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ARTICLE

Teachers' Readiness in Implementing the Flipped Classroom Method Using Technology and Non-Technology Approach in Chemistry Education

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Abstract

The study aims to analyse teachers' readiness to implement the flipped classroom method in chemistry education, using both technological and non-technological approaches, through a systematic literature review (SLR). Twelve high-quality articles published in reputable journals over the last five years were analysed. The findings indicate that flipped classroom implementation in chemistry education predominantly employs web-based technologies, such as learning management systems. Instructional videos and online collaborative platforms. Teachers' readiness in technology-based approaches is characterised by digital literacy and the ability to integrate technology into instructional design. Meanwhile, teachers' readiness in non-technology-based approaches emphasises content mastery, pedagogical competence, and effective face-to-face classroom management. The results also reveal differences in teachers' readiness between technology-based flipped classroom approaches, particularly in learning adaptation and the use of instructional media. This study recommends that future research further explore instructional strategy development and provide comprehensive solutions to challenges in implementing flipped classroom learning in chemistry education.

Keywords:

Technology-enhanced learning; Technology-based learning; disruptive learning; educational technology; learning innovation

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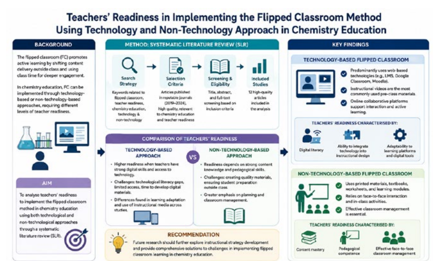
Graphical Abstract



Introduction

Over the past decade, advances in educational technology have encouraged the adoption of innovative learning models to enhance student engagement and learning outcomes (Fanguy et al., 2021; Venton & Pompano, 2021), including e-modules (Ramadhani & Arista, 2026), game-based learning (Suhartatik et al., 2026), digital books (Samat et al., 2026), podcasts for learning (Musdalipah et al., 2026), and more. One such model is the flipped classroom, which reverses the traditional learning sequence by shifting content delivery to pre-class activities, while classroom time is devoted to active learning, discussion, and problem-solving (Heiss & Oxley, 2021; Cormier & Voisard, 2017). This approach has been widely implemented in various educational contexts and is considered particularly relevant for chemistry learning, which involves abstract concepts, complex problem-solving, and the need for higher-order thinking skills (Sigmon & Bodek, 2022; Ponikwer & Patel, 2018).

According to Love et al., (2014), the flipped classroom is designed to reverse the conventional classroom paradigm, where students learn instructional content prior to class, while in-class time is dedicated to problem-solving and practice activities. Furthermore, previous studies have shown that the flipped classroom has the potential to improve student retention and has been widely implemented in science, technology, engineering, and mathematics (STEM) education (Talley, 2013; Velegol et al., 2015). In addition, the flipped classroom has been found to enhance students' conceptual understanding (Love et al., 2014), and promote greater interaction between students and teachers (McLean et al., 2016)

Previous studies have reported that the flipped classroom can improve students' academic performance, conceptual understanding, and engagement, especially when supported by digital technologies such as learning management systems, instructional videos, and online collaborative platforms (Macale et al., 2021; Nja et al., 2022; Venton & Pompano, 2021). Consequently, many flipped classroom implementations emphasise technology-based approaches. However, differences in technological access, infrastructure availability, and digital literacy among teachers and students may limit the effectiveness of technology-dependent flipped classroom models (Lo et al., 2020). In response to these challenges, non-technology-based or low-technology flipped classroom approaches have been applied by emphasising pre-class preparation through printed materials and maximising face-to-face classroom interactions (Heiss & Oxley, 2021).

Despite the growing body of research on flipped classroom implementation in chemistry education, existing studies predominantly focus on students' learning outcomes and perceptions (Cormier & Voisard, 2017; Nja et al., 2022). Comparatively little attention has been paid to teachers' readiness, which plays a critical role in the successful implementation of flipped classroom learning. Teachers' readiness encompasses pedagogical competence, content mastery, technology skills, and attitudes toward instructional innovation (Schafer et al., 2021). Without sufficient readiness, flipped classroom implementation, whether technology-based or non-technology-based, may not achieve its intended outcomes in chemistry learning.

