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Students' and facilitators' experiences with synchronous and asynchronous online dialogic discussions and e-facilitation in understanding the Nature of Science

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Abstract
The existing literature lacks a precise understanding of how online facilitation and dialogic discussions can positively impact students' comprehension of the Nature of Science (NoS). This study delves into the experiences of students and facilitators engaged in synchronous and asynchronous online dialogic discussions and e-facilitation to enhance our understanding of NoS. An innovative experiment employed a digital dialogue game to engage postgraduate students in a Postgraduate Certificate in Education (PGCE) secondary science course. The participants included sixty-five PGCE science students and three lecturers specializing in different science disciplines (Physics, Chemistry, and Biology). Qualitative data collection methods and analysis, including transcripts of online discussions about NoS topics, were followed by critical event recall interviews to identify specific online dialogue events that significantly contributed to the comprehension of NoS. The findings contribute significantly to comprehending students' processes in grasping complex and debatable topics such as Nature of Science (NoS) within online dialogic discussions supported by e-facilitation. They emphasize the importance of establishing an open and expansive dialogic space, with a focus on the crucial roles of e-facilitators. The results also highlight a tension between active and passive roles in both synchronous and asynchronous online discussions. Additionally, the study sheds light on the influence of space, time, and texts in understanding NoS through e-facilitated online dialogic discussions. Notably, the research emphasizes the live chat room's significance within Interloc, accentuating its role as a social space fostering a sense of community and a safe environment for inquiry in online dialogue which supported understanding NoS.

Keywords PGCE science · E-facilitation · E-moderation · Digital dialogue games · Epistemic agency · Social knowledge construction · Live chat room · Social space · Online dialogue · Digital games · Nature of Science Nos

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1 An introduction

The main aim of this study is to investigate the perspectives of PGCE science students and facilitators in the context of facilitating dialogical discussions within online learning environments, with a specific focus on the Nature of Science (NoS). NoS remains a subject of ongoing debate in the field of science education, with diverse viewpoints. Some argue that science is an objective, value-free process aimed at discovering empirical facts about the natural world, while others propose that it is a socially constructed activity influenced by cultural and historical factors (Lederman & Lederman, 2019).

Several studies emphasise the critical role of the quality and depth of peer dialogues in collaborative learning (Chi, 2009; Mercer et al., 2019). Certain dialogue strategies predict individual learning gains, including explaining ideas to others (Chi, 2009), giving and receiving detailed help (Webb, 2009), elaborating on each other's ideas and collaborative problem-solving (Molin, 2017; Muhammad, 2021; Noroozi, 2021; Salmon, 2012), and participating in reasoned argumentation (Mansour et al., 2016).These factors have been found to significantly impact the learning outcomes of the collaborative activities in face to face or online learning environment (Mercer et al., 2019). Monitoring and intervening in small-group dialogue during collaborative tasks have been recommended by many educational experts (e.g., Molin, 2017; Muhammad, 2021; Noroozi, 2021; Salmon, 2012). This practice allows instructors to provide timely support, scaffold discussions, and address any misconceptions that may arise during the collaboration (Mercer et al., 2019).

Active participation in online dialogues, coupled with effective facilitation or moderation, can significantly contribute to the development of critical thinking skills, improved scientific literacy, and a more accurate understanding of the Nature of Science in online learning environments (Mansour et al., 2016; Halpern et al., 2012). For this study, the terms "facilitator" and "moderator" are used interchangeably. As described by Salmon (2012), an e-moderator plays the role of guiding and overseeing electronic meetings or conferences, bringing a wealth of expertise to support and engage participants effectively (p. 3). However, a complex aspect noted by Asterhan and Schwarz (2010) is the role of e-moderators in online synchronous peer discussions, as they often face varying expectations from students and online facilitators. Salmon (2012) elucidates that the e-moderator plays a crucial role in fostering human interaction and communication by modeling, conveying, and building knowledge and skills. By employing effective e-facilitation and e-moderation strategies, educators can guide and support students in exploring diverse perspectives, questioning assumptions, and collaboratively constructing knowledge (Yang & Chang, 2013). Consequently, the study explores the experiences of students and facilitators participating in both synchronous and asynchronous dialogic discussions, aiming to better understand their dynamics and potential disparities (Halpern et al., 2012). Additionally, the study investigates how online dialogue and facilitation can enhance students' learning experiences and epistemic agency

in understanding NoS. Epistemic agency refers to students' ability to actively participate in the scientific community, engage in scientific practices, and develop a deeper understanding of scientific concepts (Zhang et al., 2022).

1.1 Dialogue and Interloc "digital dialogue games" in learning science

The term "dialogue" extends beyond a misconception that it refers exclusively to an interaction between two people. Originating from Greek roots, "dia," signifying "through" or "across," and "logos," a term often translated as "discourse," "speech," or "reason," emphasizes a more comprehensive and nuanced definition (Phillipson & Wegerif, 2019). Dialogic approaches are inherently relational, recognizing that dialogue extends beyond the mere words used, encompassing the broader dynamics of communication between individuals (Bakhtin, 1981). Dialogic approaches have the capacity to illuminate our understanding of natural science phenomena and aid in the enhancement of science teaching by building upon students' existing comprehension (Siry et al., 2016). Dialogic and open-ended approaches in science education can function as inclusive methods, positioning learners to build on their existing knowledge and fostering curiosity (Siry, 2020).

Mansour's 2020 study reveals that the utilization of dialogic pedagogy is impacted by the application of evidence pedagogy in teaching school science through inquiry. This influence is further shaped by individuals' perspectives on scientific evidence and science. The study emphasizes the essential role played by science teachers in implementing dialogic pedagogy, particularly in evaluating the scientific evidence presented by students during the dialogue to support their claims or perspectives on science or the Nature of Science (NoS) (Mansour et al., 2016; Mansour, 2020). Thus, science educators must possess a clear understanding of their own scientific viewpoints to grasp those of their students. This comprehension empowers them to effectively interact with these perspectives and advance the utilization of dialogic pedagogy by integrating these scientific beliefs into the discourse on science (Mansour, 2020; Chowning, 2022; Kilpelä et al., 2023).

InterLoc, as a digital dialogue game, leverages instant messaging technology to facilitate online discussion activities within small groups. By employing "dialogue games," InterLoc encourages learners to collectively explore relevant topics, media, or materials. These games are designed to promote synchronous reasoned dialogue, critical thinking, and creative discussions (Leaning, 2015; Mao et al., 2022; Qian & Clark, 2016). Furthermore, InterLoc allows participants to generate reusable content based on their group experiences, fostering knowledge integration and collaborative learning (Leaning, 2015; Ravenscroft & McAlister, 2009).

The online dialogues facilitated by InterLoc are structured as threaded discussions, where linked messages are organized topically (Noroozi, 2021). Threaded discussions offer a distinct advantage over face-to-face discussions, as they provide an equal opportunity for all students to express their thoughts and actively participate (Meyer, 2003). In this format, participants have a leveled playing field, promoting inclusivity and ensuring that all voices are heard (Belcher et al., 2014). However, it is commonly acknowledged in scholarly circles that creating

the anticipated meaningful dialogue through online discussions poses a significant challenge (Warren, 2018).

The nature of threaded discussions poses challenges for tutors in maintaining control and guiding the dialogue compared to face-to-face interactions. The absence of real-time interaction makes it more difficult for tutors to regulate the flow of the discussion and intervene when necessary (Asterhan & Schwarz, 2010). Despite these challenges, the asynchronous format offers benefits such as increased reflection time for participants, leading to more thoughtful and in-depth contributions (Hew & Cheung, 2013). Additionally, InterLoc supports synchronous dialogue games, enabling real-time online discussions and debates. These synchronous interactions aim to develop higher-order conceptual skills among participants (Asterhan & Schwarz, 2010). By providing opportunities for immediate feedback and dynamic exchanges, synchronous dialogue games promote active engagement and enhance the quality of discussions.

