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LIVE-STREAMING PERFORMANCE IN INQUIRY-BASED SCIENCE LEARNING WITH ACTION: TEACHERS' PERSPECTIVES

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Abstract. *Online teaching has become an imperative approach in today's society. However, as an essential approach, using live streaming to teach students in small groups, particularly rural primary school students, has not been extensively studied. To address this gap, an inquiry-based model, predict-do/observe-quiz/discuss-explain-transfer (P-D/O-Q/D-E-T), was adopted for live streaming with action, and its performance was analysed. Reflection by teachers can lead them to a deeper understanding to capture the profound impact of an educational program. In the present study, eight teachers who had experience assisting rural students in this experiment were invited to rate their points of view on immersion, social interactivity, humanness, and value perception. Examining the consistency of teachers' viewpoints using the hermeneutic method, the results showed that they highly supported viewing these four constructs using live streaming to conduct inquiry-based science learning with action. As expected, using live streaming to deliver teaching with the P-D/O-Q/D-E-T approach can enrich other online science teaching.*
Keywords: *educational program, inquiry-based science learning, live-streaming, teachers' perspective*

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Introduction

The rise of live streaming has highlighted the importance of understanding how the embedded functions of learning platforms, known as affordances, shape students' experiences and impact teachers' attitudes toward students' needs. In particular, live streaming platforms, where students can watch real-time and live videos delivered by streamers, have become one of the most important platforms for use in distance education today. However, how live-streaming functions embedded in science learning can be leveraged for inquiry-based learning has not been extensively studied. Thus, the present study used a live-streaming approach to teach science to rural students. Live streaming effectively enhances communication and entertainment promotion through the Internet's intuitive design, rich content, robust interactivity, unrestricted location, and audience segmentation (Yu et al., 2018). Streaming feedback allows the streamer to adjust the program's content to meet the user's needs (Bilal et al., 2018). In the past, live streaming was mostly limited to electronic entertainment media. However, with the increasing popularity of broadband networks and the improvement of computing power, live streaming is now being used for educational purposes through the Internet (Chen & Lin, 2018; Payne et al., 2017). For example, real-time surgery conditions can be transmitted via live streaming, and most of the students who watched the live stream showed a significant subjective increase in knowledge after watching the live stream. The findings suggested that live-streamed surgeries should be offered as a permanent component of medical teaching (van Bonn et al., 2022). However, few studies have examined inquiry-based science learning, in particular, following Dewey's "learning by doing" educational pedagogy (DuFour et al., 2016). Therefore, the present study developed an inquiry-based science learning with an action approach, entitled predict-do/observe-quiz/discuss-explain-transfer (P-D/O-Q/D-E-T), for rural primary school students to learn science. To solve the problem of the lack of science teachers available to teach in rural areas of Taiwan, a live-streaming platform was implemented to conduct four P-D/O-Q/D-E-T lessons. To explore students' experience of live streaming to practice inquiry-based learning, the on-site assisting teachers observed and reported the students' performance effectiveness.

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According to the socio-technical system theory, the essential factor for optimizing output is the synergy between the technical component (technology) and the social component (interpersonal interactions) (Kong et al., 2019). The unique advantages are the real-time interactivity, visualization, and personalized services fostered by live streaming (Zhang et al., 2022). In line with this, P-D/O-Q/D-E-T inquiry-based science learning with action was designed for rural primary school students, and how teachers perceived their students' involvement in the socio-technical system was reported in this study. The current research posited that users' inclination towards live streaming is contingent upon their perception of the matching degree of task difficulty and their capability (Zhao et al., 2018). Confronting challenges, they can perceive the positive aspects of the task, view the challenging stress as a driving force, and consider obstacles as pressure (González-Morales & Neves, 2015). This study aimed to bridge the present gap by examining the driving factors behind the intention to broadcast on educational live-streaming platforms. Unlike the development in the field of practice, live streaming is still not receiving sufficient attention in the academic field (Li et al., 2021). This led to the research question: What is the role of perceived value, perceived humanness, social interactivity, and immersion in users' participation in the live-streaming process? The results of this study can provide some evidence for helping science teachers teach science to students in rural areas around the world.

