and apply their competency in their lives. Among the various informal learning environments, an art exhibition, which was originally emphasized by an educational philosopher, John Dewey [20, 21], was chosen; learning through art can motivate learners and provide opportunities for self-reflection and thinking outside the box during the interpretations of the meaning of works of art [15, 57, 60, 95]. Thus, informal learning through art exhibitions is regarded particularly effective in provoking learners to think critically [49]. To specify the educational goals and design intent of the exhibition, our research team analyzed 33 previous studies related to AI literacy. Given that the participants were non-AI experts and an informal learning approach was used, three AI literacy competencies were identified as the basis for critical thinking; 1) understanding and distinguishing AI [12, 44, 86, 93, 94, 105], 2) imagining future AI [3, 25, 76, 107, 114], and 3) understanding the positive and negative impacts of AI [13, 76, 98, 99, 103]. These three competencies were set as the goal of the learning experience as well as the standard for the overall research, including the processes of designing the exhibition, creating exhibits, and user study.

3.1.2 Collaborative workshop for creating art exhibits. To design art exhibits based on the three competencies relating to AI literacy, five collaborative workshops were conducted. We established four guiding criteria to create well-grounded art exhibits by extensively reviewing works related to AI education, informal education, AI literacy, and education through art; 1) interactivity [28, 46–48, 54, 96], 2) abstract and implicit expression [10, 18, 31, 42, 51], 3) incorporating mixed perspectives [8, 10, 76, 103], and 4) narrative

Table 1: Definitions and purposes of guiding criteria used to create exhibits.

Guiding criteria	Definition	Purpose
Interactivity	The installations should include embodied and responsive interaction to allow the audience to directly interact with the exhibits.	Through direct interaction with the artwork, the audience can actively engage in the learning experience and increase their understanding of technology.
Abstract and implicit expression	The art exhibits' intention (or message) should be delivered to the audience in an open-ended manner with various possibilities rather than straightforwardly.	Through interpreting various meanings of abstract exhibits, the exhibition experience can induce creative thinking in audience.
Incorporating mixed perspectives	The perspectives on the technology in the exhibits include both positive and negative aspects rather than being biased.	By perceiving both sides of technology, the audience can expand their thinking on the impact of AI on society.
Narrative	The art exhibitions and art exhibits include storytelling related to our lives.	By empathizing with a story, the audience can easily immerse in the art exhibits without expert knowledge.

[10, 16, 41, 79, 110]. All art exhibits were developed to incorporate each of these criteria, with creators adopting this approach as a guideline during workshops. A detailed explanation of the guiding criteria is presented in Table 1.

To incorporate the guiding criteria, we recruited HCI designers for AI systems, AI developers, and artists with the following relevant experience [53, 58, 70, 78]. We recruited HCI designers with strengths in interaction design to lower the barrier for the youth to experience the exhibition. We also targeted AI researchers or AI developers with experience in building and applying technology to art exhibits. Lastly, we chose artists who could express complex messages through the exhibits and had experience in creating AI-related artwork. Consequently, a total of 12 creators, comprising four designers, four developers, and four artists, were recruited. Subsequently, three creators for each type were grouped as a team, and four teams produced four works. Each creator was compensated with $500, including the cost of materials used. All the creators were Korean.

Five collaborative workshops were held on Zoom with the aim to create well-grounded art exhibits and reflect on various perspectives through discussion. The first author moderated all the workshops, coordinated the opinions of different stakeholders, and encouraged the creators so that the exhibits and the exhibition could be designed well aligned with the research goals. In the first workshop involving all four teams, the first author explained the definition of the three AI literacy competencies and the purpose of the exhibition. Furthermore, for consistency with the overall theme, they discussed the preliminary research material on AI studied by each creator to reach a consensus on the AI concept. In the second workshop, which was conducted independently by each team, the creators were asked to envision the impact of AI, and they provided a total of 38 scenarios. The third workshop was also conducted by each team, and the creators were asked to select the most appropriate topic for cultivating three AI literacy competencies. In the process, some teams focused more on topics biased toward the negative aspects of AI. To balance their perspective, the first author asked the creators to consider the positive impact of AI in case the audience would only think of biased aspects of AI. However, these creators thought that allowing the youth to realize problems they did not recognize was more important for fostering critical thinking competency, particularly by focusing on the characteristics of today's youth, who focuses primarily on the positive aspects of current AI technology. The first author respected their intentions and encouraged creators to fully incorporate their intentions into the exhibits because the creators discussed the topic for a long time and decided on the topic by considering guiding criteria. Next, the creators began creating the artwork while applying the four guiding criteria (Table 1). In the fourth workshop, each team elaborated on the final concept as a low-fidelity prototype. In the final workshop, all four groups collectively introduced concepts and evaluated each other's work and perspectives on how well each concept met the three AI literacy competencies and four guiding criteria. Then, all teams fixed the overall narrative and order of installations in the exhibition. After the workshop, they were required to finalize the concept by referring to other teams' feedback. The creators were allowed to continue their work until March 2022, when the exhibition began.

3.1.3 Art exhibits: outcomes of the workshop. We address each exhibit in order. We also describe the creator's intentions, the way in which the guide was applied to achieve educational goals, and the interaction method of the exhibits. At the end of the section, Table 2 summarizes the applications of each guiding criteria.

Figure 2: Interaction method and order of "Being data to feed AI." From left to right: (1)Audience members are asked to measure their body temperature using a thermal camera outside the exhibition hall before entering the exhibition. (2) Audience members can see their captured faces used as a part of the artwork inside the exhibition hall. (3) Abstract image of an AI that morphs the facial data of the audience members to appear more like a human being.

Figure 3: Interaction method and order of "My AI's life after I died." From left to right: (1) Audience without a VR device can view the diaries dating from 2010 to 2040 of the main character in the exhibition hall. (2) Audience can view the last diary dated 2050 when the main character died. (3) Subsequently, the audience continues to view the AI's life after the main character dies, wearing a VR device and facing the blank canvas on the left. Audience can view the personalized AI's diaries dating 2060–3080 via a VR controller.

Exhibit 1: "Being data to feed AI" This art exhibit aimed to inspire audience to consider the facial recognition technology, ethics of personal data, and AI applications surrounding them. The creators intended to encourage the audience to recognize that their faces could always be detected and recorded without their knowledge. Thus, the creators attempted to increase audience's awareness of facial recognition technology. Creators focused on situations wherein people could not experience the negative impact of facial recognition sensors in daily life because this technology is typically used in security for unlocking their phones or doors. The creators aimed to provide an opportunity for critical thinking by recalling the AI usage experience for the audience. Rather than conveying a negative perspective to the audience, the creators aimed to deliver a new stimulus to familiar situations.

As part of the first exhibit, the youth audience was required to measure their body temperature using a thermal camera as per pandemic regulations before entering the exhibition. Subsequently, as soon as the audience entered the exhibition hall, they noticed that their faces were captured by a camera applied to the artwork in the exhibition hall right away. As the audience looked at their own faces in the art exhibit, they began to consider AI recognition technology and possible abuses of the collected data. Furthermore, the AI image in the video abstractly expresses the technology developing into a human-like appearance by learning the image of the audience's face. Finally, audience was alerted to the fact that devices can capture human faces and potentially violate their privacy. The interaction methods are described in detail in Figure 2.

Exhibit 2: "My AI's life after I died" This exhibit aimed to communicate AI-related competencies such as the positive and negative impacts of personalized AI, AI's decision-making process, the principles of recommender systems, and personal data and its associated lifecycle (Figure 3). "My AI's life after I died" shows what could happen if a man who lived in coexistence with AI died, leaving his personalized AI behind. This exhibit aimed to provide an opportunity for the audience to consider the impact of AI technology through various scenarios. The creators focused on the situation wherein people readily provided their personal information to a content recommendation system without considering the impact of personalized AI. The art exhibits were presented as diaries with illustrations. Diaries from 2010 to 2040 demonstrated the AI and the main character living together. Evidently in 2050, the main character died without deleting his personalized AI data. Subsequently, diaries from 2060 to 3600 showed that a personalized AI autonomously lived his life by meeting the main character's children and changing the house's interior.

