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Understanding students' learning of technology through interaction supported by virtual reality

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Abstract

Given the profound influence that technology has on society, shaping our behaviours, conversations, and decisions, it is essential to understand its development and nature. Obtaining a complete understanding of technology requires us to explore both the nature of technology and its historical aspects. This study examines how using supportive images in a virtual reality (VR) learning environment, combined with verbal interactions, supports students aged eight and nine in developing an understanding of the nature of technology. Data were collected during an ordinary technology teaching activity and the analysis highlighted that these students, through interactions and VR images, demonstrated knowledge of all dimensions of technology, as described by DiGironimo (2011). The analysis of the findings indicated that the students' knowledge could be categorized, but there seemed to be more complexity in their utterances than DiGironimo's model could capture. Additionally, I employed a discursive analysis to achieve a deeper comprehension of the students' perceptions of the history of technology. Here, the findings indicate that VR images can promote students' interaction related to the history of technology, which often leads to exploratory conversations. The findings have the potential to support teachers in planning and conducting technology activities in primary schools, where images and verbal interactions could provide decisive support for developing an understanding of the nature of technology, especially the historical dimension of technology.

Key Words

DiGironimo, Discursive moves, Historical dimension of Technology Primary students, Technology Education, Virtual reality images, Virtual reality.

Introduction

It is essential to understand how technology develops and what it is, not only because most of our modern society depends on it but also because technology employs a significant presence and pressure in various aspects of our daily lives, shaping our behaviours, interactions, choices and even our thought processes (Arthur, 2009). Society and technology are determined and emerge in an intertwined sociotechnical activity (Bijker, 1999). Therefore, knowledge of technology is too important to be left to a few specialists (Arthur, 2009). In this regard, the Swedish curriculum states that teaching technology should enable students to think about technological change and historical perspectives on the development of technology (Hallström, 2023; Skolverket, 2022).

Learning about technology's historical failures and successes could explain how an emerging technological society is shaped (cf. Condoor, 2004; Read & Alexander, 2019). Latour (1990) argued that to be able to achieve an understanding of technological systems (such as infrastructures) and incorporate new narratives about them, one could follow the development of an invention. Technology and society are interrelated regarding the development of each other (Franklin, 1999).

Eliasson et al. (2023b) stated that the historical dimension of technology, as part of the nature of technology, is important to be able to understand new emerging technologies and their advances and that technology is a central part of civilisation (see also Liou, 2015). Therefore, becoming technologically literate involves knowledge in and about older and newer technology and is thus about becoming historically educated in technology to be prepared for readiness for action in the future (Hallström, 2023). Consequently, if the historical dimension of technology is not included in the general understanding of technology, it will not be easy to develop knowledge and understanding of the emerging modern technology's impact on society, humans and the environment (cf. DiGironimo, 2011; Eliasson et al., 2023b; Liou, 2015). Further, excluding the historical dimension makes it difficult to understand contemporary technology issues and their effect on society and humans (Eliasson et al., 2023b). Therefore, teaching and learning about the history of technology is central to technology education.

The present study focuses on students' interactions concerning mundane technology. To get close to the students' thoughts on the history of technology, a *virtual reality learning environment* (VRLE) was designed. The VRLE includes communicative situations in the classroom where *virtual reality* (VR) images support the students' verbal interactions. Here, VRLE incorporates an environment where the students can engage in exchanging ideas and provide conditions to interact on technology. Through the teacher's questions and interactions with fellow students, they may jointly develop an understanding of mundane technology, both contemporary and historical.

Less is known about the impact of VR images in promoting young students' developing knowledge of the nature of technology. This study examines student interactions and delves into how VR environments support student discussions. By closely examining these interactions within VR learning environments, the study reveals the potential that VR environments hold in enriching students' understanding of the nature of technology. Therefore, the present study examines how interactions incorporating image-based virtual reality experiences can support primary students in demonstrating knowledge of the history of technology.

Aim and research questions

The study aims to investigate primary students' developing knowledge of the nature of technology. An additional aim is to examine how supportive images in a virtual reality learning environment support students' verbal interaction.

These aims led to the following research questions:

- In what ways do primary students demonstrate knowledge of the nature of technology?
- In what ways do images in a virtual reality facilitate small group interactions related to the history of technology?

To give the students opportunities to develop knowledge of the history of technology, it was achievable to let them partake in a VR experience where two parallel timelines were displayed.

Theoretical background

Students' development of technological knowledge

DiGironimo (2011) constructed a conceptual framework (see Figure 1) including five dimensions that represent the nature of technology. Each side represents different perspectives of technology, labelled as *artefacts* (including products of technological innovation and educational technology tools), *a human practice* (the role humans play in the production, maintenance and use of technology), and *a creation process* (the technological design process and methods of technology). These sides cannot exist without each other, indicating that one cannot engage in technology as a human practice without engaging in the dimensions of technology as artefacts and technology as a creation process. *The history of technology*, technology as an essential part of human history, forms the base of the prism, while the way the prism stands up represents the technology evolving out of its history. The purpose of technology, *The Current Role of Technology in Society,* is placed at the top of the prism to show time in a vertical direction and that the prism will never be fully complete.