1.2 Dialogue and epistemic agency in understanding the NoS

An essential aspect of science education involves empowering learners to actively construct knowledge by developing their epistemic agency (Erduran & Dagher, 2014; Miller et al., 2018). Through participation in scientific inquiry, argumentation, and reflection, students assume responsibility for their learning and contribute actively to the classroom community (Bell et al., 2013). Epistemic agency, defined in various ways, emphasizes students' capacity to shape the knowledge-building process and play an active role in their learning (Miller et al., 2018). Science educators strive to foster epistemic agency to cultivate a more accurate understanding of the Nature of Science among students. The Nature of Science encompasses how scientific knowledge is constructed, validated, and communicated. Developing epistemic agency allows students to grasp the social and cultural dimensions of science, acknowledging that scientific knowledge is dynamic and evolves through ongoing investigations and revisions (Mansour et al., 2016; Erduran & Dagher, 2014). This heightened understanding of the Nature of Science enables students to engage in authentic scientific practices and appreciate the dynamic nature of scientific inquiry (Halpern et al., 2012).

Moreover, engaging students' epistemic agency contributes to promoting equity and social justice in science education. By empowering students from diverse backgrounds to participate in the knowledge construction process, educators create inclusive learning environments where all voices are valued (Mansour, 2013; Yang & Chang, 2013). While knowledge building has been shown to be effective in promoting student learning, there are also debates and discussions around its implementation and effectiveness. One debate centers around the role of technology in knowledge building. Some argue that technology can facilitate knowledge building by providing a platform for collaborative discourse and knowledge construction (Scardamalia & Bereiter, 2014), while others argue that technology can be a distraction and hinder face-to-face interactions (Turkle, 2011).

1.3 Online dialogue and online facilitation in promoting epistemic agency

In the realm of higher education, Laurillard (2000) contends that it is imperative to move beyond mere access to information and content, placing greater emphasis on engaging with others to gradually develop personal understanding. Computer-Supported Collaborative Learning (CSCL) has seen a surge in popularity, with both synchronous and asynchronous online discussions being widely employed in educational settings. However, within the realm of online instruction, asynchronous communication has emerged as the primary method due to its convenience for both students and instructors (Asterhan & Schwarz, 2010). It allows them to engage in online discussions flexibly, regardless of time and location (Ho & Swan, 2007). A notable characteristic of asynchronous online discussions is that all participants have an equal opportunity to contribute to the conversation and thoroughly contemplate their classmates' input before sharing their own ideas (Ho & Swan, 2007). Nonetheless, a significant challenge in the realm of online learning is the preservation of high-quality and deeply engaging student interactions. Students often grapple with obstacles when attempting to participate in profound discussions and offer thoughtful contributions to ongoing discourse (Asterhan & Schwarz, 2010).

In online discussions, students often prioritize recent posts, potentially overlooking older messages. E-facilitators play a crucial role in guiding learners to older postings and aiding recall. Hew and Cheung (2013) identified three effective moderation supports: introduction (establishing a foundational role), engagement (involving activities like expressing opinions and questioning), and monitoring (suggesting new directions and summarizing discussions). E-facilitation competence involves understanding online processes, possessing content expertise, displaying appropriate personal characteristics, and demonstrating technical and online communication proficiency (Salmon, 2013). Xie and Correia's (2023) literature review outlines best practices for instructors in asynchronous online discussions, including adjusting participation based on class size, using open-ended questions, employing effective facilitation strategies, providing frequent instructional comments with genuine social engagement, and engaging in regular discussions while pursuing professional development. Vasodavan et al. (2020) summarize essential e-facilitator skills such as greetings, appreciating contributions, using humor, offering continuous support, asking open-ended questions, incorporating additional content, considering others' ideas, seeking explanations, and encouraging self-regulated learning.

It is imperative to acknowledge that the role of instructors in online learning environments has not received sufficient attention, particularly concerning the transferable skills required to transition discussions from face-to-face contexts to online platforms. This challenge becomes even more intricate when considering the distinct skills and approaches necessary for facilitating both synchronous and asynchronous online discussions, each of which entails different formats and practices (Asterhan & Schwarz, 2010). The present study endeavors to address this research gap and enhance our comprehension of e-facilitation practices in both synchronous and asynchronous online discussions, as well as the extent of student engagement in these varying formats.

While numerous studies have explored various pedagogical strategies in online education (Watson et al., 2023), there remains a need for in-depth research into how instructors engage in online dialogic discussions. For instance, Xie and Correia (2023) emphasize the importance of understanding how instructors effectively use online instructional strategies to promote student engagement and enhance learning outcomes. Research on the presence and interaction of instructors in online courses has shown that active instructor involvement positively influences student satisfaction and learning (Vasodavan et al., 2020). However, there is still limited exploration of best pedagogical practices for fostering instructor presence and meaningful interaction in online environments. This paper seeks to examine the significance of e-facilitation and e-moderation in online dialogues, with a specific focus on science education and the ongoing discourse surrounding the nature of science (Asterhan & Schwarz, 2010; Erduran & Dagher, 2014; Lederman & Lederman, 2019).

Research questions

1. What are the perceptions of students and facilitators regarding their experiences in online dialogic discussions within the context of learning about the Nature of Science?
2. What are the perspectives and experiences of students and facilitators in facilitating synchronous and asynchronous online dialogic discussions to support students' understanding of the Nature of Science?
3. What social presence emerges in online dialogical discussions to enhance the understanding of the Nature of Science?

2 Setting up the experiment

The PGCE secondary science program at University of Exeter is a ten-month course designed to prepare students to become effective secondary school science teachers. It includes observation weeks in primary and secondary schools, followed by nine weeks of targeted courses at the university. A dedicated school induction week provides practical teaching experience. The program focuses on enhancing subject knowledge and pedagogical skills in science education. It aims to produce competent and confident science teachers equipped for real-world teaching contexts.

To engender substantive discourse and foster critical thinking surrounding the profound subject matter of the Nature of Science and its alignment with the National Curriculum, the InterLoc intervention was meticulously integrated into the initial week of the university-based term. This synchronous electronic discussion platform served as an invaluable tool, enabling students to retain written records of their profound deliberations, which could subsequently be utilized as substantive evidence to inform and enrich their academic assignments. By actively promoting early engagement with this electronic discussion medium, the intention was to establish a solid foundation for sustained online discourse throughout students' subsequent school placements during the second and third terms of the PGCE secondary science course.

The Nature of Science, a fundamental tenet within the PGCE secondary science course, was methodically introduced through an interactive online discussion activity. Prior to engaging in these scheduled discussions, students were encouraged to extensively peruse pertinent literature, thereby ensuring a robust foundation of knowledge. Facilitated by experienced lecturers, the students were organized into small groups of six to eight individuals, thereby necessitating the establishment of nine distinct discussion rooms to adequately accommodate all participants. Each lecturer was assigned the responsibility of skilfully guiding the discussions within three of these groups, thereby ensuring a balanced facilitation approach across the program cohort.

The preparation for the discussion in InterLoc involved several activities (Fig. 1). Firstly, all students were required to read and explore the relevant sections of the national curriculum website to understand the concepts and processes of science. They were then asked to summarize their findings in a 200-word response. The information can be accessed at http://curriculum.qca.org.uk/. Secondly, half of the students in each group examined the Beyond 2000 paper to understand the purposes of science education. They created a bullet point list highlighting the objectives and analyzed the alignment with the national curriculum in a 200-word analysis. Lastly, the remaining students studied the paper "Philosophy of Science: An Overview for Educators" by Machamer (1998) to explore the Nature of Science. They created a bullet point list outlining the characteristics of science and compared it to the national curriculum in a brief analysis. The topic for discussion was whether the current national curriculum for science is sufficient for science education purposes and accurately represents the nature of science.

