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RESEARCH ARTICLE

Exploring 360° Camera Deployment in a STEM Rotation-Station Laboratory: Pre-service Teachers' Perceptions

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Abstract: 360° cameras allow for comprehensive spatial coverage in classroom settings; however, the use of these devices in STEM teacher education labs has not been adequately investigated. This exploratory study (N = 16 pre-service teachers) aimed to investigate the perceptions of pre-service teachers on the use of a 360° camera installed in a university STEM rotation-station laboratory equipped with Arduino, BBC micro:bit, Makey-Makey, and Raspberry Pi devices. A researcher-designed questionnaire was used to collect data on pre-service teachers' perceptions on the three aspects of the 360° camera's use in a STEM teacher education setting: (a) the observer effect, (b) the value of the 360° camera for teacher improvement, and (c) the potential of interactive hotspot annotations on the video feed. The results revealed minimal perceived reactivity: 60.0% of participants reported no/minimal effect on themselves, and 73.3% perceived no/minimal effect on the instructor. The value of the 360° camera for improvement was highly endorsed by the pre-service teachers; likewise, the potential of interactive hotspot annotations on the video feed for prospective teacher practice was highly appreciated by the pre-service teachers. Three themes were found to be relevant to the pre-service teacher perceptions on the use of the 360° camera in a STEM teacher education setting: complete spatial coverage, potential to monitor engagement, and potential for reflective improvement. Data on course evaluation and self-assessed knowledge confirmed the authentic and engaging nature of the setting for pre-service teacher learning. The findings should be viewed with caution as they are based on self-report data collected from a small sample of convenience; therefore, more research should be conducted to corroborate these findings using more objective methods and larger and more diverse samples.

Keywords: rotation-station model, observer effect, video annotation, hotspot enrichment, reflective practice, mobile learning

1 Introduction

Video recording of the instructional sessions has been at the center of teacher education for several decades (Allen & Eve, 1968). Comprehensive reviews have confirmed that video viewing is a reliable means of developing teachers' professional vision (Gaudin & Chaliès, 2015) and reflective teaching practices (Hamel et al., 2019).

A widely used methodological approach is the following: after video recording the instruction, the video is viewed individually or in groups, with the focus of the discussion being the goals, methods, and techniques, as well as the management of the classroom and the students. The underlying mechanism of this approach is the concept of reflective practices, where individuals reflect systematically on their practices. Empirical research shows that video analysis can have a positive impact on teacher change processes (Tripp & Rich, 2012) and can improve professional noticing skills (Sherin & van Es, 2009; Seidel et al., 2011). Blomberg et al. (2013) suggested five evidence-based heuristics for the effective use of video in pre-service teacher education, emphasizing the value of structured viewing with the support of an analytical framework.

On the one hand, the traditional method of video recording is characterized by its limitations, such as the use of only one camera, which can only capture a small area, the need for central direction by an observer, and the presence of blind spots in the recorded image. These factors become particularly important in the context of laboratory settings, where several groups work at the same time at different stations. On the other hand, the use of 360-degree cameras allows for the elimination of the above problems, since the camera captures the entire space without blind spots, does not require the presence of a director, and allows for the selection of any angle of view at any time after the video is recorded.

According to the results of the latest systematic reviews, immersive technologies such as augmented and virtual reality have been recognized as transformative dimensions in education (Sotiropoulos & Pikoula, 2018), and the use of 360-degree video is gaining popularity in the context of teacher education. For instance, Atal et al. (2023) conducted an extensive systematic review, the results of which confirmed the positive impact of 360-degree video on presence, observing, and reflection in the context of teacher education. Moreover, Rosendahl & Wagner (2024) conducted a systematic review of 44 studies, the results of which revealed the presence of five categories of added value in the use of 360-degree video in education, such as increased motivation, authenticity, immersion, multi-perspective observation, and individualized learning. Qian et al. (2025) also confirmed the positive impact of 360-degree video in the context of teacher education, as revealed in the results of the conducted scoping review focused specifically on teacher education. Jiang et al. (2024) conducted a meta-analysis of 49 studies, the results of which revealed the positive impact of 360-degree video, such as the presence of medium effect sizes in the context of learning outcomes (Hedges' g = 0.525) and non-cognitive outcomes (Hedges' g = 0.527). According to research, when you use a full 360-degree perspective to implement 360-degree video (which has also been referred to as "immersive observation" by Roche et al. (2021), there are many benefits to that for both the user (the educator) and the viewer (the student). Specifically, one of the benefits for educators is that they can see everything in their entire field of vision/no blind spots when watching 360-degree video. Additionally, 360-degree videos improve the ability of educators to develop professional skills through their educator training and preparation before they enter the classroom, as well as building their social skills/ability to relate to others in their classrooms because they are all connected to each other during the training process (Theelen et al., 2019, 2020). Ferdig and Kosko (2020) indicated that the use of 360° video increases perceptual divergence and immersion; Gold and Windscheid (2020) showed that the extent to which 360° video influences presence, emotion, and performance depends on the type of 360° video used. Walshe and Driver (2019) have found that 360° video can effectively support pre-service teacher reflective practice.