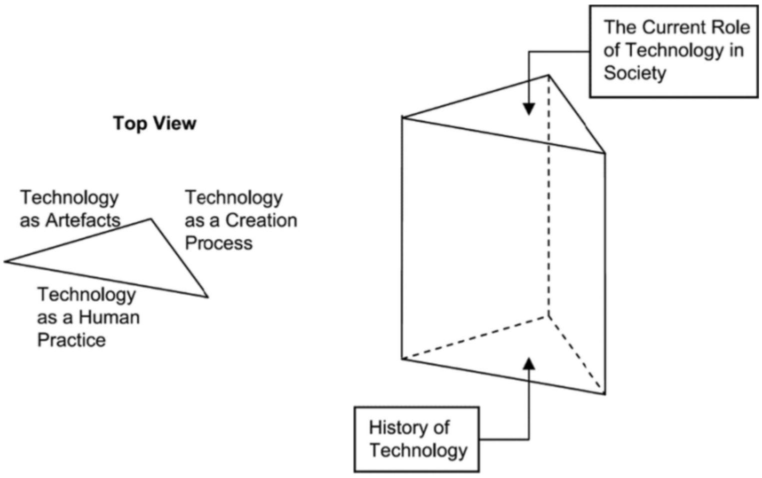

Figure 1. The nature of technology (DiGironimo, 2011)

The historical dimension of technology in the framework (DiGironimo, 2011) can be used in technology education. It is a way of showing that technology has developed throughout history and thereby gives students opportunities to develop widened knowledge about technology (cf. Eliasson et al., 2023a).

The history of technology is not a clear linear development (Mitcham, 1994), and the making of artefacts is not always a simple gathering of technological knowledge. It is not only social needs and values that are central to the development of artefacts but also philosophical ideas. This indicates that developing and manufacturing artefacts historically is not a simple process (Mitcham, 1994). In addition, de Vries (2016) presented a distinction between experience-based technology and micro-technologies. Here, experience-based technologies are referred to as technology developed through human history, and micro-technologies are referred to as technologies in which essential parts are microscopic technology, such as microchip technology.

In a study on technology teaching in preschool, Eliasson et al. (2023a) explored how technology activities are carried out and what knowledge is made accessible for the students to learn through the interaction between the participants. The results indicate that technological knowledge was established related to four of DiGironimo's (2011) five dimensions of technology. However, none of the students related to the historical dimension of technology. This is in line with an exploratory study conducted on middle-aged students (Grades 6, 7 and 8), aiming to develop a tool for analysing student conceptions of the nature of technology (DiGironimo, 2011). The students' answers to the survey were related to the conceptual framework (see Figure 1) developed by DiGironimo (2011). The results indicate that the students lack knowledge of the dimension history of technology.

Lind (2023) discussed how students perceive and develop knowledge of technological artefacts in their nearby environment. Based on the students' prior conception of technology as contemporary technological artefacts, the findings indicate that students (aged eight and nine) are capable of advancing a nuanced view of technological artefacts, for example, developing knowledge that technology could be considered as experience-based technologies (cf. de Vries, 2016) and not just contemporary artefacts functioning with electricity.

Research on virtual reality in education

VR can support students in moving outside the classroom, thereby taking advantage of opportunities to learn about things available in out-of-school settings and extending learning beyond the classroom (cf. NETP, 2017; Sala & Sala, 2005), which can lead to a deepening understanding, for example, of technology. It is also a way of processing information and making it more comprehensible (Sala & Sala, 2005). Hence, VR enables a teaching and learning environment where the visual plays an important role when the students develop an understanding of concepts (cf. Nooriafshar et al., 2004; Shao-Chen et al., 2020; Song & Li, 2018). This is a growing field of educational research that examines opportunities and obstacles in the use of VR in teaching and learning.

Petersen et al. (2022) described two features of virtual reality: *interactivity* and *immersion*. Interactivity is the degree to which the student can interact with the virtual environment the students are put in (Steuer, 1992; Mütterlein, 2018) and the freedom the students are given to control the learning experience (Petersen et al., 2022). The students' perceived interactivity could be considered as their possibility to influence the virtual environment interactively when looking at the individual's presumptions and prior knowledge of VR (Mütterlein, 2018). Immersion could be described as the feeling of being caught up in and absorbed by the virtual environment, as well as how the student enjoys the experience (Petersen et al., 2022; McMahan, 2003). Slater (2018) highlighted the concept of presence in VR, which is the illusion of being in the place and perceiving and responding to the object displayed in the VR environment.

Korallo et al. (2012) conducted a study consisting of a virtual environment with three parallel historical timelines presented to 27 undergraduate participants. The purpose was to use a virtual environment, which possibly enabled students to cross-refer while taking active action through a virtual historical environment and thereby remembering information better. The authors suggested that undergraduate participants could use the virtual environment more effectively, as they remembered historical chronology better than when the same material was taught using standard learning materials in the control group (Korallo et al., 2012). Parong and Mayer (2021) asserted that students achieve better learning outcomes through lessons utilising low-end VR equipment, characterized by low immersion and a low sense of presence, a finding supported by Selzer et al. (2019). Here, Foreman et al. (2008) found that primary-aged students answered historical chronological questions more correctly when using successive images on paper than after virtual environment experiences. Consequently, it appears that primary-aged children are slightly disadvantaged compared to older students when using virtual environments to learn historical material, which indicates that the use of paper images can be as good as using virtual environments in history teaching (Foreman et al., 2008). However, Albus et al. (2021) stressed that *signalling* (visual or auditory cues) through directing students' focus and attention (cf. Mayer, 2014) may support and improve students' learning outcomes (Ozcelik et al., 2010) in VR environments, especially when recalling knowledge and making sense of the presented material (Mautone & Mayer, 2001). Here, signalling becomes essential in the teacher's guidance of students' attention and focus on technology in the interactions to improve learning and understanding. The teacher uses signalling when overlay images and arrows to point out a specific perspective of technology, for example, historical dimensions.

Theoretical perspectives

In this study, examining verbal interactions within classroom settings proved essential for gaining an understanding of students' understanding of technology. Verbal classroom interactions between students are essential in technology education, encompassing situations where students are inspired to collaborate and become involved in discussions with fellow students to explore different perspectives on technology (Fox-Turnbull, 2018). By creating situations for interaction containing digital tools, such as VR, in the classroom, students' world of experience can be broadened (Kerckaert et al., 2015; Mercer et al., 2019). In that context, the teacher's use of signalling becomes essential for initiating and perpetuating student discussion. Lind et al. (2024) and Lind et al. (2019) highlighted that visualisations can support students in representing and communicating their understanding and knowledge of technology in classroom interactions. Walldén and Nygård Larsson (2021) emphasized that images can be advantageously chosen to enable students to make connections with their prior knowledge and personal experiences.

