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Challenges and Strategies of Informatics Teachers in Integrating Interactive Technology in Classrooms

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ABSTRACT

This study aims to identify the challenges faced by informatics teachers in integrating interactive technology into classroom learning and the strategies used to overcome these obstacles. A descriptive qualitative approach was employed with data collected through in-depth interviews, classroom observations, and document analysis. The findings reveal four major categories of challenges: limited digital infrastructure, teachers' technological competence, varied student readiness, and limited instructional time. Informatics teachers addressed these challenges through self-training, the use of lightweight and free applications, strengthening teacher collaboration, developing interactive learning materials, and implementing more structured digital classroom management. The study recommends enhanced institutional support through the provision of appropriate devices, continuous training, and reinforcement of digital learning policies to achieve optimal integration of interactive technology.

Keywords: digital education, informatics teachers, interactive technology, learning strategies.

INTRODUCTION

The rapid development of information and communication technology (ICT) has driven significant changes in modern educational paradigms. In informatics learning, the use of interactive

technology has become an essential component for facilitating visual, kinesthetic, and application-based learning. Various technologies such as smartboards, AR/VR simulations, gamification platforms, and digital design applications are increasingly utilized to enhance student engagement.

However, the integration of interactive technology does not always run smoothly. Informatics teachers encounter various challenges, ranging from limited infrastructure, technological competence, differences in students' digital literacy, to limited instructional time. These conditions require teachers to design innovative lessons, manage digital classrooms effectively, and master emerging educational technologies.

The rapid advancement of information and communication technologies has reshaped contemporary educational practices, particularly in informatics education where interactive technologies are becoming central to classroom instruction. Tools such as smartboards, augmented and virtual reality simulations, gamified learning platforms, and digital design applications have been shown to enhance student engagement and support visual and application-based learning (Parong & Mayer, 2018; Bicen & Kocakoyun, 2018). These innovations reflect a broader global trend where digital technologies are increasingly embedded into secondary education systems (Gibson et al., 2018).

The core problem addressed in this study arises from the gap between expectations for technology-enhanced instruction and the actual readiness of teachers in school settings. Research consistently shows that schools in developing regions face limitations in infrastructure, unstable connectivity, and unequal access to digital devices (Nikolopoulou & Gialamas, 2016; Player-Koro, 2013). Informatics teachers, in particular, experience this gap acutely because they are expected to master emerging technologies, design interactive lessons, and manage digital classrooms despite constrained resources.

The current state of research highlights that teacher competence, confidence, and institutional support significantly influence the success of technology integration (Ertmer & Ottenbreit-Leftwich, 2010; Liu et al., 2020). Although interactive technologies have the potential to transform learning, their implementation is often hindered by insufficient professional development, lack of troubleshooting skills, and challenges in digital classroom management (Howard et al., 2015; Hew & Brush, 2007). Furthermore, student digital readiness varies widely, shaping teachers' ability to conduct effective technology-enhanced lessons (Ng, 2012; Hatlevik & Christophersen, 2013).

Despite growing global interest in digital education, a research gap persists. Many studies describe technology adoption at a policy level, but fewer provide detailed, classroom-level analyses of how informatics teachers navigate daily operational challenges when integrating interactive tools (Tondeur et al., 2017). Studies focusing on teacher agency and practical strategies remain limited, particularly within the context of developing countries.

This study contributes to the field by offering an in-depth account of the lived experiences of informatics teachers integrating interactive technologies under constrained conditions. It documents specific challenges—related to infrastructure, competence, student readiness, and time—and identifies practical strategies such as self-directed learning, collaboration, and teacher-created digital resources. These insights respond directly to calls for more context-sensitive research on technology-supported pedagogy (Voogt et al., 2015; Prestridge, 2017).

This study aims to identify the challenges that arise during the implementation of interactive technology in the classroom and the strategies used by informatics teachers to address these challenges. Understanding these aspects is essential for schools and policymakers to provide more targeted support.

METHOD

This study adopted a descriptive qualitative design to explore the experiences of informatics teachers integrating interactive technologies. A qualitative approach is appropriate when examining complex, practice-based phenomena embedded in real-world contexts (Creswell & Poth, 2018).