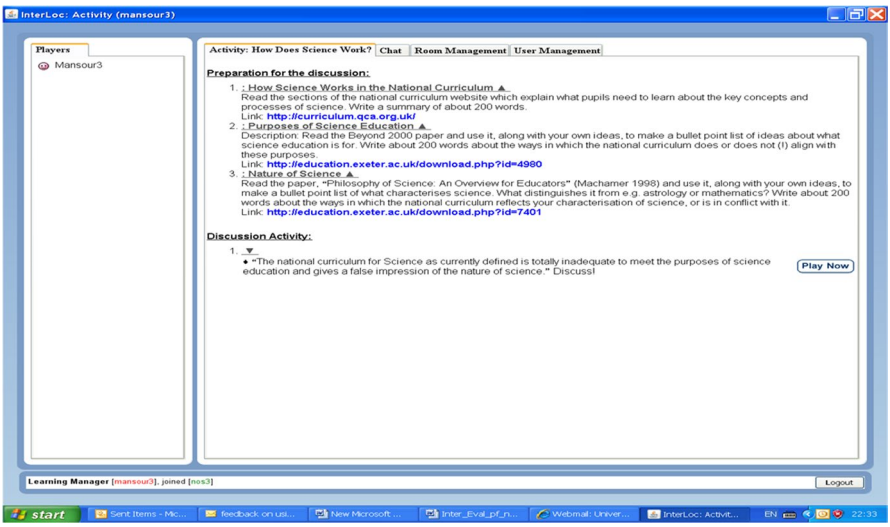

Fig. 1 The Nature of Science NoS activity and reading in the Interloc

3 Sample

The research involved a group of sixty-five PGCE students, including thirty-five females and thirty males, all of whom had science backgrounds and were pursuing careers as science teachers. All students had completed an undergraduate degree in a science subject, with several holding a Master's degree and a few having Doctorates. Among the students, forty-one specialized in biology, eleven in chemistry, and thirteen in physics. The selection of participants was purposeful, as the students were expected to find the topic of discussion and the use of a new tool beneficial for their teaching role and skills development. The discussion sessions were facilitated by three lecturers with varying levels of experience in supporting online learning and discipline background (Physics, Chemistry and Biology).

4 Research methods

The study employed a comprehensive qualitative approach to gain insights into both students' and facilitators' perspectives and experiences with online dialogic discussions and the facilitation of synchronous and asynchronous online dialogic discussions focused on the Nature of Science (NoS). Data collection involved a combination of focus group interviews with students participating in nine group discussions and individual interviews with three facilitators. Additionally, the scripts of online discussions played a crucial role in providing a deeper understanding of the participants' experiences. Critical event recall interviews were conducted to identify specific online dialogue events that significantly contributed to the comprehension of NoS-related topics (Mansour et al., 2016).

To prepare for the recall session, all participants were provided with the complete transcript of the group discussion on InterLoc. This transcript highlighted sections of the discussion where participants developed a better understanding of the Nature of Science. This step allowed participants to become familiar with the changes in their NoS scales and the content of the online discussion. The interviews covered various topics, including the ease of using InterLoc, the advantages and disadvantages of employing it for meaningful online dialogic discussions, the quality of e-facilitation, the presence of social and teaching aspects within the discussions, and the affordances of InterLoc as a digital dialogue game platform.

4.1 Data analysis

The qualitative data analysis implemented in this study entailed a comprehensive examination of interviews conducted with both students and facilitators, along with transcripts from online discussions involving nine groups engaged in dialogues and debates centered on the nature of science. The primary objective of this analysis was to gain insights into the perspectives and experiences of students and facilitators

regarding digital dialogue games and the facilitation of synchronous and asynchronous online dialogic discussions, all within the context of understanding the nature of science.

To initiate this process, the data were meticulously categorized and organized based on transcriptions of interviews and transcripts of online discussions that occurred on the Interloc platform. Nvivo software was employed to facilitate this phase, providing a structured framework for organizing, coding, and analyzing the collected data. Nvivo's capabilities allowed for in-depth exploration of textual information, enhancing the efficiency and rigor of the qualitative analysis by aiding in the identification of patterns, themes, and relationships within the dataset. The software also provided a means to attach comments and annotations, offering a way to capture valuable insights and interpretations during the analysis process. Furthermore, Nvivo proved valuable for exploring the connections between students' and facilitators' perspectives and experiences, particularly in understanding the impact of online dialogue and facilitation on student engagement.

The coding process began by generating preliminary codes from an initial reading of the online discussion transcripts for each of the nine groups. This phase aimed to comprehend the dialogue moves used by both the students within each group and their respective facilitators, shedding light on how students engaged with the subject, with one another, and with the facilitator to enhance their understanding of the topic.

For example, Fig. 2 illustrates the sequence of dialogue moves, starting with the initial dialogic move by "student_AI" regarding the "knowledge base." Subsequently, "student_St" contributes a second dialogic move concerning "the scientific knowledge of names of things." The facilitator then intervenes with a third dialogic move, emphasizing the significance of "key scientific knowledge for engaging in public reports and developing critical thinking." Finally, "student_St" initiates the fourth dialogic move, adding new information about "the scientific processes" to further develop the discussion about learning the nature of

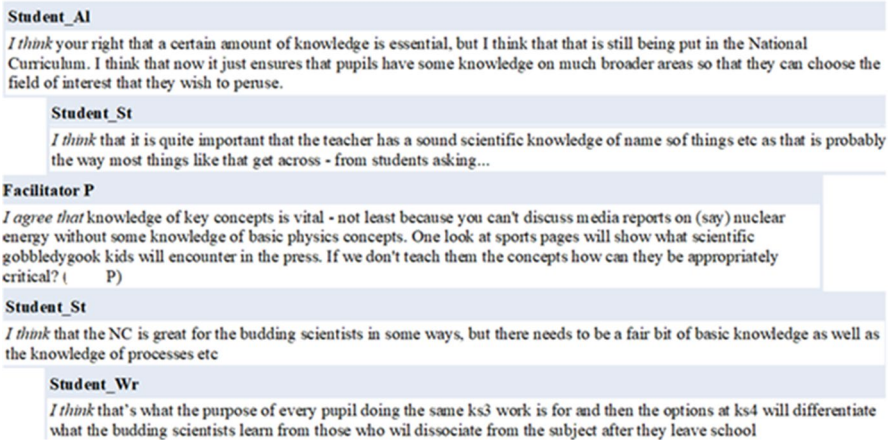

Fig. 2 An example of an interactive/dialogic e-facilitation

science. This detailed analysis of dialogue moves provides valuable insights into how participants collaboratively constructed their understanding of the nature of science through these interactions.

Following the initial analysis of the online discussion texts, which identified dialogic moves and level of constructing knowledge when debating the NoS topics, the study applied the "constant comparative technique" (Mohajan & Mohajan, 2023) to systematically analyze the interviews. This technique encompasses multiple critical stages, including open, axial, and theoretical coding.

The early phase of data analysis, known as "open coding," was conducted inductively, employing an incident-to-incident coding technique as outlined by Charmaz (2006). The subsequent step in data analysis involved the construction of categorical structures (axial coding), where categories were merged into theoretical statements. For example, two theoretical statements that emerged from this phase were "InterLoc is a valuable tool for facilitating learning and promoting critical thinking among learners" and "The degree of facilitation in online discussions fluctuated based on the facilitator's familiarity with both dialogic pedagogy and online pedagogy."

In this phase, the data analysis aimed to elucidate relationships among various categories and establish the direction of these relationships. The comparison and linking of categories were guided by Glaser's 'Six Cs': Causes, Contexts, Contingencies, Consequences, Covariances, and Conditions (1978: 74). For example, the analysis sought to understand students' experiences with online dialogue and chat rooms, investigating the connections between key scientific knowledge and processes and the nature of science. Additionally, it explored the correlations between facilitators' contributions and students' engagement and critical thinking regarding the Nature of Science (NoS).

Ultimately, the coding process unveiled the perspectives and experiences of participants regarding the use of online digital-dialogical games and the role of facilitators in helping students develop accurate conceptions of NoS. The theoretical themes presented in the findings, such as "Online dialogue and Critical Thinking in digital dialogue games," "Digital dialogue games support the challenging of ideas and new learning," "Facilitators' views of the affordances of Interloc as a digital dialogue tool," and "Facilitation of Digital dialogue games discussion," were derived from the relationships between different categorical codes. For example, the categorical codes "styles of facilitation in online dialogues" and "characteristics of Digital dialogue games and dialogic moves" were merged to form the theoretical theme "Facilitation of Digital dialogue games discussion."

By employing these analytical methods, the study aimed to unveil patterns, connections, and insights into the perspectives and experiences of students and facilitators concerning both synchronous and asynchronous online dialogic discussions, with a particular focus on comprehending the Nature of Science. Furthermore, it endeavored to explore the dynamic relationships between online dialogues, facilitation techniques, and their impact on student engagement. The subsequent section presents the findings, supported by illustrative quotations from the transcripts, offering representative insights from students and facilitators on each theme or sub-theme.