Theoretical Background

Performance Measurement

User experience involves the thoughts and feelings of using or anticipating online services. This is influenced by the personal-internal state, the system's characteristics, and the interactional context (Tham & Grace, 2020). To understand this experience more deeply, one can use a performance measurement that regularly measures the outcomes and efficiency of services or programs (Hatry, 2006). Gadamer (2008) defined "deeper understanding" as the capacity to question the subject matter and formulate further questions (p. xxii). This means that it is important to consider the value of interpretation when formulating the meaning of learning offered by participants. This involves listening, observing, testing, and reflecting from different angles (Du Plessis & McDonagh, 2021).

One way to evaluate user performance is to assess how effectively users are able to accomplish tasks within a given system (Habibi & Chattopadhyay, 2021). In order to retain and engage users, it is crucial to facilitate a positive and interactive relationship between viewers and streamers (Scheibe et al., 2016). Teachers' interpretations of students' attitudes, behaviour, and cognition are closely linked to the way their students learn. By reflecting on their students' learning process, teachers can deeply understand an educational program's profound impact (Du Plessis & McDonagh, 2021). Gadamer's theory (1975) enabled the merging and rationalization of perceptions and experiences across different participants in diverse settings, prompting Mayer (2014) to propose the use of the Cognitive Affective Theory of Multimedia Learning (CATML) for investigating how affective and cognitive factors could impact learning positively or negatively. Thus, the present study looked at the performance measurement from the teachers' point of view in their students' cognitive and affective states in inquiry-based science learning with action (IBSLA) through live streaming to rationalize beyond the science concept learning.

Immersion

When one is highly focused during an activity, one may experience a sense of success and inner peace, as well as feelings of joy and wonder. This feeling aligns with the idea of being fully immersed or present in online learning activities. Studies have found that the greater the challenge, the greater the sense of immersion (Shernoff, 2010). To achieve this level of engagement, instructional designers should develop learning activities that align with the core element of immersion, which will spark students' curiosity and capture their interest (Petersen et al., 2022). The use of live streaming can be beneficial in promoting distributed cognition by providing a platform for engagement between participants, instructors, and objects in the context of IBSLA. To create an effective learning environment, it is important to establish a framework that addresses students' learning needs and instructional objectives while also holding personal significance and applicability for the students. This approach can help students become more engaged in their science coursework and feel a sense of immersion in the learning experience. In the world of online education, students and teachers use digital avatars to show whether they are actively participating or not (Hong et al., 2022). The state of immersion emerges from the fidelity of representations and the level of interaction, making it not inherently singular (Petersen et al., 2022). However, it is worth acknowledging that these definitions

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suggest the importance of recognizing immersion, which has also been defined in educational contexts (e.g., Yeo et al., 2020). Thus, how IBSLA delineates context and meaning through a live-streaming environment that facilitates students' immersion in learning science for the successful completion of the live-streaming learning activity was explored in this study.

Perceived Social Interactivity

Described as a 'sense of being there and interacting with another,' social interactivity implies that the emotional bonds formed in mediated environments directly impact how people communicate and behave with others (Biocca et al., 2003). More specifically, social interactivity refers to the individual's ability to utilize internal socio-networking tools to connect with peers and utilize system features to engage in collaborative activities (Paramita et al., 2021). Empirical evidence suggests that offline socio-interactions significantly shape the dynamics of online experiences (Webb, 2001). Engaging in socio-interaction enables individuals to draw insights from socializing, participating, and receiving input from the virtual community (Hollebeek & Macky, 2019). In other words, participants must engage diverse cognitive functions through social interactivity to problem solve and attain their learning objectives (McCreery et al., 2012).

In our live streaming case, the streamer guided participants following a social framework and a set of interactive rules (e.g., 1 minute for thinking, 2 minutes for discussing with group members, and then presenting their answers to the streamer) and instructed students to watch presentation files. Moreover, the streamer proposed questions for students to predict and discuss with other participants as the social interactivity in the live-streaming environment. Considering the learning goals may be hindered since the learners are in a technology-driven learning environment (Petersen et al., 2022), how participants perceived social interactivity is an important component affecting their engagement in the live-streaming learning process. Thus, the way participants perceived social interactivity was explored in this study.

Perceived Humanness

According to Lortie and Guitton (2011), the reciprocity of exchanges between humans and agents is a crucial factor in perceived humanness. Regarding conversation structure, if an agent gives a question related to a previous question or response (i.e., it is easy to figure out the answer from the context presented), it will positively influence the perceived humanness (Hill et al., 2015). In contrast, when a question does not consider the context provided in the previous content, it is expected to have a negative impact on perceived humanness (de Kleijn et al., 2019). Therefore, asking immediate questions related to the ongoing discussion is essential.