Furthermore, studies that address teachers' readiness tend to be fragmented and context-specific, often emphasising either technology integration or general pedagogical practices (Dooly & Sadler, 2020). To date, there is a lack of systematic synthesis that integrates findings

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from chemistry education and broader educational studies to comprehensively examine teachers' readiness to implement flipped classroom approaches using both technological and non-technological strategies. This gap indicates the need for a systematic literature review that maps the dimensions of readiness, identifies implementation challenges, and compares different flipped-classroom modalities in the context of chemistry education.

Therefore, this study aims to systematically analyse teachers' readiness to implement flipped classroom approaches in chemistry education, using both technological and non-technological strategies, through a systematic literature review (SLR). The novelty of this study lies in its explicit focus on teachers' readiness as the central analytical lens, rather than on student outcomes, and in its comparative examination of technology-based and non-technology-based flipped-classroom implementations in chemistry learning. The findings of this study are expected to contribute to the development of flipped-classroom research in chemistry education and provide practical implications for teachers, curriculum developers, and educational policymakers for designing adaptive and inclusive learning environments.

Method

Data collection began with a search of more than 15 academic databases, including Springer Link, Wiley, ProQuest, SAGE, Cambridge, Emerald Insight, ERIC, ScienceDirect, Google Scholar, SINTA, APA, Web of Science, Semantic Scholar, PubMed, and Scopus. The keywords Used in the search process for this review were: 'Flipped Classroom' and Chemistry. The inclusion period was limited to the last five years (2018-2022). A total of 12 articles related to flipped classroom implementation in chemistry education were selected for analysis.

The selection criteria were as follows: (1) focus on flipped classroom learning, (2) relevance to chemistry education, and (3) publication in reputable journals indexed by Scimago Journal Rank (Q1-Q4). Articles from other disciplines, conference proceedings, book chapters, and review papers were excluded.

Table 1. Summary of study identification and selection process (PRISMA 2020)

Stage	Description	Number of Records
Identification	Records identified	2.703
Duplicate removal	Duplicates Removed	716
Screening	Record Screened	1987
Eligibility	Full-text assessed	46
Included	Final Studies	13

Table 2. List of selected articles and journals

No	Title	Journal	Rank	Publication year
1.	Enhancing the performance of students in chemistry through flipped classroom with peer instruction teaching strategy	*LUMAT*	**Q3**	**2021**
2.	Implementing a flipped classroom approach in remote instruction	*Springer Link*	**Q1**	**2021**
3.	Use of an Online Social Annotation Platform to Enhance a Flipped Organic Chemistry Course	*Journal of Chemical Education*	**Q2**	**2022**
4.	Teaching Engineering and Food: From Traditional Approaches to a Flipped Course on Gastronomic Engineering	*Springer Link*	**Q1**	2021
5.	"If you don't improve, what's the point?" Investigating the impact of a "flipped" online exchange in teacher education	*Cambridge*	**Q1**	2020
6.	Flexible learning with multicomponent blended learning mode for undergraduate chemistry courses in the pandemic of COVID-19	*Interactive Technology and Smart Education,*	**Q2**	2020
7..	Implementation and evaluation of flipped learning for delivery of analytical chemistry topics	*Analytical and Bioanalytical Chemistry*	**Q1**	**2018**
8..	Active teaching strategies for introducing radioanalytical techniques in analytical chemistry master degree: 40K determination in Bananas	*Springer Link*	**Q1**	2019
9.	Strategies for enhancing remote student engagement through active learning	*Springer Link*	**Q1**	**2022**
10.	Visualizing chemistry teachers' enacted assessment design practices to better understand barriers to "best practices"	*Chemistry Education Research and Practice*	**Q1**	2021
11.	Students' attitude and academic achievement in a flipped classroom	*Heliyon*	**Q1**	**2022**
12.	Adapting Educational Experience for the chemists of tomorrow	*Nature Review Chemistry*	**Q1**	2021

Results & Discussion

This section presents and discusses the study's findings in relation to research questions concerning teachers' readiness to implement flipped classroom approaches using technology and non-technology in chemistry education. The analysis focuses on identifying key themes and dimensions of readiness across the reviewed studies. The readiness of teaching staff to implement the flipped classroom method using technology.

1. Teachers' Readiness to Implement Technology-Based Flipped Classroom

   These findings indicate that teachers' readiness to implement technology-based flipped classrooms is closely associated with technological and pedagogical. And professional competencies. Most studies highlight the use of web-based technologies, such as learning management systems (LMS), instructional videos, video sharing platforms, and online collaborative tools, to support pre-class learning activities (Venton & Pompano, 2021; Heiss & Oxley, 2021).

