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Students' technological skills and attitudes toward HyFlex learning: the mediating role of online self-regulated learning, blended learning perception, and preferred learning modes

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Introduction: HyFlex learning has been used and researched in colleges in developing countries. The main challenges in HyFlex adaptation in college are technology related variables. However, the investigations about HyFlex and the factors affect it were limited.

Methods: The current study aims to explore student technological skills effect on their attitudes toward HyFlex learning using 738 Indonesian college students. The mediating role of online self-regulated learning (SRL), perceptions on blended learning, and student's preferred learning modes were also investigated. The relationship between variables were analyzed using structural equation modelling with partial least square parameter estimations (PLS-SEM).

Results: Results of structural equation modeling analysis show that student technological skills have significant effect on their attitude toward HyFlex learning. Mediation analysis revealed that student technological skills have indirect significant effect on their attitude toward HyFlex learning, i.e., online self-regulated learning, perceptions on blended learning, and online asynchronous and face to face learning preference partially mediated the effect of student technological skills on their attitude toward HyFlex learning. PLS-SEM conducted also shows that student technological skills have direct effect on their online self-regulated learning and perceptions on blended learning. Online self-regulated learning and perceptions on blended learning were also shown to have direct effect on student's attitude toward HyFlex learning.

Discussion: By comprehending the factors that influence student attitudes towards HyFlex learning, educators and policymakers can endeavor to create a more conducive environment that enhances students' motivation and engagement in this flexible learning approach.

KEYWORDS

blended learning, HyFlex learning, learning modes, online self-regulated learning, technological skills

1 Introduction

The use of HyFlex has increased in the post-pandemic era. HyFlex can be used at all learning levels with similar quality to the traditional method of learning (Garrett et al., 2021). The COVID-19 pandemic has transformed the way students learn (Shahriar et al., 2021). Online learning has been widely used globally (Dietrich et al., 2020), and higher education has changed its way of providing quality education.

HyFlex learning provides equity toward educational access for all (Wang et al., 2017). The incorporation of HyFlex learning facilitates the inclusion of students' requirements and personal circumstances tailors teaching methods to cater to diverse learning styles and strategies, enhances the availability of course materials and guidance, and promotes student choice in learning (Abdelmalak and Parra, 2016). Student choice in learning comprises face-to-face, online asynchronous, or online synchronous learning (Liu and Rodriguez, 2019).

Hyflex learning is a flexible approach to education that combines physical and virtual components to meet the needs of learners and customize the learning environment (Seraji et al., 2019). It is characterized by a combination of online and face-to-face learning components, allowing students to choose how and when to participate in different parts of the course (Binnewies and Wang, 2019). This flexibility provides students with the opportunity to engage with course material in a way that suits their learning preferences and schedules (Jordon et al., 2023).

One of the key features of Hyflex learning is the use of multiple modalities and technologies to enhance the learning experience. This includes the integration of various tools, methods, and technologies such as CD, SMS, applications, slide presentations, podcasts, and email (Seraji et al., 2019). By incorporating these different modalities, Hyflex Learning aims to engage students in educational issues, both inside and outside the classroom (Picciano, 2019). This multimodal approach allows students to experience learning in different ways, catering to their individual preferences and challenging them to learn in new ways (Picciano, 2019).

However, the implementation of HyFlex in the classroom is challenging. One of the fundamental tenets of designing HyFlex courses is to prioritize accessibility, which guarantees that students possess the necessary technological skills (Wong et al., 2023) and have equal access to all modes of participation (Beatty, 2007). Based on these benefits, colleges in some developed countries have applied HyFlex learning, especially in developed countries such as the United States, China, Australia, Canada, Hong Kong, and Singapore (Wong et al., 2023). Research has investigated the perspectives of higher education students regarding synchronous and asynchronous learning, encompassing aspects such as motivation and self-regulation (Zheng et al., 2016; Lee, 2017; Dumford and Miller, 2018). Another study also explored higher education students' perspectives on HyFlex learning (Kohnke and Moorhouse, 2021). To the best of our knowledge, there are very few published results on students' perceptions of HyFlex and its determinant factors in developing countries, such as Indonesia. Adoption of the HyFlex learning mode in higher education in developing countries is limited.