Students have varying abilities to articulate concepts as they move between everyday and scientific languages, as well as in their success in formulating subject-specific language (Nygård Larsson & Jakobsson, 2017). The concept of discursive moves describes a linguistic move between everyday discourse and a subject-specific discourse, a movement between the concrete and the abstract, as well as a movement between the specific and the general (Nygård Larsson & Jakobsson, 2017). Mercer and Wegerif (1998) defined exploratory talk as speech where students engage critically and constructively with each other's ideas to reach a joint agreement. Indicating that knowledge and ideas are explicitly debated, students' reasoning is visible, and the talk offers justifications and suggestions. In the exploratory talk, language is essential for successful participation in disciplinary discourses (Mercer & Wegerif, 1998), such as the practice of technology. To explore its impact on disciplinary discourses, discourse analysis was applied. The sociocultural discourse analysis focuses on the significance of language as a tool for teaching and learning, collaborative problem-solving, constructing knowledge and sharing understanding (Mercer, 2004). In an educational setting, discourse analysis refers to the analysis of sequences of talk in a social context, such as a small group of students solving a joint problem; in other words, how language is used and the quality of the interactions are changed during a collective thinking activity (Mercer, 2004).

Bansal (2018) identified three goals that are served by teachers' *discursive moves*. These moves are being used by the teacher to bring coherence and establish a culture of dialogue in the classroom setting. The dialogic discourse (cf. Mortimer & Scott, 2003) has been categorised as foundation, initiation, and perpetuation. Firstly, the foundation moves lay the foundation for rich discussion to occur. Secondly, the initiation move involves stimulating the students' interests and enlightening them with different perspectives. Lastly, the perpetuation move regards the teacher's perpetuating interest in the initiated subject in the dialogues. This involves teachers encouraging rich dialogues supporting students to elaborate on the reason behind their ideas, as well as organising safe opportunities for productive exchanges of ideas and basing the discourse on students' arguments and reasoning (Bansal, 2018).

Nennig et al. (2023) created a framework to analyse discourse from students' perspectives. The framework, Students Interaction Discourse Moves (SIDM), has three levels: *type of interaction*, *primary intent*, and *nature of utterance*. Nennig et al. (2023) emphasized that the first level – the type of interaction – states how students broadly interact with each other, for example, *independent work*, *instructor interaction*, *on-task*, and *unengaged*. The second level – primary intent – states the purpose of the student's interactions and involves discursive moves, such as *concluding*, *initiating*, *commenting*, *questioning*, and *external interaction*. The third level – nature of utterance – characterizes in what ways students engage in a specific discursive move; for example, *agreeing*, *assessing*, *building*, *clarification seeking*, *explanation seeking*, *information processing*, *personal remark*, *presenting a claim*, *repeating*, *rejecting*, and *summarizing*. The framework can be utilised to identify how and when students engage in specific discourse moves, essential to achieve rich descriptions of students' interactions in small groups. Further, it can be used to identify factors that promote interactions where students jointly exchange ideas with each other to develop a joint understanding (Nennig et al., 2023).

Methodological considerations

To enable interactions about the history of technology, images in VR were accessible to support students' move towards a deeper understanding of technology. In this study, the VR images were essential to the interactions. The selected VR images were closely related to a specific content area, such as technological artefacts, containing information and located in an environment students recognise, like a kitchen (see Picture 1). VR allows students to visit environments that are not otherwise available in a classroom, which can enable understanding. In exploring the VR environment, they apply pre-understanding of technology and gain new insights, enhancing their understanding of technology (cf. Hite et al., 2023).

Picture 1. Images relating to the kitchen

The immersive virtual reality learning environment (VRLE) supports active participation, discussion, and collaboration, making learning dynamic and interactive. The students engaged with the VR images and discussed the experience with fellow students to progress through the teacher's instructions and questions (see Figure 2). In that way, the VR image supports a mutual focus for the students in the class. VR can be significant for enabling subject-focused interaction on technology, which can strengthen technology teaching and enhance students' learning (cf. Bansal, 2018). In the study, the students utilised VR images to explore and identify the 19th-century environment and relate this with 21st-century overlay images. The intention of utilising two historical timelines was to create a historical relatedness between interrelated mundane artefacts. This means that the VRLE provides the students with opportunities to collaboratively engage in exchanging ideas to reach a joint understanding of content (cf. Bansal, 2018).

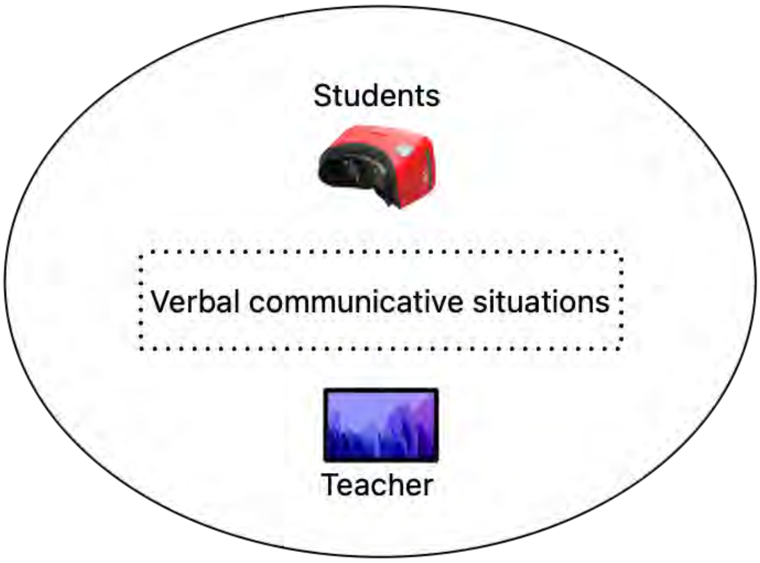

Figure 2. Virtual reality learning environment (VRLE) in this study

In this study, VR refers to hand-held low-immersive VR equipment for smartphones (see Picture 2) that has a low ability to interact with the displayed environment (cf. Juan et al., 2018). The enveloping 360° image can create a sense of temporal immersion (cf. Efstathiou et al., 2018), as the students can interact by moving their heads, thus eliciting a feeling of being present in the chosen historical time (Livatino et al., 2022).