   Teachers with adequate digital literacy can design structured pre-class instructional materials and effectively manage in-class learning activities. Their readiness is reflected not only in the use of digital tools but also in their ability to integrate technology into instructional design. This includes preparing learning videos, organising online materials, and providing clear learning guidance to support students' independent learning (Sigmon & Bodek 2022; Ponikwer & Patel 2018).

   In addition, technology-based flipped classrooms enable teachers to facilitate both synchronous and asynchronous interactions, monitor student participants, and manage group discussions through digital platforms (Venton & Pompano, 2021). These capabilities contribute to more flexible and interactive learning environments.

   However, several challenges related to technological readiness are also identified. These include limited digital skills, increased workload in preparing digital learning materials, and unequal access to technological resources (Heiss & Oxley, 2021). These findings suggest that technological readiness alone is insufficient without strong pedagogical support. In chemistry education, where conceptual understanding and guided problem solving are essential, the alignment between technology use and pedagogical objectives remains a critical factor.

2. Teachers' Readiness to Implement Non-technology-based Flipped Classroom

   Although most studies emphasise the role of technology, the findings show that flipped classroom implementation, with or without minimal technology, is still feasible in chemistry education. In this approach, teachers' readiness is primarily characterised by strong pedagogical competence, content mastery, and effective classroom management (Macale et al., 2021; Aguilera & Moreno, 2020).

Teachers prepare students for classroom learning through printed materials, guided reading tasks, or preliminary assignments conducted prior to class sessions. During face-to-face classroom activities, learning is focused on peer instruction, group discussions, problem-solving, and conceptual clarification Ponikwer & Patel (2018).

In this context, the role of teachers shifts from information providers to facilitators who guide students in applying chemical concepts and analysing problems collaboratively Aguilera & Moreno, (2020). The findings suggest that teachers' readiness in non-technology-based flipped classrooms relies more heavily on pedagogical expertise than on technological skills.

Teachers who possess strong subject matter knowledge and classroom facilitation skills are able to implement flipped classroom strategies effectively, even in environments with limited technological resources (Bagan et al. 2021; Nja et al., 2022).

However, this approach may reduce flexibility in accessing learning materials outside the classroom and requires careful planning to ensure that students are adequately prepared for in-class activities.

3. Differences in Teachers' Readiness Between Technology-Based and Non-Technology-Based Approaches

The comparison of the reviewed studies reveals clear differences in teachers' readiness between technology-based and non-technology-based flipped classroom implementations. These differences are particularly evident in terms of technological integration, learning flexibility, and modes of interaction.

In technology-based approaches, teachers' readiness is closely linked to digital literacy, the ability to design online instructional materials, and the effective use of digital platforms (Venton & Pompano, 2021; Sigmon & Bodek 2022). This approach provides greater flexibility for students in accessing learning materials and supports distance or blended learning environments.

In contrast, non-technology-based flipped classrooms emphasise pedagogical competence, classroom facilitation skills, and mastery of subject content (Macale et al., 2021; Bagan et al. 2021). Learning interactions are more direct and centred on face-to-face discussions and collaborative problem-solving.

Overall, the findings suggest that both approaches can be effectively implemented in chemistry education, provided that teachers demonstrate the readiness appropriate to the selected instructional strategy.

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Conclusion

Based on a systematic literature review of 12 articles, this study concludes that teachers' readiness is crucial to the successful implementation of flipped classroom learning in chemistry education. Teachers' readiness in technology-based approaches is demonstrated through their ability to integrate digital tools into instructional design and manage online learning environments. Meanwhile, readiness in non-technology-based approaches is characterised by strong pedagogical competence, content mastery, and effective face-to-face classroom management. The findings also indicate clear differences in readiness between technology-based and non-technology-based flipped classroom approaches, particularly regarding instructional media use and learning flexibility. These results highlight the importance of aligning flipped classroom implementation with contextual conditions and teachers' professional capabilities.

AI-assisted technology statement

While preparing this work, the authors used Grammarly to assist with improving language clarity, paraphrasing sentences, and organising the manuscript structure. After utilising this tool, the authors reviewed and edited the content as needed and took full responsibility for the publication's content.

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Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this manuscript

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