Collaborating and discussing tasks online can be done through live streaming. To promote IBSLA, it is important to have easily accessible tools and resources available. This study provided participants with various tools and objects (such as iPads and experimental materials), enabling them to take advantage of the benefits of active learning through live streaming. Using shared tools (such as Zoom, Google Meet, and Teams), students were able to engage in activities that required active learning and built an interactive model of IBSLA. The experimental materials could be easily recognized and obtained by all participants either through delivery from researchers or preparation by local teachers. That is, this study offered an interactive platform that helped establish a shared cognitive foundation for activities among both students and teachers.

Moreover, Lortie and Guitton (2011) found a relationship between the number of questions asked and the agent's perceived humanness. Beyond the visual element, interactive structure, timing, and content that make up the design of a remote human, voice is another prominent characteristic of particular interest (Heidig & Clarebout, 2011). When participants in a learning environment have access to good visuals and voice, they can actively engage in the learning activity, which is crucial in developing their knowledge. This study investigated how participants perceived humanness and how it affected their engagement in live-streaming learning.

Perceived Value

According to the Situated Expectancy-Value Theory (SEVT; Eccles & Wigfield, 2020), teachers' attitudes towards the subjects they teach and their perceived value for their students are crucial factors in their teaching. Values significantly impact individuals' cognition and coping mechanisms that affect their goals and emotions (Hernandez-Ortega et al., 2017). When individuals believe that acquisition and involvement are important for their personal

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happiness and identity, they adopt effective communication strategies to manage their intentions (Zhou et al., 2019). Live-streaming platforms offer several advantages, such as a high degree of interactivity, a strong sense of involvement, privacy, and novelty seeking (Yu et al., 2018). Perceived value significantly impacts the users' continued use of streaming services, followed by perceived enjoyment (Singh et al., 2021). By understanding the cognitive appraisal process, one can assess how live streaming affects individuals' learning and performance (Clarke, 2012). Accordingly, this study examined how participants perceived the learning value of using live streaming.

Research Methodology

Background

Husserl (1990) presented a method of descriptive phenomenology that aimed to reveal the fundamental essence of phenomena relevant to questions of knowledge. This involved setting aside existing knowledge and preconceptions about the phenomenon to uncover its core nature. Heidegger (1962), on the other hand, introduced a hermeneutic or existential phenomenology approach that emphasized understanding the essence of 'being' through interpretive sciences. This approach focused on exploring questions about existence to reveal insights and significance. Gadamer (2008) proposed that a profound understanding was inherent to 'being' and advocated using the Hermeneutic method. This method supported phenomenological observation by providing an interpretive approach (Betensky, 1995) to reflect on the meanings of phenomena as they manifested in observational experiences (Santiago et al., 2020).

The foundational philosophical principles of phenomenology proposed by van Manen (2014) encompassed two main approaches: descriptive phenomenology and interpretive (hermeneutic) phenomenology, both focused on understanding the human experience of phenomena. According to van Manen (1990), researchers engaged participants in questioning to gain profound insights into these phenomena as part of a methodology rooted in human science. Phenomenological reflection involves identifying essential themes that encapsulate the fundamental meanings of these phenomena. This process involves researchers delving into thematic analysis, selecting pertinent thematic statements, capturing thematic expressions, and contemplating the significance of observed experiences through an observational checklist. The current study developed a specialized checklist for educators to document their phenomenological observations of evaluating student performance within the context of P-D/O-Q/D-E-T lessons for science-based inquiry learning.

Data Collection

The research of van Manen (2014) suggested that the human science method provides researchers with clear guidelines for collecting and analysing data. One of the main concerns surrounding learning is the inequality among students. Teachers have observed that some students have limited access to online learning materials (Kim & Asbury, 2020). Additionally, during synchronous teaching, the restriction of learning-related interaction has made it difficult for teachers to address their students' needs due to the limited feedback they receive (Haser et al., 2022). This study used observational field notes and comprehension checks as primary data sources.

In this study, five physics units, such as surface tension, buoyancy, and so on, were conducted with live streaming in the fall semester of 2022. Every unit was implemented in the morning before regular class for 30 minutes. Eight rural schools joined this study, with one teacher participating in each school. Finally, six teachers returned their checklists for statistical analysis.