Developing countries face different challenges in digital transformation in educational settings, such as HyFlex learning. The main challenges are associated with the Internet and technology (Jagannathan, 2021; Shahriar et al., 2021; Al Masri and Rimawi, 2022). This study will include technological skills as potential determinants of students' attitudes toward HyFlex learning. The determinants include online self-regulated learning and student-preferred modes of learning (face-to-face, online asynchronous, and synchronous). This study provides prior information on the application of HyFlex in higher education in Indonesia.

2 Purpose of the study

The purpose of this study is to investigate the adoption and impact of HyFlex learning in higher education, with a specific focus on developing countries, as exemplified by Indonesia. As the COVID-19 pandemic has spurred a global transformation in educational practices, the increased use of HyFlex learning has become more evident, particularly in developed nations. However, the challenges associated with digital transformation in developing countries such as Indonesia raise critical issues related to Internet accessibility and technological constraints. This study aimed to assess the perceptions of higher education students in Indonesia regarding HyFlex learning, considering technological skills as potential determinants influencing their attitudes. The examination will encompass factors such as online self-regulated learning and students' preferred modes of learning, whether face-to-face, asynchronous, or synchronous. By shedding light on the specific challenges and opportunities associated with the implementation of HyFlex learning in a developing country such as Indonesia, this research seeks to provide valuable insights for educators, policymakers, and researchers, ultimately contributing to the enhancement of educational practices in the post-pandemic era.

3 Significance of the study

The significance of this study lies in its potential to inform and guide educational stakeholders in addressing the unique challenges and opportunities associated with implementing HyFlex learning in the context of higher education in developing countries such as Indonesia. As the world grapples with the evolving landscape of education in the post-pandemic era, understanding the specific determinants that influence students' attitudes toward HyFlex learning becomes imperative. By focusing on technological skills, online self-regulated learning, and preferred modes of learning, this study aims to uncover nuanced insights that can contribute to the design and implementation of effective educational strategies. The findings of this study have the potential to guide policymakers, educators, and institutions in tailoring HyFlex approaches to the specific needs and circumstances of students in developing countries, thereby fostering inclusivity and equitable access to quality education. Additionally, this study's emphasis on the Indonesian context adds a valuable dimension to the existing literature, offering a unique perspective on the challenges and opportunities associated with digital transformation in educational settings within the developing world. The outcomes of this research will not only contribute to academic discourse but also offer practical implications for enhancing educational experience in a rapidly changing global learning environment.

4 Literature review and hypothesis

According to the KAB framework, knowledge serves as a foundation upon which attitudes and behaviors are built (Dumitrescu

et al., 2011; Ng et al., 2022). It is believed that knowledge about a particular topic or behavior can influence one's attitude toward that topic, which in turn can affect one's behavior (Chen et al., 2022). This study has an exogenous variable of technological skills, which is regarded as knowledge related to HyFlex learning. Thus,

> *H1*: Students' technological skills positively affect their attitudes toward HyFlex learning.

Another psychological framework, the theory of planned behavior (TPB), states that an individual's behavioral intention is influenced by three main factors: attitudes, subjective norms, and perceived behavioral control (Steinmetz et al., 2016; Prabandari and Chong, 2022; Oamen, 2023). Attitude is related to perceived behavioral control. Self-efficacy, as part of a student's self-regulated learning, is associated with behavioral control (Aguilera-Hermida, 2020). The above argument led to.

> *H2*: Students' online self-regulated learning positively affects their attitudes toward HyFlex learning.