Picture 2. VR technology used in the classroom

The teacher guides the teaching from a tablet and switches images alongside verbal questioning and instructions. Following this, opportunities appear to decide what the students should look at; for example, some points of interest in the enveloping 360° image, such as a pair of shoes. The teacher verbally and by signalling directs the students' attention to a specific artefact to involve it in their interactions (Albus et al., 2021), making it possible to direct the students' attention and coordinate a mutual focus on specific content. In conclusion, the virtual reality learning environment can facilitate and frame teaching (see Figure 2). In addition, VR supports the students in delineating and directing attention to the essential parts that the teaching aims at.

As described earlier, VR is utilised to create immersion and enable the teacher to, through signalling, add and display 2D overlay images to emphazise technological artefacts in the enveloping image. Thus, the distance between the present and the past is shortened, as the enveloping 360° image represents a 19th-century house, and the overlay images are from the 21st century.

Settings and participants

This study was conducted in a multilingual municipal school in the southern part of Sweden and followed ordinary teaching in technology. The class involved 24 students, aged eight and nine, and their teacher. The participating students were familiar with learning activities involving VR. In these, the VR images function as a mutual focus of the student's interactions. The empirical data consisted of one audio and video-documented technology activity (60 minutes) encompassing a VR experience. The audio recordings (using six pieces of equipment) were undertaken while students worked in small groups (2–4 students in each), while the video recording equipment mainly focused on the whole class discussions. By creating communicative situations, the students were given opportunities to develop and deepen their subject-specific language, for example, by using fellow students' statements and using them to demonstrate new knowledge (cf. Mercer et al., 2019). In the present study, a statement means anything that has been verbally uttered by anyone in the group. Therefore, the meaning of the utterance could differ between groups and individuals regarding the students' verbal abilities, such as second-language students. In these situations, working in small groups creates better conditions for facilitating interactions (e.g. Jakobsson & Kouns, 2023).

Earlier research has stated a positive relationship between VRLE and learning outcomes (cf. Korallo et al., 2012), such as making information and concepts comprehensible (cf. Sala & Sala, 2005). Using VR images achieves positive learning outcomes (for example, in technology teaching), regardless of the level of immersion. To investigate these outcomes, a study was conducted in a VRLE in a classroom setting (see Figure 2). The verbal interactions among students, teachers, and VR images were recorded, transcribed, analysed, and discussed concerning previous research.

Ethical approval

Ethical approval was required. Therefore, informed consent from the guardians was collected (Shamoo & Resnick, 2015; Ministry of Education and Research, 2021). In addition, an application for an ethics review was made, with a positive response (Codex, 2022). Ethical aspects were treated according to the current ethical considerations of the Swedish Research Council (2017).

Collecting data

The aim was to investigate how students demonstrate knowledge of technology through verbal interactions supported by images in VR. Therefore, getting close to the student's knowledge and understanding of mundane technology was desirable. The technology content in the activities included finding and discussing technological artefacts in the enveloping 360° VR image. This gave opportunities to answer the research questions.

The audio recording equipment was placed in each group to record the individual students' expressed knowledge of technology. The whole-class discussions were recorded on the video-recording device. The focus of the interactions was directed towards technology. In total, the empirical data encompassed 257 minutes.

To ensure the results were reliable, I spent time in the classroom before data collection to ensure that I affected the learning situations as little as possible. The conclusions are drawn from a solid theoretical foundation based on previous research on students encountering technology in school. The findings are not generalizable, but transfer to similar contexts is possible, although students' various ways of interacting may affect the findings (cf. Tracy, 2010).

Analytic process

Thematic analysis is a reflective method that is useful when investigating various perspectives of participants and identifying similarities and differences (Nowell et al., 2017). The deductive thematic analysis aims first to address the research question of how students demonstrate knowledge of the nature of technology and categorise students' knowledge of technology by utilising DiGironimo's framework, which offers a comprehensive understanding of technology by also emphasizing its historical dimension. This means distinguishing within which dimensions of the framework the students express knowledge. Secondly, the analytic procedure continued with a discursive analysis approach to achieve a deeper understanding of the students' understanding of the history of technology.

All of the collected data were reviewed rigorously, carefully and repeatedly (cf. Cohen et al., 2011; Nowell et al., 2017), and content-related situations during students experiencing technology in a VR environment were selected (257 minutes). The content-related situations consisted of students verbally expressing knowledge of technology, which captures a theme and involves qualitative richness (Nowell et al., 2017).

The focus was on the chosen content-related situations in which the students more explicitly demonstrated knowledge of technology. This involved situations where students explained the technology perceived in the VR experience to fellow students and the teacher. The utterances were transcribed and written down. All transcripts were translated from Swedish to English. This material would be used for the in-depth analysis of the student's knowledge of technology with supportive 360° VR images (197 minutes). In this phase, the analysis process focuses on deductive coding based on DiGironimo's five dimensions of technology (Nowell et al., 2017), with a specific focus on the first research question.

An in-depth analysis of the chosen excerpts was conducted. Accordingly, utterances were analysed concerning the framework presented by DiGironimo (2011). To illustrate how the students absorb technological knowledge, some examples of extracts from the transcribed empirical work were chosen, where the students show their understanding of technology. It became possible to identify situations where the students' interactions correlated with the images in the VR experience (cf. Efstathiou et al., 2018; Livatino et al., 2022; Sala & Sala, 2005). In this phase of analysis, DiGironimo's framework was found to be wide, as all five dimensions were represented in the small-group interactions.