5 Findings

5.1 Students' views and experiences in online dialogic discussions

5.1.1 Open and expansive dialogic space

Overall, the InterLoc platform emerged as an invaluable instrument for facilitating the acquisition of Nature of Science (NoS) knowledge and cultivating critical thinking among learners within the context of the UK science National Curriculum. Its specific utility lies in the facilitation of idea development and comprehension enhancement, concurrently exposing participants to diverse perspectives held by their peers. One participant reported:

> *The online discussions about NoS and what science is provide a platform for me to analyze and evaluate my own arguments Vs. different arguments. It forces me to think critically about the evidence presented and articulate my thoughts effectively.*

The students affirmed the idea that establishing a dialogic space when learning science or about science characterized by openness and expansiveness, where questioning, challenging, and building upon others' ideas are promoted, is essential for fostering effective teaching and learning. One participant expressed:

> *Through the online dialogic spaces, I found that discussing scientific concepts with my peers allowed me to actively construct my knowledge about NoS. It wasn't just about memorizing facts; it was about engaging in meaningful conversations that deepened my understanding of NoS.*

5.1.2 Time and space in dialogic pedagogy

Participants praised the InterLoc platform for facilitating discussions within a meticulously structured temporal framework, providing ample time through asynchronous online dialogic discussions for the contemplation of their views on the Nature of Science (NoS) before actively engaging in the dialogic discussion of others' perspectives on the features of NoS. This setup, inherently linked to the theoretical underpinnings of time and space, contributed to a controlled and thoughtful exchange, fostering a conducive environment for reflection and deliberate participation. The intentional alignment with the dynamics of time and space on the InterLoc platform enriched participants' dialogic experiences, emphasizing the profound impact of these elements in shaping meaningful interactions. One participant says:

> *The ability to go back to the online discussions record permits me to examine diverse viewpoints at my preferred speed. This introspective review assists me in improving my critical thinking abilities and attaining a more comprehensive grasp of the subject of Nature of Science (NoS).*

Another student says:

Having the freedom to engage in asynchronous online dialogic discussions gave me the time to digest different perspectives on NoS. It's like each idea had its own space to be explored.

5.1.3 Use of chat room as social space

The study identified the chat area as a social space that some students used to break the intensity of the discussion and add off-topic comments. One student found it useful to have a space for unstructured thoughts, while another saw it as a break from the discussion. Some students also used it for technical support. Interestingly, during the interview, it was observed that some students who were frustrated waiting for their turn to reply started using the chat room to get their points across. However, not all students had the chat room open, so these points were lost to the main discussion. As a result, the study suggests that there needs to be some form of alert when new messages are posted in the chat room. One participant emphasized the necessity of having a social space for taking a mental break.

The chat area was like a breath of fresh air during intense discussions. It allowed me to share off-topic thoughts and take a mental break from the main discussion, providing a social space within the online platform.

Another student expressed that the chat room is useful for technical support, providing assistance without causing disruption to the ongoing discussion.

The chat room served as a valuable resource for technical support. Whenever I had issues or needed clarification, I could quickly reach out to others in the chat, creating a collaborative space for problem-solving.

A significant number of students found the social chat room to be a valuable space for sharing initial and personal views on the Nature of Science (NoS), contributing to the development of confidence for the subsequent online discussion of the topic. He Said:

I found the chat room useful for expressing unstructured thoughts about my understanding or misunderstanding of the NoS. It was a great space to express naive views without getting embarrassed. It was like a creative outlet within the dialogue, where I could jot down ideas that might not fit directly into the main discussion but were still relevant to general understanding of the NoS topic.

In the same sense, another student say:

There were moments when waiting for my turn got frustrating. That's when I started using the chat room to get my points across without disrupting the flow of the main discussion. It became an alternative channel for expression.

5.1.4 The threads and written texts as a space of inquiry about NoS

The students express a positive perception of the value and utility of the threads and written texts within online discussions as effective tools for enhancing their understanding of the Nature of Science. They perceive these components as instrumental in facilitating meaningful learning experiences, allowing for in-depth exploration and comprehension of scientific concepts and principles. The interactive and dynamic nature of the threads and written texts creates a collaborative learning environment, enabling students to engage with diverse perspectives, exchange ideas, and deepen their insights into the complexities of the Nature of Science.

Students commented that the threads and texts of the online discussions created an interactive and collaborative learning environment:

The collaborative nature of the threads made learning of a complex topic like NoS more enjoyable. It was like we were all on a learning journey together.

Another student commented on the diverse perspectives and how this helped in gaining a deep understanding of the Nature of Science (NoS)

Engaging with diverse perspectives in the threads widened my understanding. It was a collaborative space where everyone's input contributed to a more holistic view of the Nature of Science.

Students highlighted the exchange of ideas and deepening insights of NoS, one student says:

"The discussions allowed for a free flow of ideas. It wasn't just about what I knew; it was about learning from my peers and expanding my own insights.

Another students mentioned:

"The dynamic nature of the written texts and threads deepened my insights. It wasn't a one-way communication; it was a constant exchange of ideas that enriched my understanding.

Students highlighted the significance of the online discussion tool as a record-keeping resource, enabling them to revisit key points of NoS discussed in the group, reinforce learning, and enhance their overall understanding of NoS. one student commented:

Through online discussions of the NoS topics, I discovered the power of collaboration. It wasn't just about what I knew about nature of science; it was about how we, as a group, could elevate our understanding of science and its nature collectively.

Students embraced the opportunity for remote discussions as a viable alternative to commuting for face-to-face interactions. Above all, they emphasized that the anonymity provided by typing allows them to confidently express opinions, organize thoughts, and write with clarity. One student express:

Online discussions allowed me to break through the barriers of shyness. I felt more comfortable expressing my thoughts and opinions in writing, contributing to a richer learning experience.

5.2 Students' views of e-facilitation of online dialogic discussion

5.2.1 Supported scaffolding by the facilitator

The InterLoc platform has the potential to support the challenging of views, even though the communication during the discussion was somewhat limited. This may be due in part to the fact that many learners were new to the topic and had not yet developed their understanding to a point where they felt comfortable challenging views. However, the discussion did stimulate critical thinking about the subject matter. Students noted that the depth of discussion and learning depended on prior knowledge, highlighting the importance of appropriate task scaffolding by the facilitator. One participant reported:

The facilitator's role in encouraging active participation, promoting respectful discussions, and providing timely feedback has empowered us to express our views of science, challenge each other's ideas, and foster a more profound comprehension of the nature of science.

Learners expressed concerns that discussions could easily lack depth if challenges were not based on factual information. Some students felt that they had not learned anything new from the discussion, while others felt that it was helpful for broadening their understanding of the NoS topic. There were also concerns about the fast pace, lengthy discussions, and large number of participants, which could make it difficult for learners to contribute critically. In this sense one student reported:

The mediator was skilled in keeping the discussion balanced. They ensured that no one dominated the conversation and encouraged quieter students to share their ideas. They helped us build on each other's contributions and created a collaborative atmosphere where everyone's voice was valued.

The usefulness of multiple threads was also debated, with some finding it helpful for reflection and others finding it made it harder to follow the discussion. These findings suggest that while the InterLoc platform can be a valuable tool for facilitating critical discourse, it is important for facilitators to carefully scaffold tasks and discussions to ensure that learners are adequately prepared to engage in meaningful conversation. One student reported:

The facilitator had excellent time management skills. They kept the discussion moving at a steady pace, ensuring that we covered all the important points within the allocated time. They also reminded us of the discussion goals and helped us stay focused on the main topic.

5.2.2 The role of facilitators in e-facilitation

The study found that the e-facilitation of the online discussion groups varied based on the prior experience of the facilitator in online support. Facilitators mainly kept the discussion focused and used the pop-up window to carry out this function. They contributed when needed, provided guidance and direction, and stimulated the discussion. However, the general perception was that facilitators could be more active. Some students felt there was a lack of facilitator input, while others appreciated their help in keeping the discussion on track and clarifying things. One student reported:

> *They helped us build on each other's contributions and our own views and understanding of NoS and created a collaborative atmosphere where everyone's voice was valued.*

The role of the facilitator in setting up the activity was also important, as they had to create an inclusive learning environment where all participants felt comfortable to contribute. Facilitators were expected to contribute to the subject under discussion by asking key questions, emphasizing important points, providing fresh ideas, and giving direction to the discussion whenever there was a lag or veering off the topic. Students also expected facilitators to read the transcript and provide constructive feedback as part of their role. One student reported:

> *The facilitator played a crucial role in guiding our online discussions. They created a supportive environment where everyone felt comfortable sharing their thoughts. They asked thought-provoking questions about NoS that encouraged us to think deeply and engage with each other's ideas.*

5.3 Facilitators' views of the affordances of the digital games

5.3.1 Dialogue games as a support learning for NoS

The facilitators expressed a positive view of digital dialogue games as a tool to support learning, which is consistent with the feedback from students. Facilitator 3 noted that:

> *InterLoc was easy to use and fit for purpose, while another emphasized the need for prior hands-on experience to become familiar with the tool.*

The facilitators agreed that InterLoc adeptly supported electronic discussions on topics concerning the nature of science, especially for participants situated in different locations. They noted that InterLoc effectively achieved its goal by promoting the exchange and questioning of perspectives among participants, fostering conversations on scientific matters, and improving understanding of the nature of science. Furthermore, they highlighted that the platform simplified the identification of misconceptions in science or the nature of science.