In this exhibit, the diaries dating from 2010 to 2050 were presented in physical form in the exhibition hall (see Figure 4). When

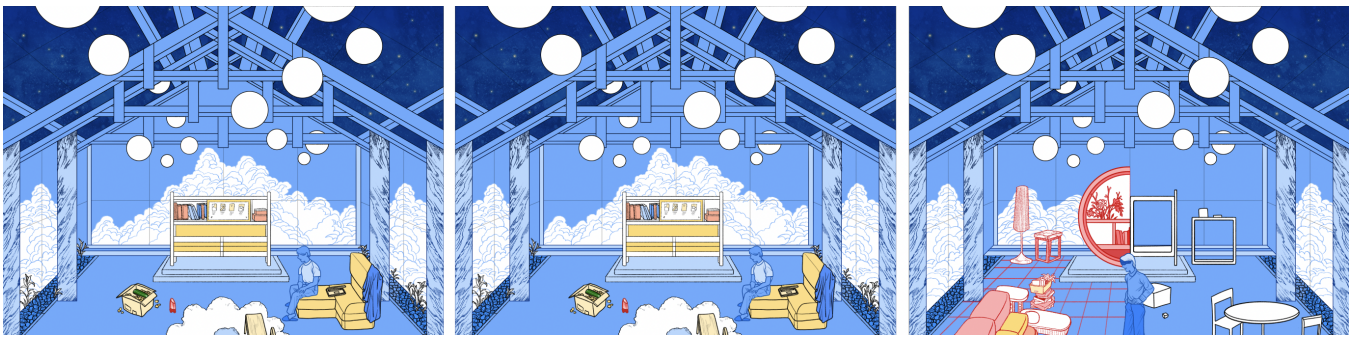

Figure 4: Selected illustrations from 2010, 2020, and 2040 in that order from "My AI's life after I died".

Figure 5: Selected illustrations from 2050, 2070, and 3000 in that order from "My AI's life after I died"

Figure 6: Interaction method and order of "AI recommendation: Comfort or losing control?" from left to right: (1) After appreciating the second exhibit, the audience passes through the door. When audience enter the new section, they can see a vision of a dark future where users are overly dependent on AI. (2) When the movement of the audience is sensed, a central device representing AI rotates and the wire representing the animal data is pulled out and wound around the central device. With that power, the armchair moves, and the animals rest comfortably. (3) The audience examines the animals that have lost their uniqueness one by one and identifies them, realizing that they have lost the ability to memorize phone numbers or find places by themselves due to the convenience of AI.

AI's autonomous life began, the diaries dating 2060–3600 were in a digital form and could be viewed by wearing a VR device to distinguish the future in which AI and humans coexist (see Figure 5). The interaction methods are described in detail in Figure 3. In the overall stories, the man who is the main character of the diary from 2010 to 2050, and AI, who is the main character of the diary from 2060 experience both enjoyment and dilemmas. This narrative encouraged audience to consider the dual nature of personalized AI. Furthermore, the AI was expressed in red and humans in blue to easily distinguish between them (Figure 4 and 5).

Exhibit 3: "AI recommendation: Comfort or losing control?" This art exhibit aimed to express issues relating to the impact of AI recommendation systems, authority in the relationship between AI and humans, between trade-offs of losing control and convenience. The creators attempted to deliver the AI recommendations' positive impact on the convenience of personalized support and its

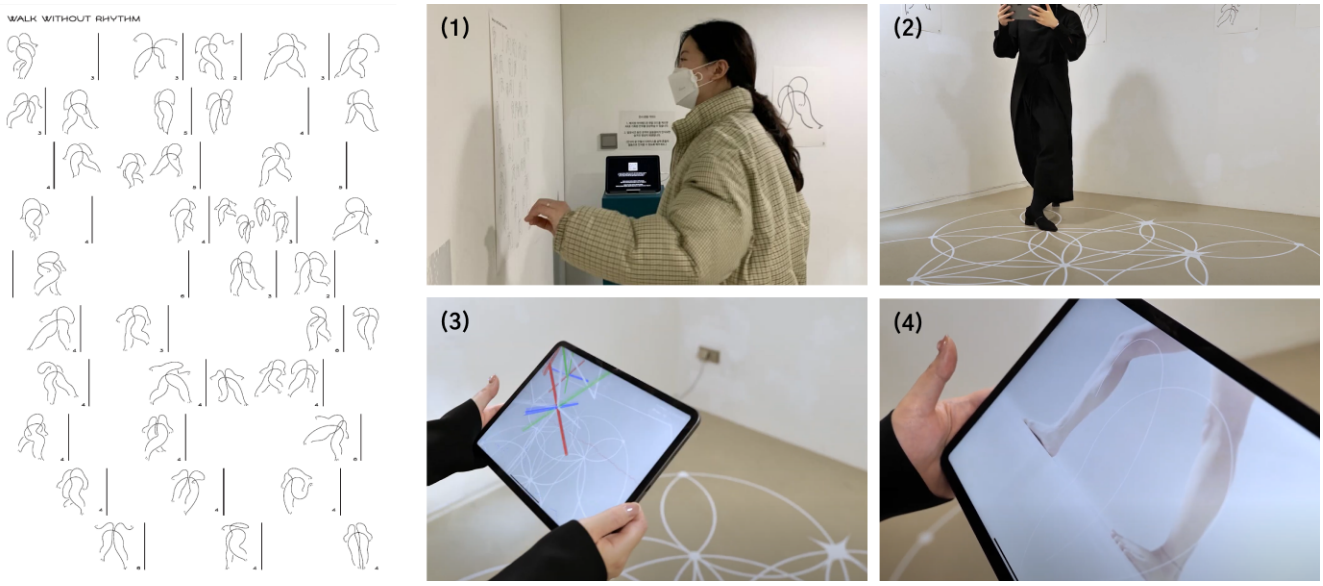

Figure 7: (Left) Choreography sheet and (Right) Interaction method and order of "Walking with a machine-unreadable gait": (1) Audience practice walking by following the choreography sheet and floor trajectory that the choreographer previously walked while avoiding monitoring by AI. (2) Audience start walking to avoid AI monitoring by holding a sensor-embedded device. (3) Audience can understand the driving principle of the sensor while watching the visualization of movement through the X, Y, and Z axis in real time on the screen and walk irregularly to deceive the AI based on clues. (4) If the audience successfully deceives the AI, a video of the choreographer's movements who escaped the AI's surveillance is suddenly displayed.

negative impact on decision-making subjectivity. Therefore, this exhibit was aimed at triggering critical thinking while simultaneously demonstrating the two-sided influence of AI. The audience was encouraged to analyze the current situation; for example, the difficulty faced in choosing content to watch and traveling without AI recommendations. Based on this background, creators envisioned a future where this trend continues and human subjectivity disappears.

This art exhibit expressed a future where users have lost their identity owing to AI dependence while being comfortable owing to AI recommendations by artistically presenting future users as animals that rest in the armchair and lose their unique characteristics (such as short-necked giraffes and squids with malformed tentacles). In the stuffed animals, wires representing parts of their bodies were pulled out by the device in the middle representing an AI. However, the animals rested comfortably in rocking chairs without recognizing this issue. The creators indirectly demonstrated a potentially dilemmatic future through this installation with expressive animals, where users trade their identity and control for comfort. Consequently, the audience appreciates the work while connecting themselves with the animals, recalling that they allowed their facial data to be captured without awareness during the prior installation. The interaction methods are described in detail in Figure 6.

Exhibit 4: "Walking with a machine-unreadable gait" This exhibit aimed to communicate AI-related competencies such as AI surveillance, understanding sensors through data visualization, and sensing the impact of AI technology on basic human behavior. The creators focused on existing sensor technology that can distinguish users based only on their gait characteristics. With this exhibit, the creators encouraged the audience to imagine a future in which even the most mundane human behavior can be processed as data and become a means of surveillance, and where people will actively alter their normal behavior to escape AI surveillance.

In the process of creating the art exhibit, the creators first experimented with the choreographer. The choreographer was asked to walk unusually while wearing sensors to ensure that the AI could not detect their movement as a gait; subsequently, the choreographer's gait trajectory was visualized. The visualized results of the choreographer were created as a choreography sheet (Figure 7 (Left)), floor trajectory, and a video for the audience to watch in the exhibition hall.