Other studies have shown that past experiences are associated with attitude (Kaplanidou and Vogt, 2007; Jalilvand and Samiei, 2012; Higuchi et al., 2017; Koay et al., 2021; Sahadev et al., 2023). According to TPB, attitudes are formed based on the cognitive and affective components of behavior, which can be influenced by past experiences (Kofidou et al., 2017). Past experiences shape the evaluative aspects of attitudes, including beliefs, thoughts, feelings, intentions, and overt behavior. These past experiences can be conscious or subconscious and play a role in shaping attitudes (Kofidou et al., 2017). As students' perceptions of blended learning were regarded as an experience, we can hypothesize the following:

> *H3*: Students' perceptions of blended learning positively affect their attitudes toward HyFlex learning.

A study found that students' individual preferences significantly affect their attitudes toward online learning as a new mode of learning (Tichavsky et al., 2015). Individual preferences can be linked to their learning mode preferences, comprising face-to-face, online asynchronous, and online synchronous learning. One reason why Students prefer face-to-face learning is because of their familiarity with it (Tichavsky et al., 2015). Students familiar with online learning show a positive attitude toward the learning mode (Cheung et al., 2020; Xhelili et al., 2021). Online learning has two types of communication: synchronous and asynchronous (Obasa et al., 2013; Nieuwoudt, 2020). This leads to the following two hypotheses:

> *H4*: Students who prefer online synchronous learning have stronger attitudes toward HyFlex learning.
>
> *H5*: Students who preferred asynchronous online learning had higher attitudes toward HyFlex learning.

By contrast, those who were unfamiliar with online learning as a learning mode had a lower attitude toward the learning mode (Gaur et al., 2020). This lack of familiarity can be linked to conventional face-to-face learning. Thus,

> *H6*: Students who preferred face-to-face learning had lower attitudes toward HyFlex learning.

5 Significance of the study

The significance of this study lies in its potential to inform and guide educational stakeholders in addressing the unique challenges and opportunities associated with implementing HyFlex learning in the context of higher education in developing countries, exemplified by Indonesia. As the world grapples with the evolving landscape of education in the post-pandemic era, understanding the specific determinants influencing students' attitudes toward HyFlex learning becomes imperative. By focusing on technological skills, online self-regulated learning, and preferred modes of learning, this research aims to uncover nuanced insights that can contribute to the design and implementation of effective educational strategies. The findings of this study have the potential to guide policymakers, educators, and institutions in tailoring HyFlex approaches to the specific needs and circumstances of students in developing countries, fostering inclusivity and equitable access to quality education. Additionally, this study's emphasis on the Indonesian context adds a valuable dimension to the existing literature, offering a unique perspective on the challenges and opportunities associated with digital transformation in educational settings within the developing world. The outcomes of this research will not only contribute to academic discourse but also offer practical implications for enhancing educational experience in a rapidly changing global learning environment (Figure 1).

6 Materials and methods

The study was quantitative non-experimental research conducted by sending digital surveys to Indonesian college students.

7 Samples

Of the 800 students, 738 completed the survey completely. The distributions of participants in the study based on demographic variables are shown in Table 1.

8 Instrumentation

8.1 Students' technological skills

Data on students' technological skills were gathered using the Media and Technology Usage Scale developed by Rosen et al. (2013) $\left(Cronbach's\ \alpha = 0.93\right)$. However, the number of items used was reduced to 10 to prevent biases, which may result in a long survey.

8.2 Online self-regulated learning

The online self-regulated learning scale (Martinez-Lopez et al., 2017) was used to collect data on student self-regulation in online learning. The scale has four factors: goal setting, environment structuring, task strategies, and time management $\left(Cronbach\,\alpha = 0.92\right)$.