Instrument

Five domain experts had to explicitly state the assessment constructs and items based on the existing study of the checklists. For the systematic review, each domain expert analysed constructs and assessment items found to be potentially relevant to this study. Afterwards, an expert panel meeting was conducted to gain agreement on the meaning of each item and construct in the previous template. Consequently, the checklist consisted of four constructs with six items each. Moreover, Gadamer (1975) described lived experience as a "significant whole" made up of several parts or clusters of meaning, a framing that underlines the need to "understand the whole in terms of the detail and the detail in terms of the whole" (p. 258). Thus, perceived humanness and perceived social interactivity were adapted from Fernandes and Oliveira (2021), and immersion and perceived value were adapted

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from Li et al. (2021). Thus, questionnaire items were designed as listed below.

Immersion
1) My students are immersed in the live-streaming environment.
2) My students felt that the live-streaming session ended faster than they expected.
3) My students did not feel frustrated with the length of speaking in the live-stream sessions.
4) My students lost outside awareness when they joined the live-streaming course.
5) My students were so excited when they interacted with the live-streaming platform.
6) My students' eyes were blinking when they were in the live-streaming sessions.

Perceived Social Interactivity
1) I find that my students are pleasant to interact with during discussion sessions.
2) I feel that the live streamer could understand my students' replies right away.
3) When interacting with the live streamer, my students could process the content easily.
4) When watching a live stream, my students could exchange and share opinions with the streamer.
5) When my students were watching a live stream, the streamer provided sufficient opportunities to respond and ask questions.
6) When watching a live stream, my students could exchange and share opinions with other school students easily.

Perceived Humanness
1) Sometimes my students felt that the live streamer seemed to really be in the classroom.
2) When my students were watching a live stream, the streamer knew they were close to him or her.
3) When watching a live stream, my students felt close to the streamer.
4) When my students were watching a live stream, the platform processed their comments very quickly.
5) When my students were watching a live stream, seeing comments sent by other viewers was very fast.
6) When my students were watching a live stream, when they voted, they could see the result very fast.

Perceived Value
1) I think the live-stream program with inquiry learning is useful for students to learn science.
2) I think the live-stream program with inquiry learning can help students develop an inquiry attitude towards science.
3) I think students can get used to the P-D/O-Q/D-E-T process after several practices.
4) I think students can retain those science concepts learned via the live-stream program longer than those learned in a normal class.
5) I think my students can transfer their science learned from live-stream programs to daily events.
6) I think my students are interested in using live streaming to learn science.

Data Analysis

In behavioural sciences research, it is crucial to ensure reliability and agreement. Reliability refers to how well a scale distinguishes between items when categorized, while agreement measures how close two assessments of the same items are (Gearhart et al., 2013). Good reliability is important for ensuring the validity of a measurement scale, particularly when assessing the agreement of variables between observers and the attenuation effect (Lee, 1997). The Kendall's *W* statistic, also known as the coefficient of concordance, is a non-parametric measure utilized to evaluate the level of agreement among various raters. It ranges from 0 to 1, where 0 indicates no agreement among raters and 1 represents perfect agreement. The statistic is calculated on an interval or ordinal scale (Howell, 2002). Accordingly, Kendall's *W* statistic can be used to assess the quality of a live stream for science inquiry-based learning.

Kendall's coefficient of concordance (*W*) is employed to gauge the level of concordance between random variables and their order statistics (Fuchs & Schmidt, 2021). In this study, the interrater reliability (McHugh, 2012) of the usability classification system was evaluated. Following institutional review board approval, six raters participated in an experiment centred around inquiry-based science learning facilitated through live streaming. The raters observed students' management of achievement emotions and their associated control value during this experiment. The calculation and reporting of interrater reliability were conducted using Kendall's *W*. The formula

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of Kendall's *W* is as follows (Kendall & Gibbons, 1990):

$$W = \frac{12S}{k^2(N^3 - N)} \qquad \text{......eq. 1}$$

$$S = \sum_{i=1}^{N} (R_i - \bar{R})^2 \qquad \text{......eq. 2}$$

R: Rating scale (3 ranks in this study).
N: Assessing items and constructs (4 constructs with 6 items in each construct).
K: Total rating members (6 pedagogical experts in this study).
S: The sum of squared deviations.

If *W* is 0, the raters have no overall agreement trend, and their responses may be considered random. Intermediate values of *W* indicate a greater or lesser degree of unanimity among the raters, so *S* will have the maximum value when the raters are entirely consistent. The harmony coefficient is the ratio of the actual obtained *S* to its maximum possible value, as $0 \leq W \leq 1$.