In the exhibition hall, the audience acted as future users who wanted to escape from the surveillance of AI by following the choreographer's choreography sheet and floor trajectory. Thus, they experienced a future where the most basic behaviors of humans may need to be altered owing to AI. The interaction methods are detailed in Figure 7. Although this exhibit focused primarily on the negative aspects of AI, the creators focused on the situation in which users take it for granted that the smart watches accumulated user data all day. Thus they aimed to deliver the message that data sensing for health could have a negative impact in the future.

3.1.4 Art exhibition <AI with Weird Wonderland>. Based on the created art exhibits, we designed the narrative of the exhibition by connecting art exhibits so that the audience could be gradually immersed in the overall narrative of the exhibition. The narrative

Table 2: Summary of how the guide was applied to each art exhibit.

	1. Being data to feed AI	2. My AI's Life after I died	3. AI recommendation: Comfort or losing control?	4. Walking with a machine-unreadable gait
Interactivity	The images of the audience' faces recognized through facial recognition sensors are sent directly to the artwork.	Wearing a VR device allows the audience to experience an AI's life after its owner (user) diedindirectly through virtual reality.	When the audience crosses the door, the art exhibit senses the audience's movement and starts to move.	The audience can directly experience the sensor technology and see their visualized movements in real time.
Abstract and implicit expression	AI's complex appearance is artificial; nonetheless, it is also natural because AI has learned from human data.	The metaphorical expression of each element in the diary. Human and AI lives are distinguished by color.	While the exhibit primarily presents a negative atmosphere, animals rest comfortably in armchairs. In addition, the animals lost identities are expressed as stuffed animals, thus emphasizing their contradictions.	Combining the situation of AI surveillance with gamification and negative behaviors to avoid AI surveillance with dance blurs the line between positive and negative impacts.
Incorporating mixed perspectives	AI gets smarter with moreuser data, while simultaneously increasing the risk of privacy breaches.	Open-ended stories with both positive and negative impact are told about a personalized AI that knows users too well.	AI's recommendations can make users comfortable; however, simultaneously, users can lose control and their identity.	A highly advanced sensing technology can provide a better user experience, but may simultaneously perform ubiquitous surveillance.

was intended so that the audience could trigger critical thinking throughout the entire exhibition experience to not influence the audience's thoughts by being dependent on each work. In addition, when guiding the narrative, moderators tried to fully explain the creators' intentions so that the audience could experience the exhibits with balanced views, considering that some works were more focused on the negative aspects. The floor plan of the exhibition hall and the installation location of the art exhibits are shown in Figure 8. The first exhibit intends to arouse audience's recognition of the role of sensors in everyday life (Figure 8.(1)). Then, the second art exhibit allows the audience to imagine the expanded future societal impact of AI with the future scenario beyond the influence of AI technology in daily life shown in the first exhibit (Figure 8.(2)). After audience cross the door to move from the second to the third art exhibit, the audience moves into a distant future in which AI vastly impacts our society (Figure 8.(3)). The third and fourth works show two different social changes that may occur when AI significantly impacts our lives. Thus, the audience can experience the various influences of AI technology (Figure 8.(4)). Consequently, audience gradually experience a range of effects from the trivial impacts of AI in their daily life to the potentially extreme influence of AI in the future.

After the exhibition design process, the exhibition was held for 7 days at CP Gallery in Seoul, Korea [36]. We selected this location because it is the one of the speculative design exhibition space in

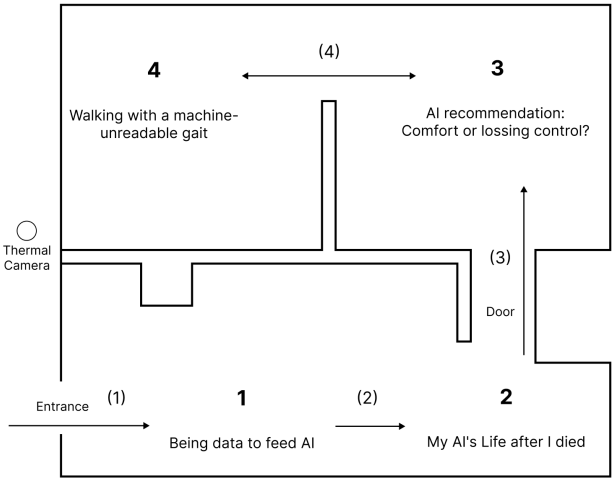

Figure 8: Art exhibition hall floor plan and narratives between art exhibits

Figure 9: View of the exhibition hall

Korea and the space composition of the exhibition hall is appropriate for active discussion while experiencing the exhibition (Figure 9). Although we designed the AI-related art exhibition to target youth, we also opened the exhibition to the public by promoting it through social media and blogs. As a result, a total of 178 audience members visited and experienced the exhibition.

3.2 Informal learning experiences in the AI-related exhibition

3.2.1 Participants. We recruited 25 participants aged 15–24 in various ways, including via posting on social media and school communities. Before the participants were selected, potential participants who expressed an interest in our study were provided with preliminary questionnaires for basic information. We filtered participants based on age diversity with aim to form small groups with friends based on the survey responses. A total of 35 applications were received, of which 25 participants were selected. Two of the selected 25 participants could not participate in the study because they tested positive for COVID-19. Consequently, 23 participants were recruited, and divided into six small groups for effective discussion; the groups consisted of 3, 5, 5, 4, 4, and 2 participants. The age of the participants ranged from 14 to 24 years, with the average age being 18.17 (SD = 3.12); further, all participants were Korean and were compensated $40.

3.2.2 Procedure for experiencing the exhibition. Before the exhibition experience, the participants were asked to complete a pre-exhibition survey a day prior their exhibition visit to understand their preconceptions of AI. The pre-survey questionnaire had four main questions on the three AI literacy competencies and 14 sub-questions based on prior research [76, 103]. These included open-ended questions on participants' perceptions of existing and future AI systems, the impact of AI, the direction of ethical AI, and the relationship between AI and themselves. In addition, participants were asked to respond on a 7-Likert scale to multiple-choice questions regarding their knowledge of five items; 1) understanding existing AI, 2) imagining future AI, 3) standard of ethical AI, 4) understanding the impacts of current AI, and 5) imagining the impact of future AI. Although evaluation with the Likert scale could have limitations in understanding the changes in critical thinking competency [62], a survey was conducted to help the youth self-explaining their preconceptions and aid qualitative data, not to evaluate their changes with quantitative results.

During the exhibition experience, the six groups, comprising a total of 23 participants, were asked to visit the exhibition on different days, and the study was conducted for six days. When a group visited the exhibition space, the moderator briefly explained the study, and then the participants proceeded to the exhibition space. The participants were asked to experience the exhibition along with an exhibition experience guide to ensure an immersive experience and facilitate the understanding of the exhibition's narrative. For a guided experience, the purpose of the exhibition, exhibits, and overall story were explained according to the narrative of the exhibition. First, the participants experienced the exhibits, followed by an explanation of the exhibits; subsequently, they were allowed to freely discuss the exhibits. When explaining the narrative, moderators fully explained the creators' intentions, considering that some works were focused more on the negative aspects, to ensure that the audience experienced the exhibits with a balanced view. During the exhibition experience, the moderator did not engage in participants' interactions and discussions. Instead, while the participants waited for the other participants to experience the exhibition, the moderator stimulated their thoughts by individually questioning them based on the results of the pre-exhibition survey. The session of exhibition experience took approximately two and three hours, respectively.

After the exhibition experience, to understand each participant's critical thinking process and thought changes, the group was asked to come to the interview place in the exhibition hall as part of the guided experience. As measuring whether critical thinking has developed precisely in a short period is difficult [65], the previous study suggests open-ended task for measuring critical thinking [30, 62]. Thus, open-ended questions were used to understand the thinking of individual youth in-depth. In particular, as each youth had different preconceptions and thought processes, evaluating with open-ended questions was appropriate to understand each individual's critical thinking processes and thought changes from unstructured informal learning activities rather than evaluating it with rubrics. Each participant was asked to share the art exhibit that impressed and evoked their thoughts the most. Subsequently, the moderators asked open-ended questions regarding their perception of AI and how it developed or changed after the exhibition (see Appendix). Afterward, items identical to those in the pre-exhibition survey were re-evaluated on a 7-point Likert scale to understand how the participants' knowledge or perceptions of AI changed. Furthermore, an item on the effectiveness of the learning experience

in the exhibition compared with existing AI education was added. As self-perceived change is important for fostering critical thinking competency [72], the survey was re-evaluated to determine the changes that participants perceived as stimuli for debriefing interviews and self-explaining [34]. Finally, referring to the changes that participants reported themselves, they were asked to describe changes in their thoughts and allowed to discuss more with friends. This session took approximately one and a half hours.