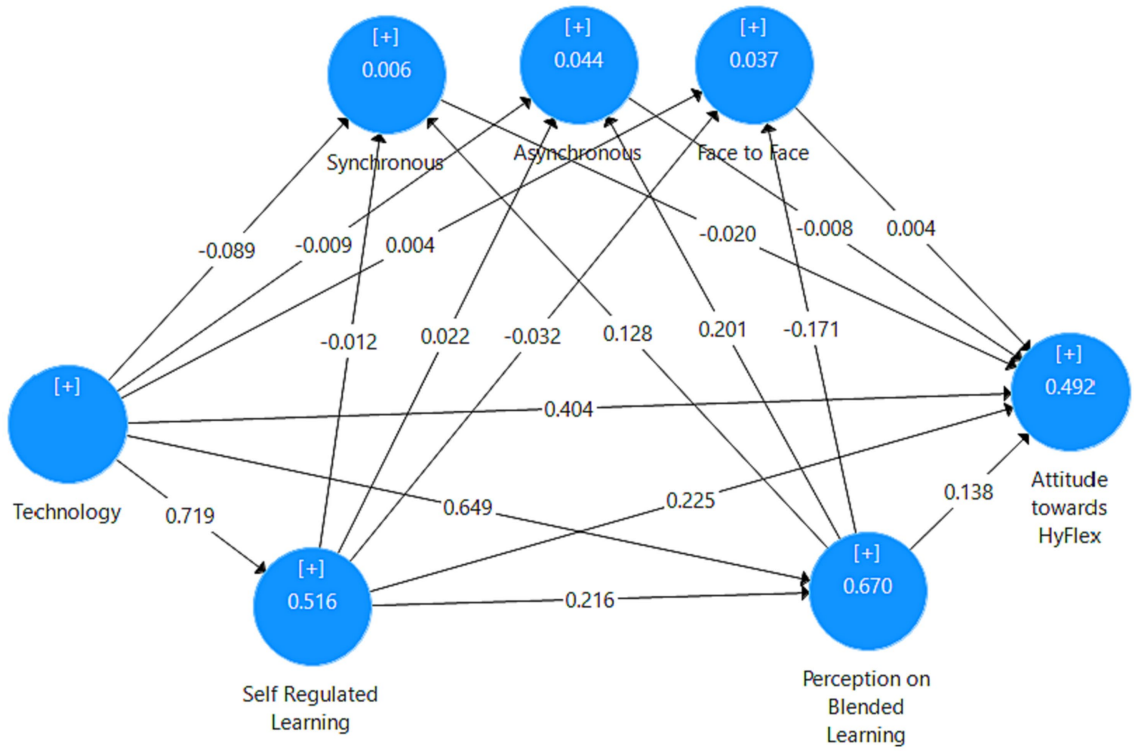

FIGURE 1
Results on structural model analysis using 5,000 replications with bootstrapping methods.

TABLE 1 Participant distribution based on demographic variables.

Variable		Count	Proportion (%)	$p(\chi^2)$
Gender				<0.001
	Male	250	33.9	(76.8)
	Female	488	66.1	
Grade				<0.001
	First-year student	296	40.1	(1734)
	Sophomore	202	27.4	
	Junior	130	17.6	
	Senior	110	14.9	
GPA				<0.001
	Less than or equal to 2.75	11	1.5	(351)
	2.76–3.00	41	5.6	
	3.01–3.50	206	27.9	
	3.51–3.75	266	36.0	
	More than 3.75	214	29.0	
Region				<0.001
	Western Indonesia	278	37.7	(44.9)
	Eastern Indonesia	460	62.3	

8.3 Perception of blended learning

Student perception of blended learning was gathered using a scale developed by Han and Ellis (2020) consisting of perceptions of the integration of face-to-face and online learning $(Cronbach\,\alpha = 0.88)$, perceptions of online contributions $(Cronbach's\,\alpha = 0.89)$, and perceptions of the online workload $(Cronbach's\,\alpha = 0.84)$.

8.4 Preferred mode of learning

Preferred mode of learning was measured by asking participants to choose their learning mode preference from three modes of learning: face-to-face, online asynchronous, and online synchronous. The preferred mode could be greater than one.