360° video has been shown to have educational advantages in K-12 settings beyond teacher education, according to previous research. A comparison of 360° videos with print and web materials during an environmental education project involving 44 primary (9-10 years old) students conducted by Fokides and Arvaniti (2020) revealed significantly greater levels of learning with very large effect sizes from using the 360° video; immersion was identified as a major explanation for the difference. A later study by Fokides and Vlachopoulou (2024) using the same sample size (n = 44) of kindergarten students learning about wild animals revealed similar results that using 360° video produced significantly greater knowledge acquisition compared to using print and that immersion was the only factor that positively influenced learning outcomes at a statistically significant level. In both studies, low-cost head-mounted displays (HMDs) and interactive hot spots were used, evidencing that providing low-cost access to 360° video still yields significant benefit to all ages and subject matter areas.

On the other hand, video annotation tools have also received increasing research interest. Rich and Hannafin (2009) have found that video annotation tools can effectively support teacher reflection; McFadden et al. (2014) have found that digital video annotation can support pre-service novice science teacher reflective practice. Moreover, Evi-Colombo et al. (2020) have reviewed the potential of video annotation tools from a technical and pedagogical perspective; interactive "hotspots," *i.e.*, information points on the video screen, have been found to be an interesting but under-explored potential of video annotation tools. The combination of 360° video with video annotation tools has not yet been explored extensively; there are only a handful of studies on the application of video annotation tools in the context of hands-on teacher training with a 360° video (Draghina et al., 2023).

The gap that this exploratory pilot study aims to address is that very little research has been conducted on the application of a 360° video in hands-on STEM labs where pre-service teachers work in groups on different stations with physical computing devices.

The role of 360° video technologies is, however, only one aspect of a larger perspective concerning mobile/digital learning spaces. Currently, 360° camera technologies can create content that can be viewed on mobile devices, uploaded to cloud hosting applications, and shared with others asynchronously as reflective experiences regardless of time or location. Pre-service teachers can view video footage of their lab work on mobile devices, and they can pause and navigate forward in the 360° panoramic view or return again later to view specific areas of lab videos.

In addition, mobile devices (cell phones) and head-mounted displays (HMDs) that can be used to view lab videos are both mobile technologies. Therefore, applications of 360° video aligned with the theory of mobile learning as they are learner-centered, contextually-aware, and accessible to learners across multiple contexts (Crompton, 2013). Current research suggests mobile technology has the potential to assist in the preparation of pre-service teachers to use STEM concepts in the classrooms in which they will be employed (Kalogiannakis & Papadakis, 2020). Therefore, adding to the existing mobile preparation model for pre-service teacher education, that is focused on mobile-mediated ICT practices, the addition of 360° video recorded laboratory practices would be a natural progression of the existing model. Additionally, integrating interactive hot spot annotations into the 360° video hosted in the cloud would further extend the opportunity to create 360° video digital learning resources that provide rich interactive digital content to be used across the distance in geographically dispersed teacher education programs (Crompton, 2013). Other studies have also confirmed this trend: Papadakis and Kalogiannakis (2022) found that engaging in hands-on activities with educational robots promotes computational thinking, while Zourmpakis et al. (2023) created a framework for Adaptive Gamification in physics education using technology-mediated interactive experiences; and Kalogiannakis and Papadakis (2019) found that pre-service kindergarten teachers had positive perceptions about using programming tools as part of teaching students about computational thinking and science. This indicates that pre-service teacher preparation programs may be an excellent way for pre-service teachers to become comfortable using new technology such as 360 video for reflective practices associated with their lab experiences.

The research questions are:

RQ1: How does the application of a 360° video influence the students and instructor in a STEM lab?

RQ2: What are pre-service teachers' perceptions of the potential of video recording with a 360° video for pre-service teacher training?

RQ3: What are pre-service teachers' perceptions of the advantages of a 360° video compared to a traditional video?

2 Materials and methods

2.1 Study design

The present research used a descriptive and exploratory design because there was very little previous research on how to employ 360-degree cameras in hands-on STEM labs. The purpose of this study was to evaluate the feasibility and acceptability of this new technology from the participants' perspectives (observing effects/how willing participants are to interact with 360-degree video). The primary goal of the study was to provide baseline data for future research. The objectives of the study included: conducting an initial examination of how to install/provide credibility to the use of new technology by examining placement protocols, ethical procedures, and technological workflows; collecting baseline data regarding how participants perceive the feasibility of the new technology; and collecting baseline perception data for use in the estimation of effect sizes and for modifications to methods prior to this research phase (Ruangsomboon et al., 2024; Muresherwa & Jita, 2022). Ethical guidelines on station/face-to-face data collection that were followed were based upon those found in Petousi and Sifaki (2020).