3.2.3 Data analysis. Survey data from the participants before the exhibition experience, video data from the conversations and interactions they had during the exhibition, and post-exhibition survey, interview, and discussion data after the exhibition experience were collected. Qualitative data from interviews and discussions were analyzed to explore the thinking process and outcomes of critical thinking competency, with focus on our educational goals. Quantitative data from before and after the survey were analyzed to explore youth's self-reported change and support the qualitative data to comprehensively understand the exhibition experience effect.

In the qualitative analysis, the first author transcribed the discussion and interview data from before, during, and after the exhibition and organized the data by adding responses to open-ended questions from the pre-exhibition survey. According to previous studies, concluding the development of critical thinking competencies is challenging [30, 65], particularly in an informal learning environment. Moreover, all the youth have different ways of critical thinking. Considering the characteristics of informal education with the advantages of youth-led learning, we tried to discover new patterns through thematic coding analysis [38]. We believe this approach is appropriate to analyze the outcome of informal learning activities distinct from a structured curriculum; additionally, it allows exploring the starting point of each youth's thinking, development process, results of thinking, and flow of change in depth. For this purpose, four authors open-coded the data based on our educational goals (three AI literacy competencies). To validate the reliability of the open-coding process, four researchers each reviewed the same data and proceeded with coding, then the codes were iteratively clustered and discussed through three rounds together. The thematic coding process resulted in 173 initial codes, which were then discussed, deleted, and merged by four of the authors. Subsequently, we comprehensively reviewed the data and cross-checked the transcript three times to further validate the change in perception of participants and the factors that led to it. In this process, 16 of 173 codes were excluded, and 157 codes were finally used in our analysis. These codes were categorized into 18 sub-themes of the participants' changes in perspective and the associated process through the affinity diagram [11]. Consequently, we structured seven themes with sub-themes based on 1) changes in the participants' perspectives, 2) why the changes occurred, and 3) the process involved in the change. Table 3 lists seven themes and 18 sub-themes from the analysis.

In the quantitative analysis, we evaluated the normality of the Likert data using the Shapiro–Wilk test; only Q 1,2,3, and 5 were found to be normally distributed. Therefore, a Wilcoxon signed-rank test was performed for the five items. Note that evaluating changes in thinking presents a limit because participants in the exhibition experience can give higher scores owing to *demand characteristics* [89]. Nevertheless, as critical thinking competency is meaningful for learners to evaluate changes on their own, a quantitative analysis was conducted to identify changes in learners' self-reports [34, 72] and aid qualitative data rather than generalize the survey results.

Table 3: Primary themes and subthemes from thematic coding.

1. The way of interacting with exhibits in the exhibition hall
1) Discussion on AI-related topics among youth
2) Co-learning with friends on how to interact with the exhibits
2. Understanding the AI around youth
3) Recalling the youth's previous AI experience and usage
4) Understanding current AI driving principles and impact
3. Connecting between AI and youth
5) Imagining a relationship with future AI
6) Seeking a direction for positive coexistence with existing and future AI
7) Reflecting on the youth's AI usage experience and connecting it with the exhibition experience
4. Finding AI-related problems the youth didn't recognize
8) Recognizing the limitations of how AI is portrayed in mass media
9) Recognizing the problems in current data processing methods
10) Recognizing the problems in personal AI experience and usage
5. Changing Perspectives on AI
11) A critical perspective that perceives the duality of AI in a complex way
12) Increasing interest and curiosity regarding AI
13) Changing attitudes and the way of thinking about AI
6. Ideating the design and development direction of future AI
14) Seeking a direction for positive coexistence with future AI
15) Specifying the ethical direction of future AI
16) Exploring solutions to current AI-related problems
7. Attributes that led thought changes
17) Characteristics of exhibits
18) Characteristics of exhibition experience

4 FINDINGS

We present the findings of this study below. First, we describe the overall impact of the exhibition with participants' reactions about each exhibit and its attributes that influenced the participants to reconsider their perspective. Second, we show the exhibition experience and process of critical thinking. Lastly, we describe how the participants changed their viewpoints on the subject of the exhibition through the learning experience.

4.1 Overall effect of AI-focused art exhibition and its attributes

First, the survey results were examined to explore youth's self-perceived change in AI literacy competencies after the exhibition experience. The results of the Wilcoxon-signed-rank test indicated that the difference between before and after the exhibition was statistically significant across all five items. Additionally, all five items indicate a large effect size ($r > 0.5$) [109]: understanding existing AI ($Z = 3.68$, $p < 0.05$, $r = 0.76$), imagining future AI ($Z = 3.07$, $p < 0.05$, $r = 0.64$), understanding the ethical direction of AI ($Z = 3.45$, $p < 0.05$, $r = 0.71$), understanding the impact of existing AI

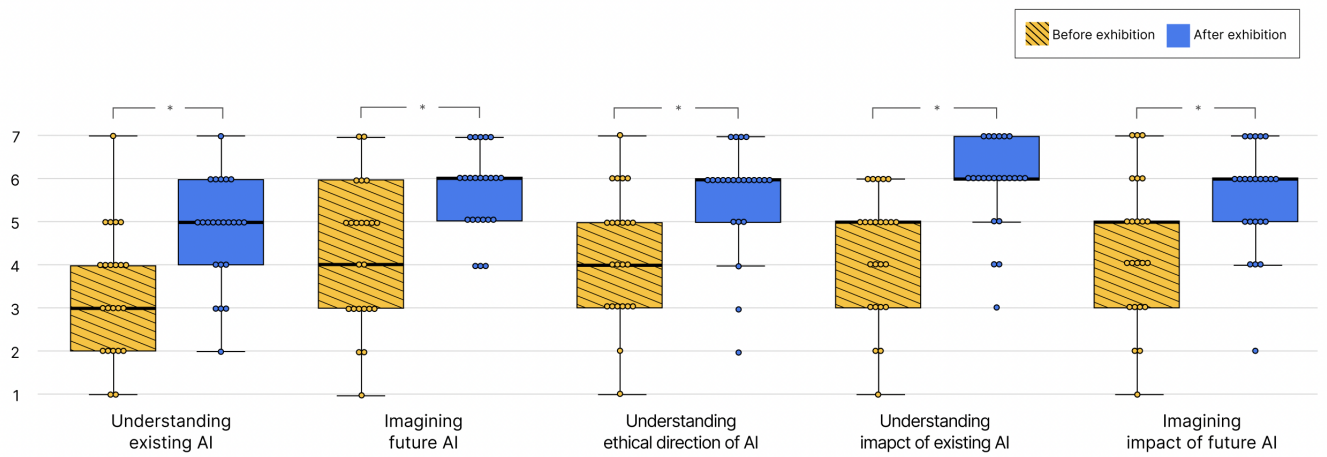

Figure 10: Changes in the five AI literacy competencies (n=23) before and after the exhibition from the results of the Wilcoxon signed-rank test. A black bold line within the box marks the median. An asterisk indicates significance at $p < 0.05$. All five competencies exhibited significant differences.

($Z = 4.00$, $p < 0.05$, $r = 0.83$), and imagining the impact of future AI ($Z = 3.45$, $p < 0.05$, $r = 0.71$).

However, although significant differences were observed across all items, interpreting that AI literacy competency changed in a short time through the exhibition is challenging owing to the possibility of the *demand characteristics* [89]. Therefore, the quantitative results were reported as exploring the overall change in the youth's self-reported evaluation and as a reference for qualitative findings.

4.1.1 Overview of participants' reactions about each exhibit. This section provides an overview of the participants' reactions to each exhibit by analyzing the conversations they had and their answers to questions regarding the most impressive exhibits after the exhibition experience.