8.5 Attitude toward HyFlex learning

Student attitude toward learning was collected by a self-developed instrument using the affective, behavioral, and cognitive (ABC) model of attitude (Solomon, 2017). The self-developed instrument consisted of three items that reflected each part of the ABC.

9 Data collection and analysis

The study was quantitative non-experimental research conducted by sending digital surveys to Indonesian college students. The collected data were analyzed using a structural equation model with partial least squares parameter estimation (PLS-SEM). PLS-SEM is preferable for a complex model with numerous variables (Akter et al., 2017; Hair et al., 2021). The PLS-SEM analysis was conducted using SmartPLS 3. The analysis consists of two parts: measurement and structural models (Hair, 2011).

Since the study includes variables measured on a scale with numerous items, the number of items on student technological skills was reduced to 10 items chosen based on expert judgment. The same was also applied to online self-regulated learning, which was reduced to eight items, and perception of blended learning, which was reduced to nine items. The reliability of these brief questionnaires was investigated using the structural model of PLS-SEM.

10 Results

The results of this study are summarized in two parts: (1) descriptive and correlational analysis and (2) structural equation modeling.

10.1 Descriptive statistics and correlation

Table 2 shows the descriptive statistics and correlations between variables. The mean value of the participants was nearly 7 for technological skills $(M=7.307,\ SD=2.29)$, online self-regulated learning $(M=7.293, SD=2.255)$, and perception of blended learning $(M=7.044,\ SD=2.235)$. The attitude toward HyFlex learning tended to be close to 8 $(M=7.578,\ SD=1.98)$. For learning mode preferences, most participants chose face-to-face $(p=69.4\%)$ and synchronous learning $(p=69.8\%)$, whereas a minority of participants chose asynchronous learning as their preferred learning mode $(p=35.9\%)$.

Technological skills of the students also indicate significant association with online self-regulated learning, perception of blended learning, face-to-face preference, asynchronous preference, and attitude toward HyFlex learning. Online self-regulated learning, perception of blended learning, face-to-face preference, and asynchronous preference also showed a significant correlation with attitude toward HyFlex learning.

10.2 Structural equation model

The first part of PLS-SEM is a measurement model that evaluates the reliability and validity of latent variables (Hanafiah, 2020; Sarstedt et al., 2022). Since all scales used in this study were modified versions of the original scale, the reliability and validity of the scales should be investigated. Table 3 shows the reliability and validity of the scale.

Based on the measurement model, all constructs (except the single-item constructs) showed reasonable reliability, as Cronbach's alpha was between 0.7 and 0.95. These metrics indicate that the model and its constructs satisfy the criteria used in confirmatory research (Hair et al., 2019). Furthermore, the constructs demonstrated satisfactory convergent validity, as evidenced by their ability to account for more than 50% of the variance observed in their respective indicators, as determined by the Average Variance Extracted (AVE) values. Lastly, the Heterotrait-Monotrait (HTMT) coefficients (Henseler et al., 2015) were consistently below 0.85, indicating a clear distinction between all constructs examined. Therefore, the constructs used in this study were valid and reliable (Table 4).

Based on this framework, students' technological skills determine their online self-regulated learning, preferred mode of learning, perception of blended learning, and attitude toward HyFlex learning. However, the analysis found that this hypothesis is partially supported. Technological skills only significantly affect students' self-regulated

TABLE 2 Descriptive statistics and correlations between the variables.

Variable	*M*	SD	Correlations						
			1	2	3	4	5	6	7
1. Technological skills	7.307	2.290	—						
2. Online self-regulated learning	7.293	2.255	0.7***	—					
3. Perception of blended learning	7.044	2.235	0.798***	0.663***	—				
4. Face-to-face learning	0.694	0.461	−0.165***	−0.148***	−0.188***	—			
5. Synchronous learning	0.698	0.460	0.005	0.011	0.043	−0.194***	—		
6. Asynchronous learning	0.359	0.480	0.172***	0.152***	0.21***	−0.728***	−0.092*	—	
7. Attitude toward HyFlex	7.578	1.980	0.659***	0.606***	0.598***	−0.107**	−0.01	0.121**	—

***$p<0.001$, **$p<0.01$, *$p<0.05$.

TABLE 3 Reliability and validity of the scale used.