Research Design

This study employed a descriptive qualitative design to explore the lived experiences of informatics teachers in integrating interactive technologies into secondary school classrooms. A qualitative approach was chosen to capture rich, context-dependent data about teacher perceptions, practices, and adaptive strategies that cannot be fully represented by quantitative measures. The design emphasized naturalistic inquiry and purposive sampling to generate thick descriptions that inform practice and policy.

Research Setting and Participants

The research was conducted at SMA Negeri 1 Langowan, a public senior secondary school in North Sulawesi, Indonesia. Participants were six informatics teachers selected purposively to ensure variation in teaching experience, familiarity with educational technologies, and class levels taught. Inclusion criteria were: (a) current assignment as an informatics/computer science teacher, (b) minimum of three years classroom teaching experience, and (c) active use or attempted use of at least one interactive technology (e.g., smartboard, gamified platform, video-editing tools) during the current academic year. Participant demographics (gender, years of experience, highest qualification, types of technology used) were collected to provide contextual description.

Sampling Strategy

Purposive sampling was used to identify six informatics teachers from SMA Negeri 1 Langowan who met inclusion criteria related to teaching experience and prior use of interactive technology. Purposive sampling is commonly used in educational technology research to ensure the selection of information-rich cases (Miles et al., 2014). The sample size was determined based on the principle of saturation, data collection continued until no new themes emerged across interviews and observations. Maximum variation was sought by including teachers with different tenure (3–10 years), differing degrees of self-reported digital competence, and those teaching multiple grade levels, in order to capture a wide range of experiences.

Research Location and Subjects

The study was conducted with informatics teachers at SMA Negeri 1 Langowan, with teaching experience ranging between 3 and 10 years.

Data Collection Techniques

Data were collected through semi-structured interviews, classroom observations, and document analysis. Triangulation of methods supports credibility and strengthens trustworthiness (Lincoln & Guba, 1985). Interview protocols examined teachers' experiences, beliefs, and strategies, while observations captured authentic classroom interactions and technological issues. Document analysis included lesson plans, digital modules, and multimedia resources. Multiple qualitative data sources were triangulated to enhance the depth and credibility of findings. Data were collected through:

- In-depth semi-structured interviews
    - Each teacher participated in one in-depth semi-structured interview (60–90 minutes).
    - An interview protocol guided questioning across domains: background and teaching responsibilities; experience with interactive technologies; perceived barriers and enablers; instructional design strategies; classroom management practices related to devices and connectivity; professional development experiences; and recommendations for institutional support.
    - Interviews were audio-recorded with participant consent and transcribed verbatim for analysis.
- Classroom observations
    - Observations (2–3 sessions per teacher, each 40–90 minutes) were conducted to document actual technology use, teacher-student interactions, classroom management practices, and real-time technical issues.
    - An observation checklist and field note template captured specific items: type of technology used, lesson phase where technology was applied, student engagement indicators, technical interruptions, teacher scaffolding behaviors, and adaptive strategies (e.g., fallback activities).
    - Observational data complemented interview accounts by providing behavioral evidence of reported strategies.
- Document analysis (lesson plans, digital learning media, digital modules)
    - Relevant documents were collected and analyzed, including lesson plans, instructional materials (e.g., digital modules, video tutorials), school policies on device use, and sample student artifacts produced using interactive applications.
    - Document analysis provided corroborative evidence about teachers' design practices and the extent to which institutional documents supported or constrained technology integration.
- Supplementary Data
    - Where available, informal conversations with school administrators and IT staff were used to contextualize infrastructure and policy conditions. Relevant infrastructure records (e.g., inventory of devices, internet bandwidth reports) were reviewed when accessible.

Data Collection Procedure

Data collection proceeded in three phases. First, ethics approval and school permission were secured and participants provided informed consent. Second, background interviews and a document request were conducted to map teacher profiles and available materials. Third, classroom observations were scheduled during lessons where teachers planned to use interactive technology; follow-up interviews were conducted when necessary to clarify observational findings. All audio files and documents were stored in encrypted folders accessible only to the research team.