2.2 Participants

The sample consisted of 16 pre-service teachers from the course "Innovative Educational Technologies and Teaching Approaches" in the Department of Informatics at the University. One participant completed Section A (course evaluation) but did not answer questions in Section C (Q1 to Q6). Thus, the sample for all 360° camera questions was N = 15. As participants were from the Department of Informatics at the University, they all had high digital literacy and knowledge of technology. The sample was from the whole population of students in this course. Thus, it was a convenience sample but in parallel the sample was not large enough to generalize to other populations. It is appropriate for exploratory studies of new educational technologies in natural settings (Theelen et al., 2019; Walshe & Driver, 2019). The sample was large enough to exceed the minimum required sample to investigate novel educational technologies (Julious, 2005).

2.3 Context and setting

This course focuses on innovative technologies and methods of teaching and includes work in hands-on laboratories. Each lab was structured with rotations; students had assigned groups that rotated through four stations, each with its own physical computing platform: (a) an Arduino; (b) a BBC micro:bit; (c) a Makey-Makey; and (d) a Raspberry Pi. Physical computing (PCT), which is the use of tangible, programmable devices that respond to or interact with the physical world, is considered an important part of the current computing curriculum (Hodges et al., 2020; Sentance & Csizmadia, 2017). The groups at each station worked for a predetermined length of time before rotating into the next station, creating an active learning environment for many groups simultaneously, which is not possible using a single camera perspective.

2.4 The camera and its placement

A 360° camera (dual lens, 3840 × 1920 resolution, and integrated audio capture capability) was used to capture the full field of view (up to 360° in both the horizontal and vertical axes). In this experiment, audio was also captured to provide context to the video when analyzing the captured video. The audio was not transcribed and was not used in the analysis; however, it was saved and encrypted to the same level of restriction as the video capture. Before actual deployment, three locations were considered for the camera's placement: (a) close to the instructor, (b) close to the students, and (c) centrally located and 2.5 meters from the ground. Finally, location (c) was chosen, as this location offered the most balanced view of all stations. This location was also chosen to minimize the camera's visual impact, potentially reducing observer effects.

2.5 Procedure

The structured protocol for this intervention involved the following steps: (1) Students were given information about the process of being recorded as well as written consent to be recorded. (2) Prior to the recording occurring, approval from the institution was obtained. (3) A camera capable of recording all 360 degrees was mounted at a predetermined location prior to the students arriving to the laboratory session. (4) The same laboratory session was conducted as it would have been without any modifications. (5) Once the laboratory session was complete, students were asked to complete a questionnaire. The study protocol was conducted according to the ethical guidelines from the institution for conducting research with human subjects. Students provided written consent for both video recording and questionnaire completion. The recorded video was saved to an encrypted institutional server with access limited only to members of the research team, and no facial-recognition processes were utilized.

2.6 Instrument

A specific questionnaire was also developed for immediate administration after the lab session. The questionnaire was composed of 15 items distributed into three parts: A—Course Evaluation (4 items), B—Knowledge Self-Assessment (5 items), and C—360° Camera Perceptions (6 Likert-type items + 1 open-ended item). Specifically, A—Course Evaluation included participants' perceptions regarding the quality of course content, learning process overall, teaching method adopted by the instructor, and activities developed during the lab session using a set of descriptive ordinal scales ranging from excellent to poor. B—Knowledge Self-Assessment included self-assessed pedagogical knowledge before and after the course, teaching skills for microcontroller-related subjects before and after the course, future teaching intentions, and a single open-ended item focusing on participants' perceived strengths and weaknesses regarding both the course and the instructor. Finally, C—360° Camera Perceptions included participants' perceptions regarding the observer effect on students (Q1) and on the instructor (Q2), which correspond to RQ1; value for instructor improvement (Q3), student self-improvement (Q4), use of hotspot-enriched video for student enhancement (Q5), and micro/peer teaching improvement (Q6), which correspond to RQ2; advantages of using a 360° camera versus a regular camera (Q7—open-ended), which corresponds to RQ3. Q1-Q6 adopted a 5-point Likert-type scale ranging from 1 (Not at all) to 5 (To a great extent). The content validity of the questionnaire was ensured through a review process with two domain experts from the field of educational technology. Face validity was ensured by administering a pilot version to a group of three graduate students. Finally, no calculation of Cronbach's α was conducted for the questionnaire since Q1-Q6 measure participants' perceptions on a set of conceptually distinct concepts; hence, internal consistency is not a relevant factor for evaluating the validity of this questionnaire. The development of a more comprehensive questionnaire—potentially using a set of items from the eXtended Reality Presence Scale (Gandolfi et al., 2021)—is considered a future direction for conducting further research on the subject.