While the second research question aims to investigate how VR images support students' small-group interactions, concerning the history of technology, I felt it was important to add another perspective on the students' interactions. Following this step, the analytic procedure continued with a detailed evaluation of the earlier chosen excerpts, in line with the framework defined by Nennig et al. (2023). The framework was the starting point for further elaborating on the students' interactions in this study, describing students' discursive moves while working through an assigned task. The discourse analysis primarily builds on the three-level characterization of students' interaction discursive moves (SIDM).

Each excerpt was read thoroughly to ensure a comprehensive understanding of the content. The excerpts were systematically organised according to the first level – *type of interaction* –as the initial dimension of analysis. This level is identified by how students broadly interact with each other. This was followed by a second, detailed reading, after which the excerpts were recategorized based on the second level – *primary intent* – of the interaction, describing the purpose of the students' posts in the discussions. A third reading was then done to classify each excerpt according to the third level – *nature of utterance* – which constituted the third analytical dimension of the framework. This is characterized by how students display a specific *primary intent* and what purpose the students' utterances serve for the small-group interactions.

Finally, the students' discursive movements were examined, focusing on the interplay between everyday language and subject-specific language (Nygård Larsson & Jakobsson, 2017). To identify how the teacher tries to bring understanding and create communicative situations, the teacher's discursive moves were analysed – categorised as foundation, initiation and perpetuation (Bansal, 2018). This approach facilitated a nuanced understanding of the interactions present within this learning environment.

Table 1. Thematising of the students' utterances related to DiGironimo (2011)

The nature of technology	Students' utterances
Technology as an artefact	*Stove, oven* *Kitchen, cottage* *Stuff* *Where is the toilet?*
Technology as a creation process	*Certainly, cook there.* *Cooked cold food.* *It is made from wood.* *Shoes are made from wood.*
Technology as a human practice	*They cooked food.* *You open the door so and so and then you close it – so* *They had a coffin as a wardrobe.* *Where are they pooping and peeing?*
The history of technology	*So old.* *It was a long time ago.* *Old stove, how the old stove looks like?* *What did the humans' clothes look like, I want to know that.*
Current role of technology in society	*[…] stuff we need.* *Help us to survive.* *I have one of these at home.* *I have one that comes with wheels.*

Findings and analysis

Thematising the students' utterances

The first part of this section focuses on the first research question and categorises students' utterances according to the five dimensions of DiGironimo's framework. The findings are presented in the form of short utterances from longer interactions. It was clear that the small group interactions gave opportunities for students to demonstrate knowledge of technology within all dimensions of the framework (see Table 1). This is not in line with previous research (e.g., DiGironimo, 2011; Eliasson, 2023a), as the dimension of the history of technology became visible in this study's interactions.

Students' utterances related to DiGironimo and VR

To approach the second research question, regarding whether VR promotes students' understanding of the history of technology, an in-depth analysis of the student interactions related to the teacher's question "How technology used to be?" was conducted. The displayed excerpt serves as a typical example of how the students in group interactions demonstrate knowledge of the dimension of the history of technology. These utterances can be categorised as identified perspectives of technology, in line with DiGironimo (2011). In addition, Efstathiou et al. (2018), Livatino et al. (2022), and Sala and Sala (2005) argued that VR environments can create immersive experiences of a historical situation and make the presented information easier to understand.

Excerpt 1: How technology used to be?

V1	Cy	*So old. Everything is wood, and porcelain.*
V2	Moha	*There was something in the door.*
V3	Cy	*Do they have metal? Do I think or…?*
V4	John	*Mmm…no, maybe.*
V5	Cy	*They have porcelain. I think they have concrete as well.*
V6	John	*I know and there is stone on the floor.*
V7	Cy	*I don't think it's concrete, it's thick porcelain.*

In *"So old"*, Cy refers (V1) to what he considers an old environment in the image displayed. The utterance implies that he perceives that technology might have been improved as it is old and, compared to new technology, everything here is made of wood and porcelain. He argues that there are two different materials in the displayed image, which could be interpreted as containing smaller parts of an artefact, for example, constructing materials. In that case, *"Everything is wood, and porcelain"* (V1) could be considered parts of the displayed technology; therefore, this could be categorised as technology as a creation process (TC). Materials are considered a small part of artefacts, and therefore, technology is considered a creation process. Instead of responding, Cy continues discovering and identifying materials (V3), *"Do they have metal?"*, which can be related to the image displayed. He states (V3) *"Do I think or…?"*, which is more likely a question aimed at himself than at the group to elaborate on. John's (V4) *"Mmm…no, maybe."* is a responding answer to Cy, which allows him to follow up with (V5) *"They have porcelain. I think they have concrete as well"*. Finally, John's statement (V6), *"I know, and there is stone on the floor"*, is a response to Cy's utterances on materials in the VR environment. Thereby, indicating that they agree on the materials, John adds stone as another material he identifies. Cy reflects (V7) *"I don't think it's concrete, it's thick porcelain"* to reach a final decision on materials in the displayed VR image. The students distinctly refer to the VR image displayed to them, which indicates that the freedom to look at what they find most interesting could motivate and engage students to actively interact around a topic that they identify and initiate themselves.

In the following excerpts, the students' questions stand as typical examples of how the VR environment possibly affects their thoughts on the history of technology. These questions can be utilised by the teacher to create communicative situations where the students elaborating on the historical technology can continue.

Excerpt 2: The history of technology related to the VR experience

V8	Jovan	*What did the humans' clothes look like? That I want to know.*

In the example, Jovan initiates a question (V8), *"What did the humans' clothes look like?"*, related to the history of technology and, in doing so, the dimension of technology as artefacts, *"clothes"*, and technology as a human practice, through humans' interaction with the artefact, becomes visible. This question comes out of group discussions regarding images of the chest and the wardrobe and the fact that humans in the 19th century could use chests as storage for their clothes, whereas, in the 21st century, humans in a Western context commonly use wardrobes or dressers.