The first exhibit surprised all participants because while performing everyday actions for safety and security, such as measuring body temperature or recognizing faces, they could unknowingly share their data. Thus, this surprise became a foothold for the audience to experience the negative aspects of AI technology, which felt positive in their everyday life (P2,5,7,18,21). In particular, the participants were impressed by the experience of their facial data becoming part of the AI's image in the exhibit (P1,18,21).

As the second exhibit comprised the main character's diary, the audience gradually immersed themselves in the story. In particular, as the diary began with a scenario wherein the user used a smartphone and AI speaker, participants could easily relate with the main character of the diary (P3,11,24). Additionally, they had opportunities to think about recording themselves as messages and photos at all times while imagining the future of how personal data could be used (P4,11,14,23).

The third exhibit was chosen as the most impressive artwork by most participants. Contrary to the dark mood, the soft material, appearance, and relaxed attitude of the animals in this exhibit made participants think about the dilemma of AI technology by dealing with the contrasting theme of a comfortable life and losing identity. Therefore, several participants equated the animal sitting comfortably with themselves, who could not live without AI recommendations. Through this immersion, the participants presented various conflicting thoughts, such as 'I want to sit comfortably like the animal forever even if I lose my identity' (P2, 9, 6, 20) and 'I cannot sit comfortably like these animals anymore' (P12, 16, 18).

The fourth exhibit allowed the participants to learn about current AI technologies as some participants were unaware that the sensor technology can identify users through their gait . Further, the participants mentioned that the exhibit was impressive because it allowed them to observe the negative aspects of devices with sensing technology that tracks health information, such as the Apple Watch, regarding which they previously had only positive thoughts. Furthermore, gamification for the interaction method provided entertainment and a sense of immersion, as though participants were actually avoiding AI surveillance in the future (P5,7,13,17,19).

4.1.2 Attributes of exhibition experience. Several attributes of the exhibition that contributed to this change in their critical thinking regarding AI were explored in the debriefing interviews. Briefly, 17 participants stated that *interactivity* contributed to the changes in their thoughts on the impact of AI. Ten participants stated that they could recognize the influence of present and future AI by physically seeing and interacting with the art exhibits. Furthermore, four participants mentioned that the ambiguous impact of AI became more evident through direct interaction and engagement compared with learning in the conventional formal context or by consuming news, advertisements, and entertainment content.

> *"When I read about AI in books or texts, I felt like I was just gaining knowledge. However, by seeing the exhibition with my own eyes and interacting with my body, I could experience AI in a more immersive and direct manner."* (P5)

Figure 11: Capturing the moment of participants' free time activities

Participants also mentioned that *abstract expression* of the exhibits helped them imagine and think divergently about the personal and societal impact of AI. Five participants shared that they could discuss various topics such as the nature and definition of AI, the qualities that distinguish good or beneficial AI systems from potentially harmful implementations, and what it might be like to experience the story themselves as the main character while interpreting the abstract nature of the art exhibits. Particularly, P15 and 16, who actively shared their imaginations about future AI in the exhibition space, described *abstract and implicit expression* attribute as follows.

> *"As an abstract art exhibit, the intention of the works is not conveyed clearly like 1+1 is 2. Rather, it inspires me to think about different things. For example, in the third exhibit, I was thinking, Why do the giraffes have short necks? Why do rats have long legs? Starting with this thought, I reflected on various interpretations."* (P15)

In addition, the *narrative* of the exhibition allowed participants to immerse themselves in the story; therefore, they could intuitively understand the relevance of AI in their lives. The individual stories of the exhibits and the overarching storytelling between the exhibits, which expressed the overall narrative of the exhibition, were successful in gradually immersing participants in the experience.

> *"In the past, even when I heard about problems AI-related problems, I didn't care because they did not affect me directly, I didn't think they [AI-related issues] would affect my daily life in future. However, after seeing an exhibition with a story like this, I feel like it could happen to me."* (P22)

Along with the narrative, guided experience played a role in closely connecting exhibitions and participants. In particular, because the guided experience was designed based on the narrative of the exhibition, it encouraged the audience to become more immersed in the narrative. In addition, participants could recognize new stories and intentions of exhibits that they could not discover alone. Furthermore, the discussion about their thoughts as part of the guided experience allowed the participants to become aware that their thoughts had changed.

> *"Before I heard the explanation about the third exhibit, the animals only looked comfortable, but I did not recognize that the animals had lost their characteristics. So I realized that I was only looking at what I thought positively. Similarly, when I use AI, I also realized that I was accepting AI recommendations without any concerns."* (P16)

4.2 Exhibition experience and critical thinking process

Although the participants experienced the exhibition by following the guided experience, interestingly, they actively performed several activities not included in the study design. First, the participants asked us to allocate free time to take pictures with their friends and share their opinions on social media to organize their thoughts. Secondly, participants established their own perspectives through discussions with friends wherein multiple parties expressed different, often contradictory opinions and persuaded one another through dialogue.

After all participants had finished interacting with the exhibits, 15 participants spent an additional 30-60 min capturing pictures of the exhibits to record the exhibition experience as shown in Figure 11. Furthermore, seven participants, in addition to taking pictures, uploaded their exhibition experiences to social media by tagging the location and using hashtags. Among them, two participants wrote reviews recommending others to attend the exhibition, and five composed long-form written posts to share their thoughts (see Figure 12). Owing to the nature of social media, they spread the exhibition experience by sharing and reposting the group's posts. Furthermore, a few days after the exhibition, our participants posted additional photos and continued their conversation on social media. Evidently, exhibition-related feeds on social media could encourage youth to continue conversations on the topics of the exhibition beyond the physical event itself.

Notably, in contrast to some studies that have reported that youth tend to express their opinions with a passive attitude owing to the consciousness of others' judgments [59], participants shared their opinions and discussed exhibition topics with their friends both during and after the exhibition experience without the moderator's intervention. In fact, the moderators planned to request a group discussion in the exhibition hall, but participants naturally began discussing ethical issues such as AI and human relationships and data authority issues with their friends while experiencing the exhibition (see Figure 13).

> P1: *"If you were in this situation, do you think you prefer to would die and leave behind an AI trained entirely on your data, or would you delete all your data when you die? I have no regrets; I'll delete it all. I hate the idea*

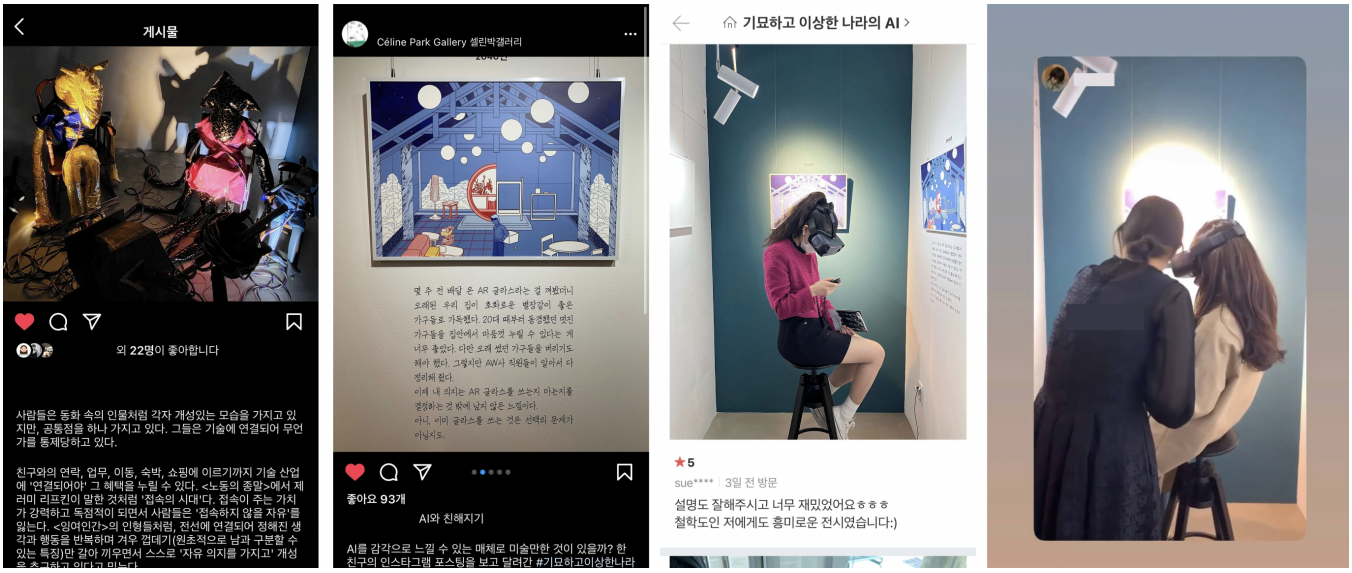

Figure 12: Posts uploaded to social media by participants from left to right: Instagram posts, reviews, Instagram stories

that an AI would live on and mimic me."
P2: *"Really? I had a similar opinion to yours before. However, now, I've changed my mind. I don't think I can delete it because it's precious as the memories I've accumulated. Also, as this exhibit showed, if an AI can talk to a child instead of me, even after I die, the AI can answer for me if my child wants to ask me anything. Isn't that good?"* (Conversation about exhibit 2)