2.7 Data analysis

Descriptive analyses, of which a number of different outputs were produced (frequencies, percentages, medians, means, and standard deviations), were performed for each of the Likert-scale items (Section C) to present the quantitative data descriptively and provide summary information about them. The quantitative data is ordinal in nature (which is a function of the Likert-type ratings), and the sample is small enough in size that the median (Mdn.) and interquartile range (IQR) are the measures of central tendency and dispersion, respectively, of choice for this data (Eiselen & van Huyssteen, 2023). Descriptive analyses of frequencies and percentages were also performed to present evaluation data for courses (from Section A) and to present self-assessment of knowledge (from Section B) together with comparisons of both sets of data. A descriptive before-and-after analysis was conducted for each of the self-assessment of knowledge data to illustrate the change in level of knowledge (as measured by the self-assessment of knowledge) following completion of the laboratory session. Open-ended data were analysed using inductive reflexive thematic analysis (Braun & Clarke, 2006); the phases of analysis included familiarisation, initial coding, searching for themes, reviewing themes, defining and naming themes and reporting the content of each theme. Data were coded by the researcher and a 'critical friend' (a colleague) assisted with a peer debriefing process for ensuring reflexivity and transparency in the interpretation of the data (Braun & Clarke, 2019). One participant responded to only four items in the self-assessment of knowledge (only the first three items in Section A), therefore there are only n = 15 participants used in most of the analyses associated with Section A and all analyses involving Section B. In isolated cases where two options were selected, the first selection was retained.

3 Results

The results are organised into five subsections. Sections 3.1–3.3 present the learning context data (course evaluation, knowledge self-assessment, and open-ended course feedback) that establish the setting in which the 360° camera was evaluated. Section 3.4 reports the descriptive statistics for the Likert-type items (Q1–Q6), and Section 3.5 presents the findings organised by research question, including the thematic analysis of Q7.

3.1 Learning context: Course evaluation

Results from all four evaluation dimensions of this course were overwhelmingly positive (see Table 1). For the quality of course materials used, 50% of respondents rated it "excellent," 43.8% rated it "very good," and only one participant (6.2%) rated it "good." There was a similar distribution for the overall manner in which the learning process occurred: 50% rated it "excellent," 43.8% rated it "very good," and 6.2% rated it "good".

Table 1 Course evaluation results (N = 16; n = 15 for lab activities)

Item	Excellent	Very Good	Good	Fair/Poor
Course content	50.0%	43.8%	6.2%	0%
Learning process	50.0%	43.8%	6.2%	0%
Teaching approach	37.5%	62.5%	0%	0%
Lab activities*	53.3%	33.3%	13.3%	0%

Note: n = 15; one partial response excluded. One participant selected both "very good" and "excellent"; the first response was retained.

The instructor's style of teaching received all high scores, with 62.5% of respondents rating it "very good" and 37.5% rating it "excellent" – there were no responses below the "very good" category from any participant. All laboratory activities also received high ratings from respondents; 53.3% rated them "excellent," 33.3% rated them "very good," and 13.3% rated them "good" (n = 15 for this item because one participant completed only part of this question).

3.2 Knowledge self-assessment

The data from self-assessments showed a pronounced increase in the participant's perception of their pedagogical knowledge subsequent to the laboratory session (Table 2). Prior to the course, 40.0% of the respondents considered that they knew nothing at all about what was required to teach microcontroller-related subjects; 26.7% reported that they had a moderate amount of prior knowledge, 20.0% had significant prior knowledge, and 6.7% had minimal amounts of prior knowledge, while one individual (6.7%) stated that they knew exactly what was necessary to do so.

Table 2 Self-reported pedagogical knowledge before and after the course (n = 15)

Knowledge Level	Before (%)	After (%)
Nothing at all	40.0	0
Minimal	6.7	6.7
Moderate	26.7	46.7
Significant	20.0	33.3
Exact knowledge needed	6.7	13.3

Note: Regarding future teaching intentions, 80.0% of respondents indicated “a little” interest in teaching such subjects in the future, 13.3% expressed “a lot” of interest, and 6.7% indicated “minimal” interest. In one case, two options were selected; the first response was retained.

Following the conclusion of the course, the overall effect was an increase in the amount of knowledge that was described in each of these categories, with 46.7% of the respondents reporting moderate knowledge, 33.3% of the respondents reporting significant knowledge, and 13.3% of respondents saying they understood exactly what they needed to be able to do to function as teachers in this area. After taking this course, only one (6.7%) individual reported minimal knowledge of the subject; furthermore, no respondent indicated that they knew nothing prior to their participation in this course, where 40% of respondents had indicated that they knew nothing at all before taking the course.

3.3 Open-ended course feedback

From the thematic analysis of the open-ended questions on course strengths and weaknesses, two major themes were observed. However, it should be noted that there were four respondents whose answers were not very informative (such as “ok,” “nothing,” or random characters); these are also excluded from the study but are presented here for completeness’ sake. The most prominent weakness observed in the course was the lack of enough time to work on the four platforms. This was evident in the open-ended answers where respondents indicated a “lack of time” to work on all the applications.