Excerpt 3: The history of technology related to the VR experience

V9	Nono	*Is there a bathroom?* *Where are they pooping and peeing?*

Nono looks at the enveloping image and asks two questions (V9): *"Is there a bathroom? Where are they pooping and peeing?"* which is prevalent in other groups as well. This indicates that this issue is relevant to some of the students in the class. Like Jovan's question, these questions could be related to the dimension of the history of technology. Further, the pooping and peeing issue is also most relevant for this student. Nono seems to want to learn about how these issues were solved in the 19th century. This is closely related to technology as a human practice as *they* could be interpreted as people and, following, that humans utilise the toilet.

Table 2. Identified perspectives on the history of technology related to VR images

Identified perspectives	**Examples of utterances**
Technological systems The students described artefacts and a conceivable technological system and questions related to a historical perspective.	*Where are they pooping and peeing?*
Materials The students identified various materials in the VR images related to a historical perspective.	*Everything is wood, and porcelain.* *Do they have metal?* *They have porcelain. I think they have concrete as well.*
Historical perspective The students perceived the history of technology.	*What did the humans' clothes look like?* *So old*

The excerpts above focus on students' statements when discussing the VR images. These utterances can be related to the dimension of the history of technology and the teacher can guide the students to make the information understandable; that is, to highlight what is and is not worth noting in this activity.

The students' interaction discursive moves

The above analysis indicates that students' utterances are more complex than the dimensions of DiGironimo's framework, which suggests that the second research question – how VR images possibly support students' interactions – needs to be further examined. Hence, it was evident that another perspective was required to investigate students' discursive moves (Nennig et al., 2023) during an assigned task. The students' discursive moves are denoted in italics throughout the paper. Excerpt 4 illustrates how the students interact when using VR images as support. In this excerpt, it was possible to highlight the aspects of **type of interaction**, **primary intent** and **nature of utterance** in the framework suggested by Nennig et al. (2023). This will be described below.

The intent of the interaction, presented by the teacher, indicates that the students are actively discussing the assigned task; this type of interaction could be regarded as *on-task*. Throughout the small-group interactions, the students are sticking to the assigned task: *on-task*.

In the following example of an *on-task* interaction, the teacher utilizes a 360° enveloping VR image from the inside of a house built in the 19th century. The teacher perpetuates interest in the assignment by encouraging the students to elaborate and exchange ideas about the image displayed.

Excerpt 4

U6	Jovan	*Check out, the shoes are also made of wood*
U7	Olivia	*Everything is made from wood*
U8	Jovan	*Except for the floor, it is..*
U9	Olivia	*We lived there…*
U10	Ruth	*Oh my God*
U11	Jovan	*Every single thing in the house is made from wood*
U12	Teacher	*(Displays an image of a modern vacuum cleaner)*
U13	Jovan	*Vacuum cleaner*
U14	Amir	*Is it a vacuum cleaner?*
U15	Teacher	*What did the vacuum cleaner look like in the past?*
U16	Olivia	*It is only with sticks and then they do like… (showing how a broom is used)*
U17	Jovan	*Yeah, sticks*
U18	Ruth	*Which are tied*
U19	Olivia	*Everything is made from wood*
U20	Teacher	*Can you imagine that we have come from the broom to …*
U21	Jovan	*…the vacuum cleaner*

The teacher initiates further discussion by displaying an image of a modern vacuum cleaner as opposed to the broom in the enveloping 360° image (U12). The displaying of images is a way to guide the students further in understanding the history of technology, as well as holding on to the interest the students showed in the class discussions. The initiation moves, as the teacher points at the broom (signalling); this involves stimulating the students' interests and enlightening them with different perspectives, which is possible as the two timelines are presented alternately to the students. Signalling in a VR environment can support students' learning, as it provides them with attentional guidance. Jovan (U13) and Amir (U14) are both *on-task* in their interaction. However, both of them also interact with the teacher about the displayed image. Here, the teacher perceives an interest and engages the students by addressing (U15) *"What did the vacuum cleaner look like in the past?"*. The question initiates another perspective on technology, as it highlights that the vacuum cleaner has a history and has been developed throughout history. In this case, the students are enlightened by another perspective of technology: experience-based technology and microtechnology. This initiation move stimulates the students' interests and provides them with different perspectives, which becomes clear as the students (U16–U19) are *on-task* in their interactions. Now, to keep the student's interest in the topic, the teacher asks (U20) "*Can you imagine that we have come from the broom to …"*, to stimulate imagination and thus obtain further perspectives on the topic. However, this question only gives one answer, which does not allow any students to elaborate further on the historical development of the vacuum cleaner.

The discursive moves, the *primary intent*, *commenting* and *initiating* are present in Jovan's statement (U6) *"Check out, the shoes are also made of wood"* as he makes a personal remark that possibly engages and initiates the discussion in the group. Olivia's (U7) *"Everything is made from wood" contributes to the discussion* as a response to Jovan's initial exclamation. It is also conceivable to identify her utterance as *commenting* on Jovan's utterance as she adds a personal remark. Jovan *initiates* (U8) the group to look at the floor, which *contributes to the discussion* and further investigates the environment. Olivia is a bit *off-task*, by *commenting* (U9) *"We lived there…"*. This could be Olivia showing her understanding of the historical development of a house. However, this passes unnoticed by the rest of the group. Ruth's exclamation (U10) *"Oh my God"* might be her *acknowledging* Olivia's idea of us living in the displayed 19th-century house. Jovan *concludes* the discussion by uttering (U11) *"Every single thing in the house is made from wood"*.