Furthermore, conflicts and tensions owing to differences in opinions, expectations, prejudices, and experiences among participants. Our participants collectively shaped their perspectives toward AI through this active discussion; they convinced their friends and disagreed about various topics including the relationship between humans and AI and the social impact of AI. Although some participants may have had similar thoughts on a specific topic of AI, some divergences in perspective existed owing to the complex characteristics of the subject. Hence, the discussion began with subtle differences in the participants' views. For example, P13 believed that humans and AI must maintain a horizontal relationship for his dream job to continue to exist in future. However, P12 believed that coexisting with AI in a hierarchical relationship is not an authentic coexistence, thus disagreeing with P13. After discussing relationships between AI and humans, P13 eventually agreed with P12.

P12: *"People usually say that a hierarchical relationship is coexistence, but if one side takes it all, that's not coexistence. Or, if AI takes over a specific role performed by people, that is also not coexistence because someone loses their job. I know it's difficult, but wouldn't AI be able to collaborate with humans as a member of society?"*
P13: *"I thought that AI had to obey humans unconditionally. However, after listening to your thoughts, it would be more convenient to just create ideas with AI together. Sometimes, AI might provide tasks for humans; at other times, humans could provide tasks for AI. Then, it would be possible to just work together in an equal or equivalent position."* (Conversation in the exhibition hall)

4.3 Changed perceptions of AI after the exhibition

As shown in previous findings, the participants experienced various activities in the exhibition and evolved their thoughts on AI independently while thinking critically about AI in relation to their own lives. Thus the post-exhibition interviews allowed us to explore how participants' perceptions of AI changed after the exhibition.

4.3.1 AI is Siri → AI could be anything. In the pre-exhibition survey, when participants were asked what they thought AI referred to, 21 participants mentioned AI assistants, such as Siri and Alexa. Additionally, in the quantitative evaluation, 12 participants answered that they did not know what AI was, with an average response of 3.39 out of 7. However, all participants scored the same or higher after the exhibition, especially, seven participants who scored 1 or 2 before the exhibition answered the same question with an average of 4.78 afterward, thus showing a significant difference. For example, P2, who initially rated their knowledge of AI at 2 points, changed it to 6 points after the experience.

"I wrote that AI meant systems like Siri. Because Siri was personified and defined by Apple, I naturally thought of all AI as being like Siri. However, I learned that AI can also be hidden or embedded in various devices, services, and places naturally rather than being like Siri and Alexa." (P2)

Figure 13: Capturing the moment during participants' discussion

For youth who have grown up in the AI era, the term "AI" is familiar and difficult to define [108]. Consequently, our participants tended to perceive AI as a simple and narrow concept that is easy to define clearly, such as AI speakers or a computer. However, after experiencing the impact of AI through exhibits, participants became aware of the possibility that anything in their daily life could involve AI, and that AI could develop a deeper relationship with humans.

> *"I thought that AI might not have much to do with me, like Siri or Bixby, for example. However, it seems that it has already more involved in our lives than I thought, so there was a connection with my life already. Thus, I realize that I have to live with the awareness of AI."* (P14)

4.3.2 AI has only good or bad sides → AI has many aspects. Before experiencing the exhibition, the participants held positive or negative biased views on AI. However, participants were able to recognize their ambivalence toward AI and expand their perception to include new possibilities through the educational role of the exhibition. In the open-ended pre-exhibition questionnaire, when the participants were asked about the influence of AI, 12 participants focused only on positive aspects such as 'AI makes human life easier'. Moreover, 8 out of 23 participants answered questions about the negative influence of AI with just 'I do not know'. Participants who focused only on the positive impact stated that their biased perspectives were based on the advertising for AI that they commonly encountered in everyday life.

> *"AI makes life more comfortable, so I only thought about the positive side. Also, I read a lot of articles that emphasized only the positive side of AI. Usually, I haven't experienced any negative impacts so far, so I didn't know much about it. However, mainly owing to the third exhibit, I reflected a bit on the negative aspects."* (P17)

Furthermore, three participants mentioned that although the volume of dystopian movies and TV series has recently increased, they felt difficulty in connecting with the real negative impacts of AI on their lives (P3,11,23).

> *"When I watched such an AI dystopia movie, I didn't feel like it would come true and felt that it was just distant or fictional. However, after I experienced it here, I think this future could really come true in my life. I was a little scared."* (P11)

Conversely, participants who focused on the negative influence of AI unconditionally expressed negative perceptions without considering any positive aspects of AI. For example, some participants who stated they never trusted AI, could identify some positive aspects through the exhibition experience (P1,19,20,22). Subsequently in the debriefing interview, they mentioned that they could reach a balanced perspective by recognizing the ambivalence of AI. P6, who only thought negatively about AI, said,

> *"When I came to the exhibition hall, I realized life coexisting with AI was not as bad as I thought it would be. I've been thinking about the good points of AI. In other words, I have discovered a new possibility that AI also has a positive impact."* (P6)

Regardless of what they had in mind previously, the participants who perceived different aspects of AI developed balanced perspectives and recognized the numerous aspects of AI (P1,2,4,5,10,12,17-19,20,22,23). Essentially, knowing about the negative aspects of AI did not change the participants' original opinions; rather, by accepting its complexity, they recognized that AI is difficult to distinguish as good or bad.

> *"Of course, I am still a bit negative about AI. Still, I realized that all future AI technologies seem to inevitably be multifaceted."* (P17)

After understanding the impact of AI and its various aspects, participants independently considered a strategy to minimize negative impacts and maximize positive benefits. Some participants became increasingly aware of personal data most relevant to their daily life (P1,3,4,5,6,14,15) and others expressed the need to become aware of AI in their lives (P2,3,5,13,22). These participants also noted that examining and using AI with awareness is not an absolute refusal of AI technology, but rather a better approach to using such systems.

> *"I just watched YouTube content without ever wondering why the algorithm recommends this kind of content. Still, from now on, it would be good to consider the reasons more actively. However, this is not because I doubt AI; if I learn more about this myself, I could use an AI technology that might suit me better."* (P3)

4.3.3 Future AIs are personal assistants in smart homes → Collaborator with my dream job. Our exhibition inspired the participants to imagine various future applications of AI and related scenarios

with their friends. Particularly, participants focused on imagining the type of relationship they might have with AI, and how their dream job might be affected. In the pre-exhibition survey, when asked to write about the future AI they imagined, 16 participants described futuristic systems, such as personal assistants in a smart home or an autonomous car commonly shown in actual advertisements. However, during and after the exhibition, some participants imagined an ideal AI that could fit their situation and help with their dream jobs through discussions with their friends, often thinking well beyond the systems presented in existing advertisements (P2,5,8-10,11-13,19,20).

> *"My dream is to become a car designer, and I had no expectations for the future of AI because I previously thought that AI would be like Siri now. However, while imagining the future with my friends, I considered that AI can design creative shapes that humans might not be able to, and I can follow instructions for an AI system or collaborate, right?"* (P13)

P5, who dreams of becoming a nurse, previously thought that AI could not become an expert. However, based on recognizing the potential of AI, he imagined that he could work as a nurse alongside an AI doctor. His friend P6, who heard P5's change of opinion, also shared a similar thought.