The most prominent strength observed in the course was the hands-on experience in the laboratory setting. This was evident in the open-ended answers where respondents indicated that the hands-on experience with the physical devices helped them understand the subject matter; thus, the experience was innovative and motivated them to work on programming. Some respondents also indicated that the instructor was very helpful; for instance, one of them indicated that “the instructor is always willing to help,” also indicating that the instructor allowed them to borrow devices from the lab.

3.4 Descriptive statistics (Q1–Q6)

Table 3 presents the response distributions, medians, interquartile ranges (IQR), means, and standard deviations for each Likert-type item.

Table 3 Descriptive statistics for Likert-type items (N = 15)

Question	1	2	3	4	5	Mdn	M	SD	IQR
Q1 – Student affect	3 (20.0%)	6 (40.0%)	2 (13.3%)	3 (20.0%)	1 (6.7%)	2.0	2.53	1.25	1.50
Q2 – Instructor affect	3 (20.0%)	8 (53.3%)	4 (26.7%)	0 (0.0%)	0 (0.0%)	2.0	2.07	0.70	0.50
Q3 – Instructor improvement	0 (0.0%)	0 (0.0%)	2 (13.3%)	11 (73.3%)	2 (13.3%)	4.0	4.00	0.53	0.00
Q4 – Student improvement	1 (6.7%)	3 (20.0%)	4 (26.7%)	4 (26.7%)	3 (20.0%)	3.0	3.33	1.23	1.50
Q5 – Improvement w/ hotspots	0 (0.0%)	3 (20.0%)	4 (26.7%)	7 (46.7%)	1 (6.7%)	4.0	3.40	0.91	1.00
Q6 – Future teacher w/ hotspots	0 (0.0%)	0 (0.0%)	7 (46.7%)	5 (33.3%)	3 (20.0%)	4.0	3.73	0.80	1.00

Note: IQR = Interquartile Range; Scale: 1 = Not at all, 5 = To a great extent. Mdn = Median, IQR = Interquartile Range, M = Mean, SD = Standard Deviation.

3.5 Results by research question

3.5.1 RQ1: Observer effect (Q1, Q2)

Regarding student affect (Q1), 60.0% of participants reported being "not at all" or "minimally" affected by the camera's presence (Mdn = 2.0, M = 2.53, SD = 1.25). One participant (6.7%) selected the highest response option ("To a great extent"), describing the camera as "bothering" them and "causing a problem," consistent with maximum perceived impact on the scale. Regarding perceived instructor affect (Q2), 73.3% responded "not at all" or "minimally" (Mdn = 2.0, M = 2.07, SD = 0.70), and no participant selected "considerably" or "to a great extent." The lower variability in Q2 (SD = 0.70 vs. 1.25 for Q1) suggests greater consensus regarding the instructor's perceived unaffectedness. It should be noted that this was the participants' first exposure to the technology, a condition under which novelty effects might reasonably be expected to be heightened; the low perceived impact is therefore noteworthy. However, several alternative explanations must be acknowledged.

(1) Participants were possibly influenced by social desirability bias to underreport distractions while their teacher was present.

(2) Habituation effects might have been active without the participants' knowledge, leading them to not realize they exhibited changed behaviors.

(3) The measures used in this study evaluate perceived reactivity as opposed to actual reactivity; a different set of behavioral indicators (*e.g.*, on-task time, movement patterns) may produce significantly different results from those produced by this study. The aforementioned limitations correspond with larger criticisms of self-report measures of effects from research participation (Gunnarsson et al., 2025; Zahle, 2023). Future research should employ objective behavioral measures to more rigorously evaluate the observer effect.

3.5.2 RQ2: Perceived value for professional development (Q3–Q6)

The perceived value for instructor professional development (Q3) received the strongest endorsement: 86.7% responded "considerably" or "to a great extent" (Mdn = 4.0, M = 4.00, SD = 0.53). This was the highest-rated item across the questionnaire. The perceived value for student improvement through video re-viewing (Q4) showed a more distributed pattern: 46.7% positive, 26.7% moderate, 20% minimally, and 6.7% not at all (Mdn = 3.0, M = 3.33, SD = 1.23). It should be noted that participants had not yet reviewed any 360° recordings prior to responding; Q3–Q6 therefore capture anticipated, rather than experienced, value. The difference between Q3 and Q4 is notable: participants perceived the camera as more valuable for instructor development than for their own improvement. This asymmetry may reflect students' limited prior experience with self-reflection through video. The introduction of interactive hotspot annotations further enhanced perceived value.