Data Analysis Techniques

Data were analyzed using the Miles and Huberman model:

1. Data reduction
2. Data display
3. Conclusion drawing

Data Validity

Data validity was ensured through:

- Source triangulation
- Technique triangulation
- Time triangulation

Data Analysis

Data analysis followed the Miles, Huberman, and Saldaña (2014) framework: data reduction, data display, and conclusion drawing. Coding combined inductive approaches with sensitizing concepts from existing technology integration frameworks (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur et al., 2017). Cross-case matrices facilitated comparison of challenges and strategies across participants. Data were analyzed using the Miles and Huberman (1994) model of qualitative data analysis, consisting of data reduction, data display, and conclusion drawing/verification:

- Transcription and Familiarization

Interview recordings were transcribed verbatim. Transcripts, observation notes, and documents were read repeatedly to achieve immersion and to identify initial codes.

- Coding and Thematic Development

An inductive-deductive coding process was used. Initial open codes were generated from the data (inductive), while a set of a priori codes, drawn from literature on technology integration (infrastructure, teacher competence, student readiness, classroom management), guided focused coding where applicable.

Codes were grouped into categories and iteratively refined into higher-order themes reflecting challenges and teacher strategies.

- Data Display and Cross-Case Analysis
  - Matrices and narrative tables were constructed to compare themes across participants and data sources (e.g., a matrix mapping challenges against teacher strategies and contextual conditions).
  - Cross-case analysis identified recurrent patterns, divergent practices, and context-specific solutions.

- Use of Qualitative Software (Optional)

Data management and coding were supported by qualitative analysis software (for example, NVivo or ATLAS.ti) to organize transcripts, track code frequencies, and retrieve coded segments. Use of software facilitated audit trails and systematic retrieval but all analytic decisions were researcher-driven.

- Interpretation and Verification

Emerging interpretations were iteratively checked against raw data and refined. Where inconsistencies appeared, debriefing with participants (member checking) and peer debriefing with research colleagues were used to validate interpretations.

Trustworthiness and Rigor

Trustworthiness was ensured through source triangulation, member checking, audit trails, and reflexive memoing (Lincoln & Guba, 1985). Ethical approval, informed consent, and confidentiality procedures were implemented according to standard qualitative research protocols (Creswell & Poth, 2018). To ensure credibility, transferability, dependability, and confirmability, the study applied multiple strategies:

- Triangulation: Method triangulation (interviews, observations, documents) and source triangulation (multiple teachers) were used to corroborate findings.
- Member Checking: Preliminary findings and thematic summaries were shared with participants for confirmation and correction.
- Audit Trail: Detailed documentation of coding decisions, analytic memos, and data matrices were maintained to allow external audit.
- Peer Debriefing: Periodic peer review sessions with qualitative researchers helped challenge assumptions and reduce researcher bias.
- Thick Description: Contextualized, detailed descriptions of setting and participants were included to enable readers to assess transferability.
- Reflexivity: The research team maintained reflexive memos documenting their own perspectives, assumptions, and decisions during data collection and analysis.

Ethical Considerations

Ethical clearance was obtained from the affiliated institutional review board prior to data collection. Participants were provided with written and verbal information about the study and signed informed consent forms. Anonymity and confidentiality were guaranteed: pseudonyms replaced real names in transcripts and reports, and identifying details about the school or individual teaching practices were masked unless explicit permission was granted. Participants could withdraw at any time without penalty. Data were stored on password-protected devices and will be retained according to institutional policies.

Limitations

The study's purposive sample and single-school setting limit generalizability. Findings are context-bound and primarily offer analytic generalization rather than statistical generalization. Observational reactivity (teachers adjusting practice because of observation) is a possible limitation,

though repeated observations and triangulation mitigate this risk. Where feasible, future research should include multiple schools and a mixed-methods design to test the prevalence and effectiveness of identified strategies.

RESULTS AND DISCUSSION

Challenges in Integrating Interactive Technology

The analysis identified four major categories of challenges that shaped teachers' ability to integrate interactive technology in their classrooms. These challenges were consistent across participants and appeared in both interviews and observed classroom practice.

a. Limited Facilities and Infrastructure

- Insufficient number of computers
- Lack of smartboards and AR devices
- Unstable internet connection

Teachers identified inadequate infrastructure, including insufficient devices and unstable internet, as the most significant barrier. This confirms earlier findings that infrastructure remains a foundational requirement for meaningful technology integration (Nikolopoulou & Gialamas, 2016; Player-Koro, 2013). Inconsistent bandwidth and malfunctioning equipment disrupted instructional pacing and limited teachers' ability to use advanced tools such as simulations or AR/VR (Parong & Mayer, 2018). Teachers consistently reported that insufficient infrastructure remained the most significant barrier. Although the school had a basic computer laboratory, the number of functioning devices was inadequate to support full classroom implementation. In several observations, teachers were required to rearrange lesson plans because not all students could access a computer or because multiple devices malfunctioned mid-lesson.