Research Results

Drawing on the literacy review, for this study, four variables were designed to measure the quality of live streaming for students to learn science, namely immersion, perceived social interactivity, perceived humanness, and perceived value for students to learn. Pedagogical experts (who participated as observers and facilitators during the live streaming) were invited to rate on a 3-point ranking scale (i.e., 1 for *disagree*, 2 for *neutral*, and 3 for *agree*). First, the average ranking values of six members in four dimensions were calculated. The results indicated: Immersion (*M* = 2.64, *SD* = 0.81, *FL* = 0.79), perceived social interactivity (*M* = 2.69, *SD* = 0.80, *FL* = 0.75), perceived humanness (*M* = 2.60, *SD* = 0.69, *FL* = 0.91), and perceived value (*M* = 2.64, *SD* = 0.81, *FL* = 0.89). Those descriptive values of constructs showed that the averages were at a high level from the teachers' perspectives (see Table 1).

Table 1
Means, Standard Deviations, Factor Loadings

Constructs	*M*	*SD*	*FL*
Immersion	2.64	0.81	.79
Social interactivity	2.50	0.68	.75
Perceived humanness	2.69	0.80	.91
Perceived value	2.60	0.69	.89

Second, the values of Kendall's *W* related to four constructs were analysed (see Table 2); the *W* value of immersion was .853, ***p < .001; the *W* value of perceived social interactivity was .836, ***p < .001; the *W* value of perceived humanness was .495, **p < .01; and the *W* value of perceived value was 994, ***p < .001. All teachers did reach a high level of agreement on the four constructs, indicating that they positively recognized the quality of live streaming for students to participate in learning science using the inquiry approach. However, the total *W* value was .705, ***p < .001, indicating that the coefficient of concordance was confirmed, and the *W* value of perceived value for students to join this learning approach was the highest. That is, the quality of live streaming for inquiry-based science learning can be highly accepted.

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Table 2
Kendall's W Coefficient of Concordance Analysis

Constructs	*N*	Kendall's *W*	*S*	*df*	*p*
Immersion	6	.853	46.079	9	< .001
Perceived social interactivity	6	.836	45.170	9	< .001
Perceived humanness	6	.495	26.746	9	< .01
Perceived value	6	.994	53.660	9	< .001

When teachers reported on students' immersion, social interactivity, humanness, and learning value, they noted that the four constructs were relatively stable for rural students. The results indicated that the teachers reported a level of 2.69 on the 3-point Likert scale for students' humanness, which was the highest rating among the four factors. Regarding immersion, teachers reported that students having access to situation-specific engagement, the students' immersion level was 2.64 on a 3-point Likert scale and was the second highest rating among four variables. Briefly, teachers' perception of using live-streaming for rural students can be conceptualized using a four-dimensional conceptualization, where the P-D/O-Q/D-E-T model may be applied.

Discussion

Measuring performance is important to gain a better understanding of a system's capabilities, according to Gadamer (2008). Adopting the Gadamerian perspective, in this study, the importance of interpretation was carefully considered. This involves examining and thinking about things from various viewpoints to determine the significance of the meaning of the learning that the participants offered (Du Plessis & McDonagh, 2021).

The level of experienced immersion depends on the representation's accuracy and the level of social interactivity. It is not an inherent trait (Petersen et al., 2022) but implies that immersion should be noted in learning concepts (e.g., Yeo et al., 2020). Meanwhile, IBSLA delineates context and meaning through the live-streaming environment that facilitates students' immersion in learning science to successfully complete the live-streaming learning activity. The result of this study revealed that, from the observation of their teachers, students can immerse themselves in IBSLA.

In the live-streaming case of IBSLA, participants in a social framework could navigate presentation files through the guidance of the streamer. Moreover, the streamer proposed questions for students to predict and discuss with other participants to provide social interactivity in the live-streaming environment. Learning goals may be hindered in a technology-driven learning environment (Petersen et al., 2022). Participants perceived that social interactivity is an important component affecting their engagement in the live-streaming learning process. The result of this study showed that the social interactivity perceived by teachers was at a high level.