Hotspot-enriched video for general improvement (Q5) was rated positively by 53.3% of respondents (Mdn = 4.0, M = 3.40, SD = 0.91), with no participant selecting "not at all." When the scenario was extended to include peer teaching combined with hotspots for future-teacher improvement (Q6), no participant selected "not at all" or "minimally" (Mdn = 4.0, M = 3.73, SD = 0.80). The reduced variability in Q6 suggests greater consensus when the professional development framing was explicit. Considered as a progression, the sequence Q4 (M = 3.33) → Q5 (M = 3.40) → Q6 (M = 3.73) reveals a consistent ascending pattern: perceived benefit increases incrementally as the pedagogical scenario becomes more structured — from passive video re-viewing, to hotspot-annotated video, to hotspot-annotated micro/peer-teaching. While the differences are small given the sample size, the monotonic increase across all three items is consistent with the hypothesis that the combination of 360° video, hotspot annotations, and peer-teaching role plays a synergistic role in professional development — a design logic that warrants formal experimental testing in future work.

3.5.3 RQ3: Perceived advantages — thematic analysis (Q7)

Inductive thematic analysis of the open-ended responses identified three main themes, summarized in Table 4.

Theme 1—Complete spatial coverage: This was the most frequently mentioned benefit. Sub-themes were eliminating Blind Spots, no need for camera operator, and thorough documentation of the entire Learning Space - Affordances that are consistent with the Rotation-STATION format where participants simultaneously engage in an activity within separate locations.

Theme 2—Engagement monitoring capability: Participants acknowledged the use of the camera to monitor student engagement throughout the Laboratory Space, monitoring and via

Table 4 Summary of themes from open-ended responses (Q7)

Theme	Definition	Exemplary Quotes
Complete spatial coverage	The 360° camera captures the entire classroom without blind spots, eliminating the need for a camera operator.	"records the entire classroom from a central angle, unlike a conventional camera that would have considerable blind spots"
Engagement monitoring capability	The camera enables instructors to observe student engagement across the full laboratory space in real time or retrospectively.	"the instructor has the ability to know what is happening with the students throughout the entire duration of the lesson"
Reflective improvement potential	Recorded footage supports reflective practice, allowing teachers to review and iteratively improve their teaching.	"improve and correct our mistakes"; "an inexperienced teacher who would review the lesson"

the ability to review recorded video footage after a session has completed.

Theme 3—Reflective improvement potential: Participants identified the potential value of recorded video footage in supporting self-improvement iteratively, especially among novice teachers. This theme parallels Q3's quantitative findings and supports the current literature on video-supported reflective practice.

The convergence of qualitative themes with quantitative data offers a level of methodological triangulation that enhances the overall findings.

4 Discussion

The positive course evaluations and the self-reported learning gains form an important setting for interpreting the findings of the 360° camera (Sections 3.1–3.3). The laboratory session was perceived by participants to be a successful learning experience that was both engaging and successful. In fact, 93.8% of participants rated the content, learning process, and teaching style of the laboratory as being either "very good" or "excellent", providing evidence that the experiences surrounding the use of the 360° camera were generally positive and therefore, less likely to colour their perception regarding the technology used to study STEM teacher education. These results are consistent with participants' self-assessed pedagogical knowledge: whereas 40.0% reported knowing nothing at all before the course, more than half rated their knowledge as either moderate or significant after the session. This shift suggests that the experiential-based laboratory format, incorporating physical computing platforms, supported the development of basic competencies related to STEM teacher preparation (Hodges et al., 2020; Sotiropoulos et al., 2025)." may reflect the participants' understanding that additional learning will be required before they would be prepared to teach, not a lack of interest. Ultimately, the data from the self-assessment do not provide evidence of performance or causal relationships but only provide an indication of the context of the authentic engagement within which the 360° camera was evaluated.

The observer effect, also known as the Hawthorne effect (McCambridge et al., 2014), is a common concern with video recordings of teaching activities. Participants in this study reported very low perceived reactivity to the 360° camera with 60.0% of students reporting that they were not impacted by and/or minimally impacted by the camera, and 73.3% of students reported that they perceived the instructor as not impacted by and/or minimally impacted by the camera; however, it is necessary to provide behavioral verification to come to any stronger conclusions about this. The current data align with the findings of Walshe and Driver (2019) with pre-service teachers. Gold and Windscheid (2020), found that 360° video elicited less emotional arousal compared to traditional classroom video, which could contribute to decreased reactivity. A number of factors may have contributed to participants having very low perceived observer effects, including: the small form factor and high location of the camera (2.5 m), which reduced the visual salience of the camera; the absence of a human operator, which eliminated the "human gaze" factor; and that participants may have had enough exposure to technology that they may have had limited awareness of the camera. However, it is important to note that reactivity is a multi-dimensional construct and cannot be adequately assessed by self-report alone, as the effects of participation can occur at a subconscious level (Gunnarsson et al., 2025; Zahle, 2023) and would benefit from using objective behavioural measures in future research— such as repeated sessions or comparison of 2D versus 360° recordings — to more rigorously evaluate the observer effect.