Network instability also interrupted teaching. Bandwidth fluctuations caused delays during activities requiring real-time connectivity, such as accessing cloud-based applications, loading multimedia resources, or conducting live quizzes. Teachers noted that even simple tasks like downloading an instructional video could take several minutes, resulting in lost instructional time and reduced lesson continuity.

The absence of advanced interactive tools such as smartboards, AR/VR kits, and touch-enabled displays further limited teachers' ability to demonstrate concepts interactively. Teachers often compensated by projecting static slides or using improvised visual aids, which diminished the intended interactivity of the lesson.

b. Teacher Technological Competence

- Difficulty operating new applications
- Lack of continuous technology training
- Troubleshooting challenges

Teachers reported difficulties navigating new applications, troubleshooting errors, and managing updates. Research shows that teacher competence, confidence, and technical knowledge significantly

influence technology adoption (Ertmer & Ottenbreit-Leftwich, 2010; Howard et al., 2015). Limited professional development exacerbated these issues, aligning with studies emphasizing the need for sustained, hands-on training (Liu et al., 2020). Although teachers were familiar with basic applications, they faced difficulties when working with newer or more complex interactive tools. Several teachers expressed uncertainty in navigating application updates, managing integration between tools (for example, linking quiz platforms with learning management systems), or troubleshooting errors during lessons.

Observed lessons showed that teachers frequently paused instruction to resolve technical problems such as frozen screens, incorrect device configurations, or software compatibility issues. These interruptions affected lesson flow and contributed to teacher stress.

Limited access to continuous professional development compounded these issues. Training, when available, tended to be short, one-time events without follow-up support, leaving teachers to rely on self-learning or peer assistance. As a result, adoption of new tools was incremental and often cautious, with teachers preferring simpler applications that posed fewer operational risks.

c. Student Readiness and Attitude

- Varied levels of digital literacy
- Students easily distracted by personal devices
- Dependence on teacher instructions

Variation in student digital literacy created challenges during interactive tasks. These finding parallels evidence that digital competence among students is uneven and influences classroom participation (Ng, 2012; Hatlevik & Christophersen, 2013; Aesaert et al., 2015). Teachers also described off-task behaviors, consistent with studies noting the need for effective digital classroom management (Ifenthaler & Schweinbenz, 2016). Student readiness emerged as a multidimensional challenge involving digital literacy, motivation, and device management. Teachers noted significant variation in students' competence in operating digital tools. While some students quickly adapted to interactive applications, others struggled with basic functions such as navigating menus, setting up accounts, or saving files correctly.

Classroom observations revealed that students with lower digital skills required continual one-on-one guidance, which slowed the pace of lessons and increased the teacher's workload.

Teachers also reported behavioral challenges unique to technology-rich classrooms. Students were often distracted by non-instructional content accessible on their devices, such as games or social media tabs running in the background. This required teachers to monitor device usage actively, shifting attention away from instruction.

In group-based activities, uneven digital literacy levels sometimes resulted in dominant students taking over tasks while others disengaged, reducing the intended collaborative learning effect.

d. Limited Instructional Time

- Device setup takes time
- Technical problems disrupt teaching flow

Teachers struggled to implement interactive activities within fixed lesson durations due to device setup time, troubleshooting, and technical delays. Prior research similarly notes that time constraints

are a major barrier to technology integration (Hew & Brush, 2007). Time constraints significantly influenced teachers' decisions to use interactive technology. Teachers explained that preparing devices, connecting to the internet, logging students into applications, and ensuring that all equipment functioned properly consumed a substantial portion of the lesson period.

Technical problems further reduced productive instructional time. In several observed sessions, teachers spent ten to fifteen minutes addressing issues such as audio not playing, screens failing to project, or student devices not syncing with the teacher's platform. These delays disrupted planned activities and led teachers to revert to traditional methods to ensure curriculum coverage.

Because national curriculum pacing guides are tightly structured, teachers felt pressure to prioritize content coverage over experimental or interactive activities. This tension made them strategically selective about when to employ technology-based tasks, often reserving them only for lessons where operational risks were minimal.