> *"I want to become a government official performing structured tasks. So I imagined I would just sit back, listen to the AI secretary, see what's going on, and just answer with yes or no. But, after listening to P5's opinion, if doctors can be replaced by AI, AI could be my boss or actively analyze documents and do everything with me on an equal footing."* (P6)

Furthermore, imagining relationships wherein they would work alongside AI was directly linked to participants' desire to learn about AI more. Some participants expressed a desire to begin studying AI to learn to effectively use and collaborate with AI technology (P1,2,4,11,20). Thus imagining AI in the context of a future dream job and the desire to learn could be unique characteristics of youth in an educational environment.

> *"I want to create music someday. So, I expect an AI musician to provide objective feedback and know my tastes. Thus, if that AI is released, I need to learn a lot first to collaborate, because when I use it, I want to maintain my creativity without being swayed by the AI's decisions."* (P11)

4.3.4 Ethical AI is defined by society → by my governing values. Through the exhibition experience, participants reflected on the standards for ethical AI that they wished to use and coexist with. In response to the question regarding the direction of ethical AI in the pre-exhibition survey, 19 participants wrote that ethical AI does not negatively affect humans and mentioned the need for regulations to help design AI within ethical guidelines. Additionally, 12 participants described ethical AI standards as familiar but used abstract phrases such as 'keeping people's data safe' or 'protecting people from biased algorithms.' The results of this survey revealed that participants perceived ethical standards for AI superficially based on words that frequently appear in mass media.

In contrast to the pre-exhibition survey responses, some participants expressed detailed attributes that the future AI should have according to their values (P1-5,6,8,10-12,14,15,17,18,22,23) such as, 'How should AI be developed in the future?', 'What steps must be taken in terms of data collection to ensure data safety?', 'What AI is needed for your future?', and 'How should the ethical direction of the relationship between humans and AI be defined to live with AI systems?' Through a discussion centered on various questions, the participants established their own standards for ethical AI by reflecting on their thoughts and values.

> *"In future, when tech companies develop AI, I hope they include not only developers but also people in various fields, like psychology, philosophy, or history. If so, when developing artificial intelligence, they could consider not only practical purposes but also various social impacts."* (P2)

Moreover, some participants had internalized AI ethical standards related to their intended future professions. Three participants who wanted to become AI developers (P1-3) felt responsible to produce ethical AI. Thus, they set a standard for the types of developer they want to become. P3 stated that he wants to develop AI to ensure that others do not have the concerns he had during the exhibition.

> *"I want to develop AI because I understand the cause of people's concerns about AI. I intend to develop AI that can explain the principles of algorithms to users to address their concerns. If possible, I want to build AI that gives users extensive information."* (P3)

5 DISCUSSION

Deliberating our findings, several implications for designing the exhibition as informal learning experiences to foster youth's critical thinking competency about AI by associating it with their lives are presented herein. At the end of the section, building on these implications, ways of designing learning experiences to extend these competencies from exhibitions to everyday life are further discussed.

5.1 Designing the exhibition as a scaffolding to connect AI with the youth's lives

The attributes of exhibitions <AI with Weird Wonderland> encouraged participants to consider the relevance and influence of AI in their lives. This section reflects on how the notable design considerations of informal learning scaffolding from our findings—*interactivity, abstract and implicit expression, narrative, and guided experience*—affect the effective learning experience. Based on attributes of our exhibition, design considerations for designing the exhibition are suggested to help the youth better understand the relationship between themselves and AI.

Interactivity including data visualization and affordances facilitated the audience's experience of the exhibition. Additionally, the high-fidelity interaction of the exhibits enabled participants to interact with the exhibits freely and independently. Previous research has emphasized the importance of embodied interaction and low barriers to entering AI-related exhibits and facilitating

learning and flexible experiences [74, 77]. Building on previous studies, a youth-centered interface and interaction design along with embodied interaction should be comprehensively considered.

In addition, *abstract and implicit expression,* which was rarely considered as an attribute of exhibits in previous research on HCI, was appropriate to include the complex aspects of AI in the exhibits. The participants in this study were able to diverge their thoughts from various perspectives while interpreting metaphorical and implicit expressions of the exhibits, rather than only obtaining knowledge regarding AI. Furthermore, this interpretation process supported the participants in envisioning their future. Consequently, to evoke critical thinking and envision the future of AI technology, the metaphorical and abstract expressions, primarily considered in artwork, need to be applied when designing AI-related exhibitions.

The *narrative* of the entire exhibition designed in this study helped the participants to relate their lives with AI by empathizing with the story of the exhibits and gradually immersing themselves in the exhibition. Taking a step further from the previous study that emphasized the narrative of individual exhibits [74], the narrative between the exhibits enables the youth to expand various imaginations related to them. Therefore, AI-exhibition curators or HCI researchers who develop AI-related exhibits need to consider designing a narrative for the entire exhibition.

Finally, our findings revealed that *guided experiences* supporting the narrative adopted the role of a communicator or storyteller, who connected the youth with the exhibition as an informal learning environment. Further, regardless of how well the exhibits are designed, a communicator is needed to connect the audience with the exhibits [27]. Moreover, as the questions about thought change triggered youth's critical thinking process, activities after the exhibition need to be included in the guided experience. Therefore, designing guided experiences, including before and after the exhibition, must be considered to allow the audience to fully experience the attributes of the exhibits.

Overall, our considerations supported the participants in effectively understanding the influence of AI and imagining its future by connecting these technologies to their own lives from a critical perspective. The above suggests that by incorporating these attributes, the exhibition needs to educate the youth on the technical aspects of AI literacy and help inspire immersion and empathy as a scaffolding to connect the influence of AI with their own lives.

5.2 Unveiling learners' self-understanding of preconceptions about AI

In this study, the pre-exhibition survey provided opportunities for the participants to retrospectively analyze their preconceptions regarding AI and organize their thoughts before the learning experience by recalling their previous experiences with AI, and by recognizing their related preconceptions.

Recently, owing to technology-oriented AI education, youth tend to easily accept AI as a field of knowledge related to programming and CS rather than as a critical issue worth pondering over [3, 111]. Similarly, participants had difficulty determining and recognizing the connection between themselves and the AI before exhibition. In this respect, it was possible to investigate how open-ended questions support the youth in unveiling their self-understanding of AI. According to Piaget's theory of cognitive development, learners' self-understanding is an essential step in acquiring and internalizing new competencies [50].

In line with this, AI educators need to consider providing opportunities for unveiling learners' self-understanding for comparison with new competencies and preconceptions on AI to develop critical thinking competencies. Although this study helped learners develop self-understanding through an open-ended questionnaire survey, this approach can be extended to existing informal learning contexts. For example, at the entrance of an exhibition, the audience could be questioned about familiar AI topics, such as YouTube algorithms. This approach could help and inspire participants who are unfamiliar with AI to consider their relationship with these technologies.

5.3 Encouraging tension-filled discussion to shape perspectives

Participants' critical thinking competencies were not fostered only through exhibitions. If the discussions presented no conflicts, the participants would have difficulty in effectively shaping their thoughts within a short time. The discussions held in this study helped organize and verbalize the participants' abstract thoughts with a concrete idea; thereby providing a lesson that could apply to their lives. As opinions about AI technology have been extremely controversial depending on what people think rather than on a single correct answer [87, 108], these active discussions aided in understanding diverse opinions and allowed the participants to organize their thoughts according to their values.

Previous studies have also emphasized discussions with others as an effective approach to AI literacy education [69, 73, 74]. In particular, discussing emotions about AI technology with groups in an informal educational environment can provide cross-learning opportunities on various topics. Aligning with other studies, the present work also considered discussion sessions for sharing thoughts and emotions in the design phase of the learning experience.

However, we did not expect the participants to initiate the discussions or that the process of expressing disagreement and engaging in persuasion would facilitate changes in the participants' perspectives. In particular, disagreements began when they expressed subtly differing views, which led to attempts at persuasion, contemplation, and changes in opinion in some cases. Consequently, the experience became an opportunity to listen to others' opinions on living and collaborating with AI and allowed the participants to actively shape their own thoughts by comparison.