After the teacher showed the broom in the enveloping 360° VR image and displayed a 2D image of the vacuum cleaner, both Jovan (U13) and Amir (U14) *commented* on the issue. The *question* by Amir *"Is it a vacuum cleaner?"* requires his fellow students to respond during the activity. The history of technology comes into focus as the teacher asks the question (U15) *"How did the vacuum cleaner look like before?"*. Here, Olivia (U16) is *commenting* on how the broom is functioning and used. She also *initiates* a discussion on both the function and the material a broom is constructed of, which is a way of *contributing to the discussion* as she adds a perspective of technology and, by that, likely *concludes* that the broom is technology. Jovan (U17) acknowledges Olivia's input by agreeing and *commenting "Yeah, sticks"*. Ruth (U18) *contributes to the discussion* and *concludes* as she ends Jovan's utterance on the broom. Again, Olivia (U19) makes a personal remark on the material in the environment *"Everything is made from wood"*, which could be considered her *conclusion* to the discussion. By stating (U20), "*Could you imagine that we have come from the broom to …"* the teacher tries to initiate a discussion on the relationship between the vacuum cleaner and the broom. However, the question spurs a single answer *"…the vacuum cleaner"*, which is Jovan (U21) *concluding* the sentence.

The nature of the utterances of Jovan's first statement (U6) could be identified as him *presenting a claim* as he suggests an answer to the teacher–initiated activity. Olivia (U7) *repeats* parts of Jovan's utterance *"Everything is made from wood"* and adds that not only the shoes are made of wood but everything. Jovan's statement (U8) *"Except for the floor, it is …" builds* further on Olivia's statement and tries to *present a claim* but is interrupted by Olivia (U9), who makes a personal remark and adds a historical perspective, which probably is built upon *past experiences*. Ruth (U10) responds to Olivia, which probably *motivates* and brings some encouragement to the group. Jovan (U11) *repeats* and *builds* on the other participants' utterances and concludes that *"Every single thing in the house is made from wood"*.

The two historical timelines are displayed as the teacher (U12) adds a 2D image overlayed on the image of the broom. Here, it is feasible to recognise that Jovan (U13) *provides information* to the whole class as he interacts with the teacher more than with his group. However, the utterance by Amir (U14) is more relevant to the group discussion as he seems to *seek* and *request clarification* from fellow students or the teacher that his interpretation of the overlayed image is correct. Amir is also *reporting* a question to move the discussion forward. His question is not further elaborated on because the activity is moving forward when the teacher adds another perspective on technology into the discussions (U15). Here, Olivia (U16) is engaged in the interaction by contributing a *non-verbal interaction* as she physically participates and shows how the broom is functioning. Olivia also tries to understand and *process the information* she gets. By doing so, she *provides information* to the discussion, which probably moves the group discussion forward. Jovan (U17) voices *agreement* with Olivia's utterance on the *"sticks"*. Ruth's utterance (U18), *"Which are tied",* could be considered her *building* on Olivia's utterance and expanding her ideas. She also *processes information* and transforms the information given by Olivia to try to comprehend and develop understanding. Finally, *information* is *provided* as Ruth adds a perspective on how the broom was made. Olivia (U19) *summarizes* by *building* and *agreeing* on earlier stated utterances in the group that all things in the VR environment are made of wood. After the last question asked by the teacher (U20), Jovan (U21) *summarizes* and concludes the sentence.

The third level, the *Nature of utterance*, gives a more nuanced view than the second level, *primary intent*. In some cases, these discursive moves were primarily related to one primary intent, such as *summarizing* and *commenting*. Most of them were related to several discursive moves, for example, *completing*, *building*, and *providing information* related to the primary intent – *contributing to the discussion* (see Table 3).

Summary of the students' interaction discursive moves

In the excerpt, it is feasible to identify that students can keep focus in the discussion: *on-task* (the first level – *type of interaction*), indicating that they are engaged in the assignment given to them. The second level, *primary intent*, is best exemplified, in this class, in the moves of *concluding*, *commenting* and *contributing to the discussion*. *Concluding* is characterized by statements that summarize the exploratory conversation, whereas *commenting* involves personal remarks and understanding of an earlier statement. When a student *completes* or *builds* on another student's utterance, this is regarded as a *contribution to the discussion*. *Building* is always displayed alongside other *nature of utterance*, such as *initiating*. Another aspect of discursive moves is *questioning*, which often occurs in small groups. The questions could be *initiated* as *seeking explanation* and *clarification* or just as an interest in moving towards a deeper understanding of a specific area, such as the mentioned issue of where the toilet is (cf. Nennig et al., 2023).

Table 3. The relation between the discursive moves, Primary intent, and Nature of utterance, in excerpt 4 (Nennig et al., 2023)

Number	Primary intent	Nature of utterance
U6	*Commenting* *Initiating*	*Presenting a claim*
U7	*Contributing to discussion* *Commenting*	*Repeating*
U8	*Initiating* *Contributing*	*Building* *Presenting a claim*
U9	*Commenting*	*Past experience*
U10	*Acknowledging*	*Motivating*
U11	*Concluding*	*Repeating* *Building*
U12	*Teacher initiates interaction*	
U13	*Commenting*	*Providing information*
U14	*Commenting* *Questioning*	*Seeking clarification* *Requesting clarification* *Reporting*
U15	*Teacher initiates interaction*	
U16	*Commenting* *Initiating* *Contributing to discussion* *Concluding*	*Non-verbal interaction* *Processing information* *Providing information*
U17	*Commenting*	*Agreeing*
U18	*Contributing to discussion* *Concluding*	*Building* *Processing information* *Providing information*
U19	*Concluding*	*Summarizing* *Building* *Agreeing*
U20	*Teacher initiates interaction*	
U21	*Concluding*	Summarizing