InterLoc successfully achieved its goal of encouraging participants to share and challenge views about science and the nature of science. The platform made it easy for us to track and address misconceptions, contributing to a deeper understanding of scientific concepts among participants (Facilitator 1).

Another facilitator says:

As a facilitator, we found InterLoc to be a valuable tool in promoting e-discussion on nature of science issues was evident in our sessions. It not only facilitated seamless communication among geographically dispersed participants but also successfully encouraged the sharing and constructive challenging of diverse perspectives on science-related topics. (Facilitator 2)

5.3.2 Use of openers

Regarding the use of openers, facilitators had mixed opinions. While one found them useful, another found them frustrating but recognized their potential to structure discussions. One facilitator suggested that greater choice of openers would be helpful as students become more mature in their argumentation. One facilitator says:

I found the restriction on the use of openers a bit frustrating but realize that these have the potential to ensure that discussions are well structured. (facilitator 3)

Another facilitator commented on improving the openers says:

It seems that the oppeners prompts are well-suited for younger students who may benefit from more structured debate guidance. However, it appears that these prompts might be somewhat limiting for our graduate students, who likely prefer a more flexible and open-ended approach to discussions. Their frustration with the constraints of the openers suggests a need for more nuanced and adaptable prompts that cater to their advanced understanding of the subject matter and desire for more expansive discourse. If you look at the WebCT discussions we have had during the rest of the term you can see that these students are in many ways producing quite sophisticated responses without the openers. So this aspect of InterLoc which is really what distinguishes it from other software, would need to have greater choice of opener as students get more mature in their argumentation. (Facilitator 1)

Another facilitator has positive view of the facilitator developed by practice:

Upon closer examination, I have come to appreciate the utility of the openers, even though my initial impression was less positive. As I engaged with them more and observed their impact, it became evident that they effectively served their purpose in facilitating discussions or activities. Despite any initial reservations, the openers have proven to be valuable tools, contributing positively to the overall engagement and outcomes of the sessions. (Facilitator 3)

5.3.3 The threaded texts on e-discussions

Facilitators encountered diverse experiences with the threaded discussion feature. While one facilitator found it straightforward to follow, another recommended the implementation of multiple windows, each displaying a separate thread for enhanced visibility. However, it was noted that incorporating this feature might pose challenges, particularly for facilitators overseeing more than one discussion simultaneously.

Facilitator 3 says:

The threaded discussion feature presented some challenges in terms of usability. Having multiple windows to display each thread would be beneficial for a more comprehensive view, making it easier to track participant interactions and contributions in real-time.

Another one expressed:

My experience with the threaded discussion feature was positive, offering a clear structure for following participant conversations. However, I understand the need for improvement, especially for facilitators juggling multiple discussions, where a more consolidated view might enhance efficiency (Facilitator 1).

Another facilitator expressed difficulty in consistently tracking the threads and transitioning between discussions in different groups.

Using many windows when supporting more than one discussion meant a lot of moving from discussion to discussion and this often led to problems – 'The way I did it was to open all three discussions and resize the window so each one took up 1/3 of the screen. That way, I could watch for and click on new messages as they came in to keep track of the discussions. It did make it hard to look in the chat rooms or anything at the same time though, because then I had to go back to the original screen and it messed up my system. (Facilitator 2)

5.3.4 Broadcast and chat room

All facilitators found the broadcast function allowing the facilitator to communicate with all the students useful as seen by the following comment:

The ability for moderators to send a message to everybody – would be good if these were recorded in the transcripts – they don't seem to be at present. (facilitator 3)

Facilitators highlight the chat room's role in fostering interaction, collaboration, and real-time feedback, demonstrating its significance in both facilitation and socially learning contexts during online discussions of NoS. The facilitator 2 commented:

I didn't really get involved in the chat room. It is a safe and social space for students to be off the task or to get ready to the task in the way the students like. It is a space to build confidence about discussing their views if science and experiences but also it is a space for a technical support. I found the broadcast function to be useful for reminders about time or possible to get students back on topic, but I don't think I made as much use of this feature as I might.

Another comment by facilitator 1:

As a facilitator, I see chat rooms as invaluable tools for enhancing interaction among students and exchanging their views of science and NoS. It's a safe space where learners can share ideas, ask questions, and engage in real-time discussions, creating a vibrant learning environment.

And a comment by facilitator 3:

The chat room is a hub for peer collaboration. Students collaborated on developing ideas and questions away from the teacher presence, and supported each other's learning, fostering a sense of community and shared understanding of the task needed in the discussion. It is helpful for students who are new to the online discussion or the topic of NoS.

5.4 Facilitators' views of facilitation the online dialogue

5.4.1 Dialogic styles and developing NOS through e-facilitation

E-facilitators play a crucial role by employing dialogic approaches in our online discussions to support and challenge students' dialogic moves, thereby fostering the development of their views and understanding of the Nature of Science (NoS). They ensure that every participant's voice is heard, maintain a respectful and inclusive environment, and prompt deeper analysis of ideas. Looking at the dialogic text in Fig. 2 from the dialogic talk (Mercer et al., 2019): interactive/dialogic, interactive/authoritative, non-interactive/dialogic, and non-interactive/authoritative, the interaction between facilitator P and their students can be categorized as an interactive/dialogic style.

In adopting an interactive/dialogic style, facilitator P engages in a multifaceted approach to facilitate online group discussions on the Nature of Science (NoS). This style is marked by a dynamic exchange of ideas, open communication channels, and collaborative interactions between the facilitator P and students. Facilitator P likely fosters an environment where students are not passive recipients of information but active participants in the learning process. This style promotes meaningful dialogue, allowing students to share their perspectives of the science and NoS, ask questions, and engage in critical discussions about NoS. The facilitator's role in this context is to guide, prompt, and encourage students' exploration of scientific concepts, fostering a deeper understanding of the subject matter. As shown from Fig. 2, the interactive/dialogic style is characterized by a conversational and collaborative tone, creating a sense of inclusivity of all students' views of science and NoS. Through

this approach, facilitator P aims to support students' learning journey, encouraging them to develop a more nuanced comprehension of the complexities inherent in the Nature of Science.

On another discussion, the facilitator (referred to as P) engages with the students in an interactive/dialogic manner, creating an environment that encourages active participation and dialogue. This is achieved by posing questions that effectively prompt the students to express their own ideas. Notably, the facilitator refrains from making immediate judgments about the validity of these ideas, instead acknowledging and considering them, thereby allowing the dialogue to progress (See Fig. 3).