The high supportive opinion on the worth of the camera as an avenue for instructional moment development (see Q3: 86.7% positive; median rating = 4.0) from the participants is congruous with prior research documenting efficacy of video based reflection. Gaudin and Chaliès (2015) reported that viewing videotape of themselves was one of the most effective methods for the development of teachers' professional vision, and Tripp and Rich (2012) found that analysis of video positively impacted teacher change process. The current data indicators suggest that teachers believe 360° video provides additional benefit due to the ability to fully capture the location in the frame and thus provide multiple view points to analyze from one same recording. The gap in perceived value to the teachers regarding their professional growth (Q3; M = 4.00) versus their perception of value regarding their students' self-improvement (Q4; M = 3.33) may indicate that the students have not yet personally experienced using video tape for their own self-review as an impact to their learning. It also could be attributable to the concept of social desirability as it may be more socially acceptable for a student to identify that they need improvement on an instructor (3rd party) rather than themselves. Kosko et al. (2021) found that pre-service teacher noticing skills improved opportunistically with the use of 360° video when compared to standard video; thus, the more that teachers become acquainted through experience with the medium, the greater the likelihood that perceptions will shift. In addition, Ferdig et al. (2023) demonstrated that fidelity of the 360° audio/visual environment has an impact on how the viewers were focused on viewing and observing.

This research presents new evidence through the favourable responses to the hotspots (53.3% of responses were positive in Q5, while Q6 did not have any negative responses), as the combination of interactive annotations with 360° video has not yet been empirically researched (Draghina et al., 2023; Evi-Colombo et al., 2020). Rich & Hannafin (2009) state that video annotation tools can help support teachers in reflecting on their pedagogical practices, and the present findings indicate pre-service teachers recognised this possibility. Similarly, Balzaretti et al. (2019) discovered that when 360° video is used with structured viewing tasks, it has greater potential to assist in developing pre-service teachers. An important design element for future investigations is who creates the annotations — students or supervising educators (McFadden et al., 2014). A follow-up study will compare both methods through an experimental approach.

The favourable perceptions reported in this study are consistent with the broader empirical literature on 360° video in education. Fokides and Arvaniti (2020) found that primary school students achieved significantly better learning outcomes with 360° video compared to both printed materials and web pages, with immersion serving as the primary explanatory factor. Fokides and Vlachopoulou (2024) found that in their study of kindergarten children, immersion was the only variable that positively impacted learning outcomes when using 360-degree videos with inexpensive HMDs. Both of these previous studies also incorporated interactive hotspot annotations within the 360-degree videos, which are the same type of features used for the hotspot-enriched approach used in this investigation. Although the present study focused on the perception of pre-service teachers rather than quantitative student outcomes, the concurrence of positive attitudes toward hotspot-enriched 360-degree videos across diverse educational levels provides a compelling rationale for supporting further investment into this instructional method. Additionally, the fact that school-aged children were able to attain significant benefits due to immersion from the use of inexpensive HMDs (Fokides & Vlachopoulou, 2024) implies that price should not be a deterrent to use of the 360-degree video format in teacher education laboratory settings. These findings, while preliminary, offer practical considerations for the deployment of 360-degree video technology in STEM laboratory environments.

Viewers should be limited in the amount of time they spend watching 360° video through VR headsets due to potential overheating of the device as well as viewer fatigue (Snelson & Hsu, 2019). Therefore, short excerpts rather than full-length recordings are preferable for reflective viewing. This study's findings illustrate that the optimum positioning for a 360º camera in the rotation station settings is centrally and elevated at 2.5m above ground level. Additionally, they have important implications for mobile and digital learning ecosystems. The 360º video recordings created in this study can be stored on cloud-based platforms in addition to being accessible off-line, therefore pre-service teachers are able to reflect on their work independently and outside of the university environment. The use of portable 360º cameras in conjunction with mobile device-compatible viewers (*i.e.*, VR headsets using smartphones) develop a low cost and scalable means of capturing and distributing immersive video recordings of classroom instruction. Furthermore, cloud-hosted video provided with interactive hotspot annotation becomes an organized digital learning resource for tuning and developing skills for independent professional growth.

Kalogiannakis and Papadakis (2020) demonstrated that mobile-mediated learning experiences can effectively prepare pre-service teachers for STEM teaching, and the present findings suggest that 360° video may complement such approaches by providing immersive, reviewable records of authentic laboratory practice. This mobile-accessible, asynchronous model of reflective practice has particular relevance for geographically distributed teacher education programmes, where pre-service teachers may have limited access to on-site laboratory demonstrations. Future implementations should therefore investigate how cloud-based sharing of hotspot-enriched 360° recordings can extend the reach of STEM laboratory experiences to remote and underserved pre-service teacher populations.

4.1 Specific contribution of this study

This study provides a few important contributions to the literature about 360° video in teacher education. To begin with, this research is one of the few studies that explores the use of a 360° camera in a STEM laboratory environment with multiple stations (*i.e.*, Arduino, BBC micro: bit, Makey-Makey, and Raspberry Pi). Because the physical arrangement of different technology at these stations creates challenges to traditional methods of video capture, using a single 360° camera allows for greater spatial coverage.