Therefore, we propose that learners with different preconceptions, experiences, attitudes, opinions, and expectations of AI be grouped together to induce disagreement and discussion beyond simply sharing their thoughts and feelings. Moreover, because these discussions occurred when the participants shared their thoughts before and after further reflection or change, the educator or moderator could promote discussion by asking questions focused on changes in viewpoints while encouraging the participants to take the initiative in engaging discussions.

5.4 How can youth bring critical thinking competency from the exhibition to everyday life?

Our previous discussions proposed several implications to foster youth's critical thinking about AI by associating it with their lives. Building upon these implications, we note that the real purpose of associating critical thinking on AI with the participants' lived experience is to continue developing these competencies even after they return to everyday life, and encourage them to become critical and responsible AI users.

Although the long-term development of critical thinking competencies in everyday life was not explored in this study, it would be necessary to attempt beyond the scope of this research. In our findings, the participants mentioned the importance of AI awareness when returning to daily life and reconsidering their use of AI more wisely than in the past, as mentioned in Section 4.3.2. Additionally, social media posts supported continuing the conversation on the topic of the exhibition even after the event concluded and the participants returned to their daily lives, as explained in section 4.2. This suggests a design direction, with respect to continuing conversations, for bringing critical thinking competencies from exhibitions to everyday life. For example, a digital platform derived from an exhibition could be provided for youth to share their thoughts even after the exhibition concluded. Particularly, if youth subsequently reflect on their thoughts during the exhibition in daily life, they can visit the website and continue engaging in the topic of AI with their friends. Further, this platform can encourage additional social activities and support learners in extending the exhibition experience into their daily lives through the transition from thinking to action via active conversation.

In an approach similar to developing sustainable thinking, Exposure Labs [63] filmed a documentary about the dilemma brought up by social media to help people maintain an awareness by providing discussion guides [64]. These attempts accelerated a user's willingness to change the way they use social media rather than ending with a documentary viewing with a large audience. Similarly, for AI literacy education, continuing to think about and developing competency from learning experiences to daily life is essential to foster the youth's critical thinking competency. If these attempts are applied in education, they can help provide opportunities for youth to develop sustainable critical thinking competency and consequently become responsible and critical users in the AI era.

6 LIMITATIONS AND FUTURE WORKS

We here outline the limitations of this study and opportunities for future research. This study focused on three aspects of AI literacy. We believed that focusing on selected competencies rather than broad competencies as educational goals would be more effective in short-term learning situations. However, because critical thinking competency is a complex process involving various other competencies, cultivating youth critical thinking competency with only the three competencies selected presents limitations. To overcome this challenge, we derived competencies through analysis of 33 papers. Future work will be needed to consider other aspects of AI literacy and other educational goals that we have not covered.

It should also be noted that we tried to recruit numerous groups of participants while maintaining small groups for effective learning. However, owing to the pandemic, only relatively few participants could be accommodated on any given day during the one-week long exhibition. Additionally, some participants were unable to participate because they tested positive for COVID-19. Therefore, further studies are needed to determine whether our findings generalize to larger youth groups.

Finally, concluding that the youth fully developed their critical thinking competency through the short-term learning experience of the exhibition is challenging. Moreover, changes in AI perceptions described by our participants, such as future scenarios, may not be novel compared to previous educational outcomes. However, this study aimed to focus more on changes in youth's thinking after experiencing the exhibition. Therefore, significant changes in the participants' thinking were determined both quantitatively and qualitatively. Furthermore, we considered that these thinking processes from exhibition experience could be good practice to foster participants' sustainable competency, which could become seeds that could lead to further applied into everyday life. In this regard, future work is needed to investigate the fostering of critical thinking competency in youth through a longer-term learning experience, as explained in the Discussion section.

7 CONCLUSION

Through the exhibition, this study investigated how youth can obtain critical thinking competencies toward AI and applied them into their lives. The exhibition <AI with Weird Wonderland>, comprising four art exhibits created via collaborative workshops with various stakeholders to ensure balanced perspectives, was organized. Subsequently, to explore changes in critical thinking competency before and after the exhibition, an informal learning experience through the exhibition was designed and a user study with 23 youth audience was conducted. Our findings indicate that despite the short-term experience, the youth engaged in critical thinking regarding AI as it is associated with their lives. Consequently, their perception regarding AI expanded, their desire to learn using AI increased, and they established their own standards for ethical AI. Furthermore, the process itself became an exercise in critical thinking competency because the youth deeply explored their thought processes. Based on this, the possibilities of exhibitions as an effective means of overcoming the limitations of formal education were explored. Drawing on the present findings, implications were proposed for encouraging youth to relate their critical thinking competencies to their lives and become sustainable critical users of AI. We hope that implications related to the education, design, and HCI fields will be useful for AI educators, HCI researchers, developers, and designers interested in AI literacy education, including critical thinking competency. Looking at a society in which AI has become a center of youth culture, education, and daily life, we hope, through a multifaceted education approach, to help the youth effectively collaborate with AI and grow into critical and responsible users.

ACKNOWLEDGMENTS

We appreciate all the creators for their contributions to creating artworks; all of our study participants for participating in exhibitions during the pandemic. We are sincerely grateful for the constructive feedback offered by colleagues, and all the anonymous reviewers on this paper. This research was supported by the 4th BK21 through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (MOE) ((NO.4120200913638).

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A APPENDIX

This section outlines the central questions about open-ended questions for the before-exhibition survey and debriefing interview after the exhibition we wanted to cover. Through the before-exhibition survey, we were able to identify participants' preconceptions. In addition, during the debriefing interview, we were able to follow up and explore participants' critical thinking processes and thought changes beyond these specific questions owing to open-ended questions.

A.1 Open-ended questions for the before-exhibition survey.

A.1.1 Understanding and distinguishing AI.

- What is AI ? Write down what comes to mind when you think of AI.
- How or what is your relationship with AI?, Please describe your relationship with the AI that you currently use.
- Do you know the principle of how AI can learn and develop like a human?
- Are you familiar with the principle of the process by which algorithms that you use daily, such as TikTok, YouTube, and Instagram, provide recommendations?

A.1.2 Understanding the impact of existing AI.

- Do you know any positive influence that current AI has on you personally? Please feel free to list what you know.
- Do you know any negative influence that current AI has on you personally? Please feel free to list what you know.
- Do you know any positive influence that current AI has on our society? Please feel free to list what you know.
- Do you know any negative influence that current AI has on our society? Please feel free to list what you know.

A.1.3 Imagining future AI and its impact.

- What will the future in which you coexist with AI be like?
- What relationship will you have with AI when you start working in the future?
- Do you know any positive influence that future AI will have on you personally? Please feel free to list what you know.

- Do you know any negative influence that future AI will have on you personally? Please feel free to list what you know.
- Do you know any positive influence that future AI will have on our society? Please feel free to list what you know.
- Do you know any negative influence that future AI will have on our society? Please feel free to list what you know.

A.2 Debriefing interview after the exhibition

A.2.1 Warm-up questions.

- Which exhibit impressed you the most?
- How was your overall experience of the exhibition?
- How was the experience of viewing the exhibition with your friends?

A.2.2 Questions about thought change.

- What thoughts come to mind during and after this exhibition?
- During and after the exhibition experience, how was your perception of AI? If it changed, please explain the changes.
- What thoughts came to your mind about AI during and after the exhibition experience?
- Have there been any changes compared with the answers to the previous questions and your thoughts about AI before the exhibition experience?
- Did this exhibition give you a new perspective or a new stimulus to your perspective toward AI?
- If there were new perspectives and stimuli, what were they?
- What made you think of a new perspective? Or what factors caused the new stimulus?
- Has this exhibition influenced your attitude toward AI?
- The goal of this exhibition was to have a critical perspective on AI. Do you feel that you have undergone a critical thinking process? If so, what are your thoughts, and why was this thought process possible?

A.2.3 Questions about the exhibition experience.

- Why and on what topics did you have a casual discussion with your friends in the exhibition hall? How did that discussion affect your thinking?
- How was your experience of freely taking photos with your friends and interacting freely with the artwork in the exhibition hall? How did this experience affect your thinking? (What content did you upload to social media?)
- What is the difference between your previous exhibition experience and this one?

A.2.4 Comparison questions with before the survey.

- Please feel free to explain if you have any changes in your thoughts while rereading your answers to the before-exhibition survey questionnaire.