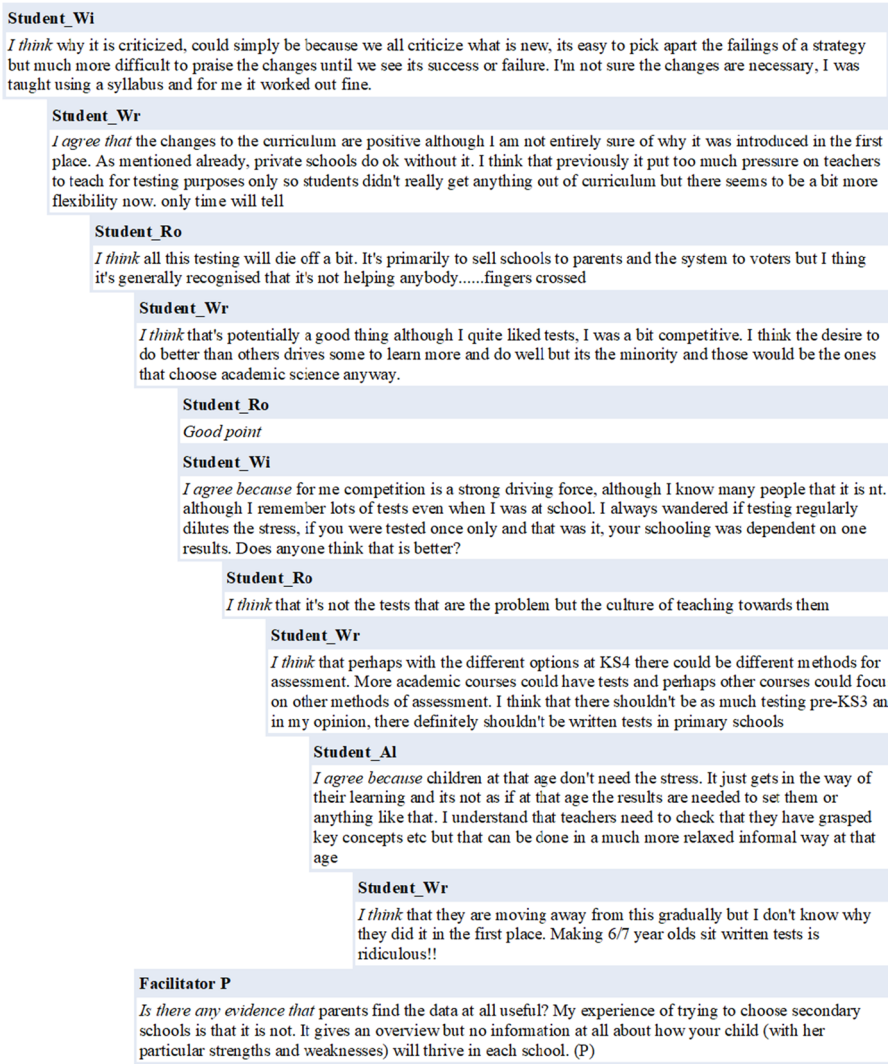

Fig. 3 *An example of an* interactive/authoritative *e-facilitation*

Contrasting the second episode (Fig. 3), in the first episode (Fig. 2), facilitator P intervenes by sharing his perspective on the topic. His intervention involves conducting "spot checks" to assess whether the students have arrived at the conclusion that knowledge of key concepts is crucial. The dialogue in this episode can be characterized as interactive/authoritative. Through the use of language, the facilitator provides students with illustrative examples that highlight the repercussions of lacking fundamental knowledge. For instance, he mentioned how discussions on topics such as nuclear energy in media reports require a basic understanding of physics concepts. By referencing the perplexing scientific jargon encountered in sports pages, the facilitator emphasized the importance of teaching these concepts to enable students to engage critically. This understanding of the significance of key knowledge or concepts when learning science is crucial for their development.

5.4.2 Balance among social, teaching and cognitive presence

Facilitators recognize the need for cognitive presence to move the discussion along and suggests that facilitators should encourage participants to discuss by asking open questions related to the contributions made. Facilitator 1 identifies that there is a need for cognitive presence to move the discussion along – *'facilitators should encourage participants to discuss by asking open questions related to the contributions that had been made.'* However, he also acknowledges the tension between "hands on" and "hands off" facilitation. While it is tempting to provide substantive input, this can close down discussion among participants.

Facilitator 2 appears to have more experience with asynchronous discussion and feels that synchronous discussion does not get the same depth or quality. Asynchronous work allows time for reflection before commenting, which can help separate well-grounded comments from strongly expressed opinions. It also provides time to craft an answer, which can be useful for non-native English speakers, and freedom from concerns about the status of participants. He says:

> *Online asynchronous work gives time to reflect before commenting (which at best can help to separate well grounded comments from strongly expressed (but ungrounded) opinion), time to craft an answer (useful if one's first language is not English) freedom from concerns about the status (age, seniority, gender etc.) of the participants.*

Facilitator 2 feels that is important in a synchronous discussion is that of social and teaching presence:

> *I think we all went for a fairly minimal level of input and saw our role predominantly as one of checking that the students were getting involved and that the system was working, and to start the ball rolling again if the discussion faltered or to answer direct questions.*

There was little perceived need for a stronger teaching cognitive presence as

The students did very well and took their discussions in lots of directions without faltering, so I didn't really do very much in the discussion myself. (Facilitator 1)

These two presences would need to definitely be stronger if the group needed to get started or needed stimulating.

Facilitator 3 is of the opinion that all, social, cognitive and teacher presences need to be the focus of facilitation

To try and keep the discussion focused on relevant points, prompt participants to expand on points when needed, challenge views which do not seem to be correct or backed up by evidence, ensure that participants are polite to each other and do not use offensive language or threats!

However in relation to facilitating the three groups the facilitator reflects that he did not feel the need to intervene as the students were enthusiastically engaged in the discussion and thus maintained a sparing social / teacher presence.

5.4.3 "Hands-on" and "hands-off." in e-facilitation

The facilitators identified a tension between two approaches to facilitation: "hands-on" and "hands-off." They expressed concerns about maintaining control and ensuring that all participants actively engage in the discussion rather than forming separate mini-groups to discuss different topics. The choice of facilitation style depended on the purpose of the discussion: understanding participants' views and their interactions or providing new ideas and teachings. The facilitators mentioned that their approach to InterLoc was more focused on understanding participants' views, while they would typically adopt a more instructive role in face-to-face discussions. Facilitator 1 reported

It all depends on whether the discussion is to find out their views and how they respond to each other or to provide more input in teaching them new ideas. I think the way I approached the InterLoc was the former, whereas I would usually have approached facilitation of a face-to-face discussion in the course as the latter.

5.4.4 Number of synchronous groups with e-facilitation

The facilitator 2 reflected on their experience using InterLoc and facilitating synchronous discussions, suggesting that in an ideal scenario, a facilitator, especially one without prior experience, would manage only one discussion at a time. They also recommended better preparation regarding the expected level of input for each discussion and the ability to ask questions to prompt students to explore interesting or relevant aspects of the debate. Although more comfortable and experienced in face-to-face discussions, they acknowledged the potential

usefulness of online discussions and believed that with practice, they could become more effective at facilitating online. Facilitator 2 reflected saying

I think that, in an ideal world, a facilitator (particularly one without prior experience like myself) would only manage one discussion at a time, would have been more prepared about the level of input expected for that particular discussion, and would be able to drop in questions to prompt the students to take their debate in interesting or perhaps more relevant directions. I am much more used to it (face to face) and comfortable in that situation. However, I can see how useful online discussion can be and think that with more practice I could be more comfortable and therefore more effective at facilitating online.

Similar to the other facilitators, there was a dilemma regarding the extent of facilitator intervention in the discussion. They expressed a desire to avoid dominating with their own views, which was less pertinent in face-to-face discussions. This highlighted their preference for face-to-face interactions, which allowed for better recognition and inclusion of reluctant, quiet, or shy participants.

Non-verbal cues, such as body language, also played a significant role in recognizing when participants were getting bored and when it was time to move the discussion forward (Facilitator 3).

Facilitators underscored the significance of honing facilitation skills prior to expanding the scope of simultaneously managed discussions. They shared their experiences moderating three groups, which proved manageable when minimal input was needed. However, they emphasized that in scenarios demanding more substantial facilitator involvement, it would be practical to moderate just one group, aligning with the group's size. Additionally, a facilitator proposed the creation of a 'training pack' for facilitators, encompassing illustrative materials on effective moderation techniques and showcasing examples of both successful and unsuccessful practices from existing discussions. This, they believed, could significantly elevate the overall quality of facilitation.one facilitator 1 says:

Managing several discussions simultaneously presented a challenge in maintaining the depth of engagement. It highlighted the need for strategic moderation to ensure quality interactions within each group.

The facilitators found that overseeing discussions in multiple groups simultaneously was feasible and did not demand an extensive, hands-on approach from the facilitator. This revelation emphasizes the adaptability of facilitation strategies based on the specific dynamics of each discussion group. facilitator 2 commented:

As an online facilitator, I've discovered that managing discussions across multiple groups simultaneously is indeed feasible, with the condition that my participation or contribution doesn't necessitate an extensive, hands-on approach.