Strategies Used by Informatics Teachers

The analysis identified five major categories of strategies adopted by informatics teachers to address the challenges associated with integrating interactive technology. These strategies emerged from both self-initiated efforts and collaborative practices within the school environment.

a. Self-Training

Teachers enhance their skills by joining webinars, watching tutorial videos, and participating in online workshops. Teachers relied heavily on independent learning to enhance their technological competence. Most participants reported that formal training opportunities were limited, which led them to engage in systematic self-study by accessing online tutorials, attending free webinars, and exploring application features through trial and error. Teachers relied on online tutorials, webinars, and trial-and-error exploration to build competence. Self-directed learning is recognized as a key element of teacher digital agency (Prestridge, 2017).

Teachers described developing personal routines such as maintaining a "technology journal" to record tips and solutions, bookmarking instructional videos, and allocating weekly time for exploring new tools. This self-directed approach allowed teachers to gradually build confidence, reduce reliance on external technical support, and adopt new tools more strategically in their lesson plans.

b. Use of Lightweight and Free Applications

Teachers utilize Canva, CapCut, Google Workspace, ClassPoint, Kahoot, and Quizizz. Given infrastructure constraints, teachers favored applications that required minimal bandwidth, functioned well on older devices, and offered free or low-cost versions. Commonly used tools included Google Workspace for document management, Canva and CapCut for multimedia production, and platforms such as Kahoot, Quizizz, and ClassPoint for formative assessment. Teachers selected tools such as Google Workspace, Canva, Kahoot, and Quizizz because they require low bandwidth and are easy to operate. Prior studies confirm that selecting appropriate tools based on contextual constraints improves technology integration outcomes (Kimmons, 2020).

Teachers reported that these tools provided a balance between interactivity and practicality. They required relatively little setup time and offered intuitive interfaces, which supported both teacher

productivity and student engagement. The strategic selection of lightweight tools also reduced the likelihood of technical disruptions during lessons.

c. Teacher Collaboration

Collaboration includes sharing best practices, discussing technical issues, and co-creating instructional materials. Collaboration among teachers played a central role in overcoming technical and pedagogical challenges. Teachers regularly shared best practices during informal discussions, exchanged digital teaching materials, and acted as peer troubleshooters when colleagues encountered technical issues. Teachers benefited from sharing resources, troubleshooting collaboratively, and co-developing materials. This aligns with the role of professional learning networks and teacher communities in supporting digital pedagogy (Trust et al., 2017; Voogt et al., 2015).

Some participants formed small, voluntary working groups that met after school hours to experiment with new applications, co-create digital content, and refine lesson plans. This collaborative culture fostered a supportive environment where teachers felt comfortable experimenting with interactive technologies despite infrastructure limitations.

In several cases, senior teachers mentored less experienced colleagues, helping them navigate application features, manage classroom devices, and design interactive activities aligned with curriculum objectives.

d. Development of Interactive Learning Media

Teachers create video tutorials, digital modules, simple animations, and interactive presentations. To address gaps in available digital resources and ensure alignment with curricular needs, teachers invested time in producing their own interactive materials. These included short video tutorials, animated demonstrations, step-by-step digital modules, and interactive slide presentations that incorporated quizzes, hyperlinks, or embedded multimedia. Teachers produced custom modules, animations, and video tutorials to tailor instruction. Teacher-created digital content is shown to enhance relevance and accessibility, particularly in resource-limited environments (Gibson et al., 2018).

Teachers reported that creating custom materials allowed them to tailor content to students' readiness levels and to anticipate where students might struggle. Observations showed that these materials often helped sustain student attention and provided more structured learning support, especially for those with lower digital literacy.

e. Strengthening Digital Classroom Management

This includes managing students' device usage, limiting access to certain apps, and providing step-by-step instructions. To mitigate student distractions and ensure smoother lesson execution, teachers implemented structured digital classroom management strategies. These included establishing clear device-use rules, guiding students through applications step by step, and monitoring device screens during activities. Teachers implemented procedures to control distractions and maintain student focus. Effective management practices are widely recognized as necessary for successful classroom technology use (Ifenthaler & Schweinbenz, 2016).

Teachers also developed fallback procedures to minimize disruptions if technical problems occurred. These included providing printed materials, switching to offline activities, or preparing low-tech alternatives to maintain lesson continuity.