Collaboration and discussion are important aspects of online live streaming, which brings people together to complete tasks. To facilitate IBSLA in live streaming, accessible tools and resources should be made available. Tulk Jesso et al. (2020) studied participants' beliefs about the interactive agent and the extent to which they perceived the interaction with an agent as a 'real person.' They found overall perception and the cues in an environment that participants used to determine humanness. In this study, the researchers provided participants with various tools and materials, including iPads and experimental objects, to encourage active learning through live streaming. Engaging students in activities that utilize shared tools, such as Zoom, can help them perceive humanness in an interactive model of IBSLA. Moreover, effective visuals and clear voice communication are crucial for active engagement in learning activities, which is vital for developing students' perceptions of humanness. Adopting a new ontological model, Isrow (2022) suggested that explaining humanness in specific activities is better. Taking IBSLA as a specific learning approach, this study showed that teachers perceived high humanness in IBSLA live-streaming, which can activate IBSLA as a shared cognitive base for learning activities.

Rural primary schools in many countries have poor educational resources and few qualified science teachers. For example, in Australia, as in many countries, rural students lag behind urban students in science achievement and interest (Echazarra & Radinger, 2019). There have been some attempts to introduce information technology to many research projects to solve some of these problems. In reviewing related research from an international perspective, an interesting finding emerges, indicating that some studies support the notion of a 'deficit model'

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for teaching rural school students (Abrams & Middleton, 2017). Some research has been analysed to determine if it adopted appropriate approaches to introducing e-learning to rural students (Lindfors & Pettersson, 2021); however, few studies have used live-streaming to implement an inquiry-based science learning model. According to Singh et al. (2021), users' intention to continue using streaming services is primarily influenced by their perceived value and enjoyment. Clarke (2012) suggested that individuals' responses to live streaming can be understood through cognitive appraisal, which can also affect their performance. As a result, this study explored how teachers perceived the value of using live streaming to conduct IBSLA and found that they considered it to be highly valuable.

Conclusions and Implications

Knowing the psychological factors that affect the implementation of live-streaming for science inquiry learning can not only aid in comprehending the characteristics of mutual understanding in human conversations but can also assist in developing and enhancing live-streaming technology to make it more human-like in the learning process. In this study, the performance of using live streaming for implementing IBSLA was evaluated based on four constructs: immersion, social interactivity, perceived humanness, and value from the teachers' perspective. The study's results provided advanced insights into adapting live-streaming for inquiry learning and suggested that it can facilitate rural students' effective science learning. While this paper by no means endeavours to provide answers to the use of live streaming for rural primary school science learning, this study touched on the tensions of lacking resources and qualified science teachers as it explored how non-science teachers experienced live-streaming learning by linking their perceptions to the inquiry-based model and provided the knowledge when using this model.

Learning with live streaming, in this study, refers to students engaging in learning from another place other than school. However, science inquiry learning with live-streaming learning refers to the type of teaching that occurs when students are co-located in the rural school's physical classroom, and the teacher offers remote instruction from another location. According to the research, momentary immersion reflects situation-specific engagement. However, current conceptualizations seem to be at each phase of P-D/O-Q/D-E-T, which may result in students only partially reflecting on the understanding of the digital context or on what the live-streaming teachers say. Thus, those factors may lead to an understanding of the growing usage of live streaming for science teaching. Moreover, to equalize the learning materials in science learning units, the researchers sent the experimental material before the live-streaming class. In this case, it is suggested that only those science units with accessible materials can be easily adapted according to the P-D/O-Q/D-E-T model. Additionally, teachers found that the P-D/O-Q/D-E-T model can be successfully applied through live-streaming in short science courses, such as those covering surface tension or gravity. For teachers who require live-stream science teaching, the focus is on identifying which science learning content would be appropriate to be designed with the P-D/O-Q/D-E-T model.

Observational research is abundant and influences education practice. However, it frequently generates unreliable findings (Wang et al., 2015). Inherent limitations of this method include generating bias and confounding means so that causal inferences cannot be reliably drawn. Because of the limitations, future evidence may be collected during experimental studies to identify how participants' cognition and affective process influence their learning effectiveness. Another limitation occurred with the Internet system, Google Meet, which was used as the platform in this study. Google Meet can accommodate many participants from many locations, but if there are too many participants, the screen of each participating group would become too small for students to clearly see other participants' reactions. It would, therefore, be helpful to study how many participating groups from different locations are most suitable to conduct live streaming in short science courses with the P-D/O-Q/D-E-T model.

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Declaration of Interest

The authors declare no competing interest.

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