6 Discussion

6.1 Digital dialogue games in promoting student engagement and understanding of NoS

The study emphasizes the effectiveness of educational digital games in fostering their engagement and facilitating learning about Nature of Science (NoS), while also encouraging them to articulate and discuss their perspectives with others. By incorporating game design elements, such as e-facilitation, challenges, rewards, feedback, and social space, as seen in Interloc tool in this study, these games can motivate students to take an active role in constructing their knowledge. Moreover, educational digital games can provide opportunities for students to engage in scientific inquiry and argumentation, which are essential components of epistemic agency (Halpern et al., 2012; Yang & Chang, 2013). This is supported by research conducted by Bell et al. (2013) and Noroozi (2021) who fund that digital dialogue games can be an effective tool for promoting critical thinking, active participation, argumentation skills and collaborative learning in higher education. As observed in this study and reported by both students and facilitators, employing digital games as a platform for online discussion and dialogue offers opportunities for collaborative learning, in-depth reasoning, and the exchange of ideas.

Throughout this study, students enhanced their understanding of the Nature of Science (NoS) by actively engaging with peers, sharing diverse perspectives, and challenging both their own and others' ideas (Mao et al., 2022; Qian & Clark, 2016). The collaborative and dialogic approach observed in both synchronous and asynchronous online discussions in this study aligns with the principles of constructivism and social constructivism. These principles emphasize the active involvement of learners in the process of knowledge construction (Vygotsky, 1978). As supported by the findings of this study, involving students in online dialogue enables them to reflect on their preconceptions of the Nature of Science (NoS) by engaging in the reasoning process with recorded texts or live discussions (Björka & Iyer, 2023). It encourages them to critically evaluate scientific information and actively participate in sense-making processes. Through these interactions utilizing functions of the digital game, such as threaded texts, recorded texts, openers, and socially supported discussions in chat rooms, students can refine their understanding of the nature of science, encompassing its principles, processes, and the ways in which scientific knowledge is generated, validated, and revised (Mansour et al., 2016; Halpern et al., 2012).

Participants commended the InterLoc platform for engendering dialogues embedded within a structured sequential and text-based framework, a notion aligned with Bakhtin's theoretical framework (Bakhtin, 1981; Björka & Iyer, 2023). The preservation of discussion records on the platform provided participants with the sequential dimension necessary for re-visitation and reflective engagement. The structured text environment cultivated a supportive learning context, fostering open and confident participation. Through this intricate interplay between time, space, and dialogue, students experienced a heightened

understanding of the Nature of Science (NoS) topics, showcasing the effectiveness of Bakhtin's theoretical lens in elucidating the dynamics at play (Kabat, 2014).

6.2 Engaging students' epistemic agency through online dialogue games and e-facilitation

The study's findings demonstrated that engaging students' epistemic agency through educational digital dialogue games and online facilitation had several positive effects on their understanding of the Nature of Science. Firstly, it allowed students to take ownership of their learning, leading to increased autonomy and control over their educational experience. This sense of control contributed to a more accurate understanding of the nature of science. Furthermore, engaging students in online dialogues exposed them to diverse perspectives of science and NoS held by their peers. Through critical discourse and interaction, students developed a more nuanced understanding of scientific concepts and gained a deeper appreciation for the complexities of scientific inquiry (Bedenlier et al., 2020; Phirangee et al., 2016).

The results reveal that engaging in dialogic online discussions supported by e-facilitators, coupled with reflective thinking, provides students with a cognitive space to critically evaluate presented evidence (Phillipson & Wegerif, 2019). In this context of sustained time, enduring textual discourse, and a collaborative atmosphere valuing every voice, students articulate nuanced perspectives, enriching their understanding of the Nature of Science (NoS) (Yang & Chang, 2013). The study also emphasized the importance of reflection in scientific inquiry. By encouraging students to evaluate their own thinking and consider alternative viewpoints, reflection played a significant role in promoting accurate conceptions of the nature of science (Vasodavan et al., 2020). The research provided strong evidence that online dialogic spaces foster active knowledge construction, critical reflection, and co-construction of knowledge within a social context. Empowering students to express their ideas, engage in critical thinking, and actively participate in the construction of scientific knowledge was found to be effective in enhancing their understanding of the Nature of Science (Mansour et al., 2016; Yang & Chang, 2013).

The study supported the notion that creating an open and expansive dialogic space, where questioning, challenging, and building on others' ideas are encouraged, is crucial for productive teaching and learning (Phillipson & Wegerif, 2019). Students who engaged in digital dialogue games demonstrated higher levels of engagement, active participation, and knowledge integration. These games facilitated productive dialogue, encouraged critical thinking, and supported the development of scientific reasoning skills, ultimately fostering an active learning environment that positively impacted student engagement and knowledge construction (Mao et al., 2022; Qian & Clark, 2016; Yang & Chang, 2013).

6.3 Chat rooms as a social space promoting a sense of community and a safe environment for inquiry in online dialogue

The findings of this study shed light on the significance of social presence in online dialogue and discussions, particularly within the context of debating the nature of science. The level of social and teacher presence was identified as a critical factor influencing student engagement and learning outcomes in online science education. Research conducted by Liu et al. (2010) supports the notion that social presence plays a vital role in online learning environments. Social presence refers to the sense of connection and belonging that participants experience in online interactions. When students perceive a strong social presence, they develop a greater sense of community and connection with their peers, which positively affects their engagement and learning outcomes. Feeling connected to others encourages students to actively participate in discussions, share ideas, and collaborate, ultimately leading to more enriched learning experiences (Molin, 2017). By emphasizing the importance of social presence, this study highlights the need for educators to design online learning environments that promote interaction and foster a sense of community. Strategies such as promoting collaborative activities, encouraging peer-to-peer interactions, and providing timely feedback can enhance social and teaching presence. This, in turn, will have a positive impact on student engagement, participation, and ultimately, learning outcomes.

One of the unique findings of this study reveals that the live chat room, identified as a social space and one of the affordances of Interloc in this research, plays a pivotal role in facilitating online discussions of NoS through easing the academic difficulty of the topic of NoS and overcoming an obstacle (Sun et al., 2018). It functions as a virtual-social space where participants can engage in real-time conversations, contributing to dynamic and interactive exchanges of views on science (Tang & Hew, 2017). In this context, the chat room acts as a platform for instant communication, enabling participants to share their thoughts comfortably and confidently, ask questions, and respond to others' contributions swiftly (Peris et al., 2002). Additionally, the chat room fosters a sense of community and connectivity among participants, providing an avenue for collaborative learning and the exchange of diverse perspectives in NoS (Klein et al., 2018). The immediacy and accessibility offered by live chat rooms contribute to the fluidity of deep reasoning, fostering an environment conducive to active engagement and meaningful dialogue (Broadbent & Lodge, 2021).

The findings affirm the idea that emotional presence in the chat room positively influenced students' cognitive presence. This assertion finds support in the work of Cleveland-Innes and Campbell (2012), which builds upon Garrison and Anderson's framework, emphasizing the significance of cultivating a supportive community in online learning. A well-designed chat room, fostering interaction and collaboration, plays a pivotal role in establishing a community that adheres to principles of psychological safety. This supportive environment enables students to critically and freely discuss their views on the Nature of Science (NoS). In this study, students utilized the chat room as a secure environment, providing a reprieve from the dominance of teacher presence (Mao et al., 2022).

The concept of a safe space supported by the findings in this study is emphasised by literature emphasizing the importance of psychological safety in learning environments. Amy Edmondson's research on psychological safety (1999) suggests that learners, when feeling secure in expressing their thoughts without fear of judgment, are more likely to engage in deeper learning and contribute meaningfully to discussions. In alignment with this, Grenny et al. (2011) argue in their book "Crucial Conversations: Tools for Talking When Stakes Are High" that an environment fostering a sense of safety in expression is vital for productive conversations. This perspective aligns seamlessly with the notion of a chat room serving as a conducive space for meaningful discussions.

6.4 E-facilitation style in online dialogic space

The study highlights a significant tension between adopting a more active or passive role in facilitating discussions. This tension arises due to the different approaches used by facilitators in guiding discussions (Asterhan & Schwarz, 2010). Active facilitation involves the facilitator taking an active role in shaping the conversation, providing guidance, and asking probing questions (Molin, 2017). In contrast, passive facilitation involves the facilitator taking a more hands-off approach, allowing participants to take the lead in the discussion. This tension is supported by research conducted by Svinicki and McKeachie (2014), who found that active facilitation can be effective in promoting student engagement and participation, while passive facilitation can lead to a lack of engagement and participation. However, other studies have shown that passive facilitation can be effective in promoting critical thinking and reflection among participants (Brookfield & Preskill, 2016).