Several teachers used simple management techniques, such as instructing all students to "screens down" during explanations or requiring students to complete short digital check-ins before accessing interactive tools. These practices improved pacing, reduced off-task behavior, and enhanced overall classroom control.

DISCUSSION

The integration of interactive technology has been shown to improve student motivation and engagement. However, its success is strongly influenced by teacher readiness, supporting infrastructure, and student characteristics. These findings support the study by Yunus & Arifin (2020), which emphasizes that limited devices and digital competence are major challenges in educational technology implementation.

The strategies adopted by teachers, self-training, collaboration, and the use of free applications, demonstrate that teacher creativity and initiative play crucial roles in successful integration. Effective digital classroom management is needed to minimize student distractions and ensure optimal learning. This study highlights the need for institutional support, including the provision of digital devices, routine training, and policies that encourage digital learning.

The findings of this study highlight that integrating interactive technology into informatics classrooms is both beneficial and challenging, with outcomes shaped by a complex interaction between infrastructure, teacher competence, student readiness, and instructional time. These results reinforce and extend existing literature on technology-enhanced learning, while also providing context-specific insights relevant to schools in developing regions.

This study reinforces existing literature on the complex interplay between infrastructure, teacher competence, and student readiness in technology-enhanced learning environments (Ertmer & Ottenbreit-Leftwich, 2010; Hew & Brush, 2007). The observed infrastructure limitations align with findings from schools in similar contexts where unstable connectivity and insufficient devices hinder adoption (Nikolopoulou & Gialamas, 2016). The study adds depth to current research by illustrating how competence gaps affect real-time instruction, contributing to interruptions and increased cognitive load for teachers (Howard et al., 2015). Student digital literacy variations also shaped lesson pacing and group dynamics, as noted in previous studies (Ng, 2012; Aesaert et al., 2015). Teachers' strategies demonstrate strong professional agency despite constraints. Their reliance on self-directed learning parallels findings on teacher-driven innovation in low-support contexts (Prestridge, 2017), while collaboration aligns with global evidence highlighting the power of professional learning networks (Trust et al., 2017). Overall, the findings contribute to global discussions on sustainable digital learning, emphasizing that successful integration depends not only on technology availability but also on teacher agency, collaborative culture, and institutional support (Voogt et al., 2015; Gibson et al., 2018).

Alignment with Previous Research

Consistent with earlier studies, this research confirms that inadequate infrastructure remains a critical barrier to effective technology integration. Prior work has shown that limited device availability, unstable connectivity, and the absence of advanced interactive tools undermine teachers' capacity to utilize digital resources in meaningful ways. The experiences of the teachers in this study support these findings and demonstrate how infrastructure constraints directly influence lesson pacing, content delivery, and the selection of instructional tools.

Similarly, the challenge of limited teacher technological competence echoes the conclusions of researchers who argue that technology integration is strongly connected to teachers' confidence, technical knowledge, and continuous professional development. The present study adds nuance by showing how competence gaps manifest during live classroom instruction, often causing instructional interruptions and stress. These real-time disruptions highlight the importance of not only introducing technology but also ensuring that teachers are adequately prepared to troubleshoot and adapt during lessons.

Contribution to Understanding Classroom Dynamics

The challenges related to student readiness and learning behavior provide an important addition to current scholarship. While previous studies describe student digital literacy as uneven, this research illustrates how such variation affects collaboration, lesson pacing, and teacher workload. Students who are digitally proficient tend to progress quickly, sometimes dominating group work, while those with lower skills require constant support. This dynamic creates additional pedagogical demands on teachers and complicates their ability to maintain equitable learning environments.

Time constraints, another key theme, have been widely acknowledged as a barrier to technology integration. However, this study shows that time pressure is not simply an abstract constraint but is compounded by technical failures, slow device setup, and the procedural requirements of digital tools. These operational details help explain why teachers sometimes revert to traditional methods despite recognizing the benefits of interactive technology.

Practical Strategies and Teacher Agency

The strategies employed by teachers reveal strong professional agency and adaptability despite structural limitations. Self-directed professional learning emerged as a crucial mechanism for skill development, supporting the idea that teachers play an active role in shaping their technological competence. The preference for lightweight, freely available applications demonstrates teachers' pragmatic decision-making in selecting tools that align with both infrastructure conditions and instructional needs.