In addition, the results of this study suggest that 360° cameras may not elicit observer effects when participants are only given one exposure to the device (*i.e.*, when they are not given prior exposure). Participants in this study received their first exposure to the device in a real laboratory situation, and it is noteworthy that most participants reported that there was little or no observer effect from their exposure to the 360° camera. This finding has significance for those researchers and/or educators who are contemplating the use of 360° recording devices in their work.

An ascending pattern of perceived value for the 360° video was seen as the level of interaction with the video returned by a participant increased. For example, Q3 (M = 4.0) indicates that participants valued the recorded 360° video for their improvement as instructors; participants anticipated that simply viewing recorded 360° video would allow them to engage in passive reflection on their instructional practices. Similarly, Q4 (M = 3.33) demonstrates how participants valued recorded 360° video for their self-improvement as learners through passive review of recorded 360° video. Q5 (M = 3.40) demonstrates that participants continue to rate recorded 360° video (now enriched with "hot spots") as useful for improving their performance as instructors. Finally, Q6 (M = 3.73) demonstrates that participants expected to increase their learning as they viewed and discussed recorded 360° video within peer-teaching contexts. This relationship provides evidence that increased levels of both interactivity and pedagogical structure will lead to higher perceptions about the ability of these methods to assist with professional development. The results from the current study require additional research with larger sample sizes, and meaningful measures of outcomes to be established first, as will be discussed next.

Finally, the implications of these findings for mobile and cloud-based reflective practices are particularly significant. The 360° video recordings created for this research can easily be viewed on mobile devices and distributed via the cloud, thus providing opportunities for asynchronous reflective practice that is self-directed and aligned with the principles of mobile learning (Crompton, 2013; Kalogiannakis & Papadakis, 2020; Papadakis & Kalogiannakis, 2017). Incorporating interactive hotspot annotation into cloud-based 360° video creates new opportunities for developing navigable digital learning resources from previously passive video archives for teacher education programmes that are geographically distributed.

5 Limitations

Several limitations must be acknowledged. Firstly, the study had a relatively low number of participants (N = 16), which limits its generalization potential. Although it is a common number for a pilot study, one must be cautious when interpreting the results. Secondly, participants belonged to a specific group: Informatics students with high digital literacy skills. These skills might not be generalizable to pre-service teachers from other fields. Thirdly, a single questionnaire was applied to measure participants' perceptions after a single session without pre-test measures, a control group, or long-term study design. Fourthly, while the questionnaire was content-validated, it was not fully psychometrically validated. Fifthly, participants' perceptions might change after repeated exposure to technology. Finally, learning outcomes were not assessed; only perceptions were measured, which is a common limitation for early-stage educational technology studies (Theelen et al., 2019). Despite these limitations, the study is fully adequate for its initial aim: to conduct an exploratory study.

6 Future work

The current study is the first step of a larger research project. The instructor will analyze the recorded video footage to determine the quality of teaching and to assess how engaged students are during each segment of footage. The instructor will use each of the two sets of videos (teacher-created and student-created annotations) to enhance the video's value for the teacher and student in the form of hotspots for each condition. Each student will be placed in a separate group for comparison purposes.

For example, videos will be shared with students through a web-based, asynchronous environment. Another area of interest will be the use of 360-degree videos with either a standard screen or VR headsets. Future studies may use tracking people with eye-tracking methods to measure the effectiveness of professional noticing, as shown by Kosko et al. (2022) and others. Psychometrically validated instruments will be used to create instruments for the entire research project, potentially including the XRPS instrument developed by Gandolfi et al. (2021).

7 Conclusion

This exploratory pilot study offers initial support for the effectiveness of the 360-degree camera in the STEM rotation station laboratory, where the device would have minimal perceived reactivity (RQ1), substantial perceived value for reflective professional development and hotspot-enriched video, (RQ2), and advantages over traditional cameras in terms of spatial coverage and independence of the camera operator (RQ3). These perceptions were obtained in an authentically engaging learning scenario, although they are entirely based on the perceptions of the small convenience sample of digitally literate individuals.

Ultimately, the potential of using the 360-degree camera as an observational tool in STEM laboratories, as well as for researching pedagogical practices and developing teachers' professional skills, appears to be promising, even though these outcomes are still preliminary due to the initial nature of this research study. In addition to the findings reported here, the meta-analysis conducted by Jiang et al. (2024) revealed small but positive effect sizes, which provide additional evidence for the usage of 360-degree video. Future research should focus on developing and validating subscale measures of the observer effect and perceived value of professional development using multiple items in order to enhance the psychometric basis for this research area. This investigation has provided the methodological and empirical bases for future, larger-scale experimental research.

Informed consent statement

Informed consent was obtained from all subjects included in the study.

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Conflicts of interest

The author declares that there is no conflict of interest.

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