This study highlighted from the students and facilitators' views that online facilitation plays a crucial role in guiding and supporting students' interactions. Skilled facilitators create a safe and inclusive environment where students feel encouraged to express their ideas, ask questions, and engage in reflective discussions (Molin, 2017). The facilitator's role is to promote dialogue, foster a community of inquiry, and facilitate the exploration of diverse perspectives (Garrison et al., 2000). Research has shown that effective online facilitation strategies, such as asking open-ended questions, encouraging evidence-based reasoning, and providing scaffolding, can enhance students' understanding of the Nature of Science (Sullivan & Puntambekar, 2019). By adopting a facilitative approach that respects students' ideas, acknowledges multiple viewpoints, and encourages critical inquiry, facilitators can create a supportive online learning environment that promotes accurate conceptions of the Nature of Science (Bedenlier et al., 2020; Phirangee et al., 2016).

The facilitators in this study reflected on their role as facilitator and mediator on the online discussion and in classroom. The findings highlighted that tension between "hands-on" and "hands-off" approaches to facilitation in online learning environments is an important consideration (Asterhan & Schwarz, 2010; Molin, 2017). The "hands-on" approach involves active facilitator intervention, while the "hands-off" approach emphasizes student autonomy. Research by Webb (2009) emphasizes the importance of facilitator presence in online learning. In this sense,

Asterhan and Schwarz (2010) assert that facilitators have a vital role in guiding and supporting students' interactions. They emphasize that teacher or tutor intervention might need to be more content-specific to re-engage the student in the flow of interaction and respond to their scaffolding attempts effectively. On the other hand, researchers like Muhammad (2021) highlight the benefits of promoting student autonomy and self-directed learning in online environments. To navigate this tension, facilitators should adopt a flexible approach that considers learners' needs and the specific context (Veerman et al., 2000). Balancing guidance and autonomy when facilitating online discussions helps learners develop critical thinking and problem-solving skills (Yang & Chang, 2013). Facilitators should continually reflect on their practices and engage in professional development to refine their strategies (Garrison & Vaughan, 2008).

This study supports previous studies shown that tutors may face challenges in maintaining control and ensuring the quality of threaded discussions due to the lack of immediate feedback and the potential for off-topic or unproductive contributions (Richardson et al., 2016; Warren, 2018; Xie & Correia, 2023). Tutors must navigate the complexities of guiding and facilitating the discussion in an online environment to foster meaningful and productive interactions among participants. In in facilitating synchronous and asynchronous online discussions, the moderator's contributions become part of the shared discussion, so posting generic prompts in a detached manner can be seen as a lack of active participation and interest. This leads to participants not responding to generic prompts and feeling annoyed by them (Asterhan & Schwarz, 2010).

7 Conclusion

The study investigated into the utilization of InterLoc as a digital dialogue game for learning in both synchronous and asynchronous online environments, highlighting the pivotal role of facilitating online discussions. To gain insight into the process of students' comprehension of the Nature of Science (NoS) or the transformation of their perspectives on science through online dialogic learning and discussions, a comprehensive examination is necessary. This exploration extended beyond the participants, encompassing both students and facilitators, and dig into an understanding of the features and capabilities of the online synchronous and asynchronous dialogic tool employed, as well as the nuances of e-facilitation integrated into the process (Kilpelä et al., 2023).

The general perception of InterLoc as a valuable learning tool was based on its ability to foster critical thinking and expose students to diverse perspectives on the Nature of Science (NoS) (Noroozi, 2021). Students found its organized tasks and controlled discussions beneficial, particularly valuing the discussion record for reflecting on their own views of science in relation to others' perspectives within group discussions (Yang & Chang, 2013). This contributed to the development of critical thinking skills. However, the effectiveness of InterLoc was noted to be influenced by students' prior knowledge of the topic and their existing views on science

and NoS. This underlines the importance of facilitators providing appropriate task scaffolding to optimize the learning experience (Belcher et al., 2014; Salmon, 2012).

Furthermore, the study emphasized the importance of empowering students to explore the Nature of Science (NoS) through educational digital dialogue games and online facilitation of the synchronous and asynchronous online dialogic discussions (Asterhan & Schwarz, 2010; Mansour et al., 2016). This empowerment provides students with a sense of ownership in their learning, fostering autonomy and developing epistemic agency and control over their educational experiences, ultimately contributing to a more precise understanding of the Nature of Science (Siry, 2020). The research emphasized the critical role of social and teacher presence of the e-facilitator in online dialogues, especially when discussing the nature of science (Evans et al., 2019; Watson et al., 2023).

Furthermore, the study highlighted a significant tension in the strategies employed by facilitators to guide synchronous and asynchronous online dialogue discussions. Active facilitation, characterized by facilitators actively shaping discussions and guiding participants in reflecting on their scientific views and presented evidence, is deemed essential for creating an inclusive environment that fosters idea expression and reflective discourse (Phirangee et al., 2016). The research emphasizes the importance of considering both "hands-on" and "hands-off" approaches to facilitation, stressing the need to strike a balance in online learning environments based on students' knowledge, perspectives on science, and the diversity of learners participating in group discussions (Chowning, 2022; Asterhan & Schwarz, 2010).

In the context of this study's findings, it becomes evident that students approach the learning of Nature of Science (NoS) topics through synchronous and asynchronous online dialogic discussions with unique expectations, distinct from the dynamics experienced in traditional face-to-face interactions (Veerman et al., 2000). Specifically, within the online setting, students expect a continuous and sustained presence of the teacher throughout the entire course duration. This expectation diverges from the conventional face-to-face classroom scenario, where the teacher's availability is often confined to scheduled class times.

However, the shift to an online environment necessitates more than just maintaining a continuous teacher presence; it requires adopting pedagogical practices that empower students to take control of their own learning time and space (Kabat, 2014). This implies fostering a learning environment that encourages student agency and self-directed learning (Yang & Chang, 2013). Therefore, the recommendation emerging from this study is that comparing face-to-face and online threaded discussions solely based on pedagogical practices is not advisable.

The distinction in time and space dynamics between these two learning modalities is crucial. The written expression of ideas, interaction patterns, and the overall structure of online discussions vary significantly (Kabat, 2014). E-facilitators in both synchronous and asynchronous online dialogic discussions play a pivotal role in employing pedagogies that align with how students navigate their online learning experience and negotiate their views on science and the scientific evidence they utilize (Molin, 2017; Richardson et al., 2016). This encompasses facilitating dialogues and understanding the Nature of Science (NoS), responding to students' contributions, and guiding them through the nuanced complexities of dialogic moves related

to NoS topics (Phirangee et al., 2016; Phillipson & Wegerif, 2019). In essence, the study emphasises the importance of recognizing the unique social characteristics of online learning environments and dialogic discussions, urging the tailoring of pedagogical approaches to enhance students' engagement and understanding of NoS.

Uniquely, the study highlights the live chat room's significance within Interloc, emphasizing its role as a vital virtual-social space for facilitating online discussions on the Nature of Science (NoS). Acting as a platform to address academic challenges related to NoS, the chat room promotes real-time conversations, fostering dynamic exchanges of scientific views. Its features enable instant communication, swift responses, and the cultivation of a community atmosphere, enhancing collaborative learning and diverse perspectives of NoS. The chat room's immediacy contributes to the fluidity of online discussions, fostering active engagement and meaningful dialogue.

In brief, the study's central finding regarding the critical role of facilitators in guiding and supporting students in synchronous and asynchronous dialogic discussions and in understanding the Nature of Science has several implications for online education (Webb, 2009). It highlights the need for professional development programs for facilitators, focusing on effective facilitation strategies in both synchronous and asynchronous settings (Phirangee et al., 2016; Vasodavan et al., 2020). Additionally, the study emphasizes the importance of balancing synchronous and asynchronous discussions, providing resources and guidance to stimulate critical thinking, and promoting strong online learning communities to enhance the overall learning experience (Bedenlier et al., 2020).

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Data availability The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate The ethics committee of (name removed for anonymous review) university approved the data collection and research methods.

Competing interests The authors declare that they have no competing interests.

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