Professional collaboration further underscores the importance of social learning among teachers. The informal communities of practice observed in this study demonstrate how peer support can compensate for limited formal training. The creation of teacher-designed digital materials also illustrates how teachers tailor resources to fit local conditions, student readiness, and curriculum demands, strengthening the sustainability of technology integration.

Implications for Policy and School Leadership

The findings point to several implications for institutional planning and policy. First, improving infrastructure remains essential for enabling more consistent technology use. Investments in reliable connectivity, functional devices, and basic interactive tools would reduce lost instructional time and encourage teachers to adopt more advanced applications.

Second, professional development must extend beyond introductory training. Ongoing, practice-oriented training that includes troubleshooting, classroom management in digital environments, and the pedagogical integration of technology is needed to enhance teacher competence.

Third, schools should support teacher collaboration by creating structured opportunities for peer mentoring, lesson study, and shared digital resource development. Such initiatives can amplify teacher expertise and reduce individual burdens.

Contribution to the Field

This study contributes to the broader discourse on educational technology by providing detailed, classroom-level insights into the operational challenges and adaptive strategies of informatics teachers. While many studies focus on policy or technological affordances, fewer examine the lived, day-to-day realities of teachers working within constrained environments. By documenting these realities, the study highlights the importance of context-sensitive approaches to technology integration rather than assuming uniform conditions across schools.

CONCLUSION

The main challenges faced by informatics teachers include limited facilities, technological competence, student readiness, and limited instructional time. Strategies used include self-training, use of free and lightweight applications, teacher collaboration, development of interactive media, and strengthening digital classroom management. Interactive technology integration has a positive impact on learning but requires adequate facilities and supportive educational policies.

This study examined the challenges encountered by informatics teachers when integrating interactive technologies into secondary school classrooms and identified the strategies they employed to address these barriers. The findings demonstrate that technology integration is shaped by four interrelated factors: infrastructure limitations, teacher technological competence, student readiness, and restricted instructional time. Each factor influenced not only the feasibility of using interactive tools but also the overall quality of classroom implementation. Infrastructure emerged as the most persistent constraint, affecting both the reliability and consistency of technology-enhanced instruction. Teachers' competence levels also played a crucial role, as gaps in technical knowledge often caused instructional delays and reduced confidence during lessons. Student readiness presented an additional layer of complexity, with differing digital literacy levels contributing to uneven participation and increased teacher workload. Moreover, limited instructional time amplified the effects of technical problems, making it challenging for teachers to balance curriculum coverage with interactive learning activities. Despite these challenges, teachers demonstrated strong professional agency through adaptive strategies that allowed them to incorporate technology in practical and sustainable ways. Self-directed learning, the use of lightweight and accessible applications, peer collaboration, the development of

teacher-created materials, and structured digital classroom management all emerged as effective responses. These strategies highlight the capacity of teachers to innovate within constrained environments and underscore the importance of contextually grounded approaches to technology integration. Overall, this study contributes to the growing body of literature on digital learning by offering detailed, classroom-level insights from a developing-country context. It reinforces the need for holistic support systems that combine infrastructure, professional development, and collaborative cultures to enable meaningful and long-term technology adoption. The findings provide valuable guidance for policymakers, school leaders, and practitioners seeking to strengthen technology-enhanced learning in similar educational contexts.

Recommendations

1) Schools should improve digital facilities such as computers, smartboards, and stable internet connections.
2) Teachers should participate in regular and systematic technology training.
3) Teachers are encouraged to build technology-based learning communities.
4) Future research should involve more schools and employ mixed-method approaches.

REFERENCES

Aesaert, K., van Braak, J., van Nijlen, D., & Vanderlinde, R. (2015). The content of educational technology curricula: A cross-curricular state of the art. Educational Technology Research and Development, 63(1), 131–158. https://doi.org/10.1007/s11423-015-9368-5

Arsyad, A. (2019). Media Pembelajaran. Jakarta: Rajawali Pers.

Bates, T. (2015). Teaching in a Digital Age. Vancouver: Tony Bates Associates.

Bicen, H., & Kocakoyun, Ş. (2018). Determination of university students' most preferred mobile application for gamification. International Journal of Emerging Technologies in Learning, 13(2), 21–31. https://doi.org/10.3991/ijet.v13i02.8148

Creswell, J. W., & Poth, C. N. (2018). Qualitative inquiry and research design: Choosing among five approaches (4th ed.). SAGE Publications.