Discussion

The present study aimed to investigate primary students' developing knowledge of the nature of technology through verbal interactions with supportive images in a virtual reality learning environment. To answer the first research question, the framework suggested by DiGironimo was applied. The findings indicate that the students expressed a wide understanding of what technology is. In the interactions, students discussed and thought together about technology, which promoted many perspectives on technology to emerge. This highlighted the variation in the students' utterances, demonstrating their knowledge of mundane technology verbally. This is not aligned with studies conducted by DiGironimo (2011), Eliasson et al. (2023a) and Liou (2015), where the historical dimension of technology was not clearly expressed by the students. In this study, by showing VR images and the teacher asking questions, students engaged in discussions about the history of the technology, aiming to deepen their understanding and knowledge in this field. In analysing this study’s results, it became evident that students’ knowledge could be categorized. However, since all dimensions of DiGironimo’s model were covered in the analysis of their discussion, I displayed greater details and nuances in their utterances than the model accounts for. Consequently, their discussions are more complex than the model can capture. This means that, to answer the second research question and to achieve a deeper understanding of how the students demonstrate knowledge of the nature of technology, I employed a discursive analysis. The in-depth discourse analysis involved the approach of mapping the students’ interactions, including discursive moves (Nennig et al., 2023).

Through signalling (Albus et al., 2021) and attentional guidance, the teacher emphasizes aspects of technology that stimulate students’ interest and support them in maintaining their focus on the assigned task thereby ensuring they remain on-task (Nennig et al., 2023), thereby bringing focus to the history of technology and encouraging them to examine and further elaborate on a specific topic. A previous study (Foreman et al., 2008) suggests that younger students are somewhat disadvantaged in using VR in learning. However, the results of the present study suggest that the teacher’s guidance through, for example, signalling enables younger students to discuss the content with the support of VR and thereby leads to a wider understanding of technology. The added VR images created conditions for the comparison of two historical periods.

To approach the second research question, I was able to identify the students’ discursive moves during VR learning activities and discover patterns related to students’ interactions related to the history of technology. The students move back and forth between different discursive moves, which often leads to exploratory conversations about the history of technology. Through the interaction with VR images, it becomes evident that the students offer new viewpoints, especially regarding technology material composition and functionality. For example, many students contribute to moving the discussion forward (primary intent) by adding or initiating (the nature of utterance) new perspectives on technology or building on other’s utterances (Nennig et al., 2023).

The results indicate that students jointly construct knowledge (cf. Nennig et al., 2023) about the history of technology, particularly through dialogues initiated by fellow students that facilitate agreement or disagreement, thereby advancing the discourse. This learning process enables them to further explore specific topics, such as the historical aspects of cooking, through collective reasoning and elaboration. Students’ contributions to the discussion sometimes appear insubstantial as they engage less than the other students. However, their contributions are essential as their questioning or statements could advance the discussion. This could encourage the students to jointly widen their understanding of the history of technology, demonstrating that everyone can learn from each other. Furthermore, the findings suggest that students have an enhanced understanding of technology’s emerging technologies and their advances (cf. Eliasson et al., 2023b), as exemplified when students and the teacher discuss which of the broom and the vacuum cleaner was preferable. In that interaction, the perspective of technology as experience-based technology and microtechnology (de Vries, 2016) is displayed by the teacher and acknowledged by the students.

In the present study, the analysis of the findings indicates that VR images, alongside the teacher's guidance, through signalling, informing, and questioning, appear to promote students' examining and jointly elaborating ideas of the historical dimension of technology. As the students interact with VR images, they spontaneously verbalize what they experience, which could enhance their engagement. The ability to perceptually focus could enhance the students' experience in VR, as it is a visual phenomenon and an individual experience (cf. Ihde, 2002). Conclusively, adding VR images to a learning environment could bring engagement to the classroom activity and support a mutual focus (cf. Eliasson et al., 2023a) on a topic such as technological artefacts. Teachers displaying an image is a way to emphasize differences and to perpetuate (Bansal, 2018) a discussion on the actual topic, for example, the history of technology. Moreover, providing VR images concerning two historical timelines appears to facilitate an exploration of the history of technology, as exemplified by students' questions about details within the VR environment, such as the location of toilets. The opportunity to move to another environment is one of the key strengths of utilizing VR experiences in learning situations, fostering a sense of 'presence', which is the illusion of being moved to another place, time, or setting, as articulated by Slater (2018). I suggest that students not only engage with but also enjoy the immersive aspect of VR experiences, a point emphasized by Petersen et al. (2022). Therefore, it is not possible, as Foreman et al. (2018) suggested, to conclude that VR contributes to less understanding of a subject area. However, different materials or the lack of something are discussed concerning the VR images, which indicates students verbalising pre-knowledge of technology. These aspects can lead to further discussions in class.

Didactical contributions

The use of VR images can provide technological context (cf. Lind et al., 2024; Lind et al., 2019), which can support verbal interactions and students' ability to understand the history of technology. Thus, images and verbal communication could mediate technological knowledge about technology. In the present study, the VRLE offers opportunities for students' self-determination to control and improve their conversation in a way they want, which causes several perspectives of technology to arise. Presumably, the students' continuous thinking "aloud" together enables the teacher to identify questions and claims to be further elaborated on. Consequently, providing framed VR learning activities could make certain school technology subjectivities possible and students' everyday experiences countable. A more precise vocabulary could advance students' concepts of how and why technology has evolved throughout history, involving past, present, and future perspectives. Given the young age of the students, images of everyday mundane technology were used to create a familiar discourse for the interactions. Additionally, the possible inspiration from the visual support to activate the students' prior knowledge can be used to expand their understanding of technological content. The historical perspective of technology can teach us how to manage challenges today and in the future, which can promote emerging technological knowledge.

Through the contributions of this study, new questions regarding advanced technology in education emerged. Future research could focus on the effects of applying artificial intelligence (AI), augmented reality (AR), and virtual reality (VR) in the technology classroom, for example, to engage students in verbal interactions and facilitate their emerging technological literacy.

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