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. Journal of Research on Technology in Education, 42(3), 255–284. https://doi.org/10.1080/15391523.2010.10782551

Gibson, D., Broadley, T., & Downie, J. (2018). Digital leadership in higher education: Current practices and future opportunities. International Journal of Educational Technology in Higher Education, 15(1), 1–21. https://doi.org/10.1186/s41239-018-0094-8

Hatlevik, O. E., & Christophersen, K. A. (2013). Digital competence at the beginning of upper secondary school: Identifying factors explaining digital inclusion. Computers & Education, 63, 240–247. https://doi.org/10.1016/j.compedu.2012.11.015

Hew, K. F., & Brush, T. (2007). Integrating technology into K–12 teaching and learning: Current knowledge gaps and recommendations for future research. Educational Technology Research and Development, 55(3), 223–252. https://doi.org/10.1007/s11423-006-9022-5

Howard, S. K., Chan, A., & Caputi, P. (2015). Modelling teachers' technology adoption: Implications for professional development. Computers & Education, 90, 1–12. https://doi.org/10.1016/j.compedu.2015.09.009

Ifenthaler, D., & Schweinbenz, V. (2016). Students' acceptance of tablet PCs in the classroom. Journal of Research on Technology in Education, 48(4), 306–321. https://doi.org/10.1080/15391523.2016.1215172

Kimmons, R. (2020). Exploring educational technology definitions and frameworks. TechTrends, 64(1), 1–3. https://doi.org/10.1007/s11528-019-00436-0

Lincoln, Y. S., & Guba, E. G. (1985). Naturalistic inquiry. SAGE Publications.

Liu, S.-H., Tsai, H.-C., & Huang, Y.-C. (2020). Collaborative professional development for technology integration: Teachers' beliefs and practices. Educational Technology Research and Development, 68(4), 2205–2228. https://doi.org/10.1007/s11423-020-09749-8

Miles, M. B., & Huberman, A. M. (2014). Qualitative Data Analysis. SAGE Publications.

Ng, W. (2012). Can we teach digital natives digital literacy? Computers & Education, 59(3), 1065–1078. https://doi.org/10.1016/j.compedu.2012.04.016

Nikolopoulou, K., & Gialamas, V. (2016). Barriers to ICT use in high schools: Greek teachers' perceptions. Journal of Computers in Education, 3(1), 59–75. https://doi.org/10.1007/s40692-015-0032-z

Parong, J., & Mayer, R. E. (2018). Learning by teaching with immersive virtual reality: A dual-earning perspective. Computers in Human Behavior, 89, 418–428. https://doi.org/10.1016/j.chb.2018.08.012

Player-Koro, C. (2013). Hype, hope and ICT in teacher education: A critical review. Nordic Journal of Digital Literacy, 8(4), 207–225.

Prestridge, S. (2017). Examining the shaping of teachers' pedagogical orientation for the use of ICT in classrooms. Technology, Pedagogy and Education, 26(4), 439–452. https://doi.org/10.1080/1475939X.2017.1291767

Sadaf, A., Newby, T. J., & Ertmer, P. A. (2016). An investigation of the factors that influence preservice teachers' intentions and integration of web 2.0 tools. Educational Technology Research and Development, 64(2), 285–312. https://doi.org/10.1007/s11423-015-9410-9

Tondeur, J., Scherer, R., Baran, E., Siddiq, F., Valtonen, T., & Sointu, E. (2017). Teacher educators as gatekeepers: Preparing the next generation of teachers for technology integration. British Journal of Educational Technology, 50(3), 1189–1209. https://doi.org/10.1111/bjet.12702

Trust, T., Krutka, D. G., & Carpenter, J. P. (2017). "Together we are better": Professional learning networks for teachers. Computers & Education, 102, 15–34. https://doi.org/10.1016/j.compedu.2016.06.007

Voogt, J., Knezek, G., Christensen, R., & Lai, K. W. (2015). Preparing teachers for technology-supported education. Journal of Computer Assisted Learning, 31(4), 261–279. https://doi.org/10.1111/jcal.12129

Yunus, M., & Arifin, Z. (2020). Technology integration in learning. Jurnal Teknologi Pendidikan, 8(2), 45–58.