Variable	*Cronbach's* α	AVE	HTMT
1. Technological skills	0.924	0.599	0.846
2. Online self-regulated learning	0.894	0.58	0.780
3. Perception of blended learning	0.925	0.645	0.734
4. Face-to-face learning	1	1	0.728
5. Synchronous learning	1	1	0.194
6. Asynchronous learning	1	1	0.728
7. Attitude toward HyFlex	0.932	0.881	0.718

TABLE 4 Direct, indirect, and total effect of paths in the study model.

Hypothesis	Path	Path coefficient						f^2
		Direct effect		Indirect effect		Total effect		
H1	TS - > AtHyF	0.404	***	0.27	***	0.674	***	0.096
	TS - > OSRL	0.719	***			0.719	***	1.067
	TS - > PoBL	0.649	***	0.155	***	0.805	***	0.618
	TS - > OSL	−0.089		0.094		0.005		0.002
	TS - > OAL	−0.009		0.177	**	0.168	***	0.000
	TS - > F2F	0.004		−0.161	**	−0.157	***	0.000
H2	OSRL - > AtHyF	0.225	***	0.029	*	0.253	***	0.045
	OSRL - > PoBL	0.216	***			0.216	***	0.069
	OSRL - > OSL	−0.012		0.028		0.016		0.000
	OSRL - > OAL	0.022		0.043	**	0.065		0.000
	OSRL - > F2F	−0.032		−0.037	*	−0.069		0.000
H3	PoBL - > AtHyF	0.138	**	−0.005		0.133	*	0.012
	PoBL - > OSL	0.128	*			0.128	*	0.005
	PoBL - > OAL	0.201	***			0.201	***	0.014
	PoBL - > F2F	−0.171	**			−0.171	**	0.010
H4	OSL - > AtHyF	−0.02				−0.02		0.001
H5	OAL - > AtHyF	−0.008				−0.008		0.000
H6	F2F - > AtHyF	0.004				0.004		0.000

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

TS, technological skills; OSRL, online self-regulated learning; PoBL, perception of blended learning; OSL, online synchronous learning; OAL, online asynchronous learning; F2F, face-to-face learning; AtHyF, attitude toward HyFlex learning.

Source: Own elaboration.

learning $(\beta = 0.719,\ p < .001)$, perception of blended learning $(\beta = 0.805,\ p < .001)$, online asynchronous $(\beta = 0.168,\ p < .001)$ and face-to-face learning preference $(\beta = -0.161,\ p < .001)$, and students' attitude toward HyFlex learning $(\beta = 0.674,\ p < .001)$. Using Cohen's benchmark (Cohen, 2013), the size of the effect of technological skills of students was strong $(f^2 = 1.067)$ regarding their online SRL, moderate regarding their perception of blended learning $(f^2 = 0.618)$, and small regarding their attitude toward HyFlex learning $(f^2 = 0.096)$.

The framework also hypothesized that students' self-regulated learning may affect their perceptions of blended learning, preferred mode of learning, and attitude toward HyFlex learning. The results show that online self-regulated learning only significantly influences student perception of blended learning $(\beta = 0.253, p < .001)$ and attitude toward HyFlex learning $(\beta = 0.216, p < .001)$. However, the effect size of online SRL was considerably small regarding perception of blended learning $(f^2 = 0.069)$ and attitude toward HyFlex $(f^2 = 0.045)$.

Students' perception of blended learning drives their choices in the mode of learning and affects their attitude toward HyFlex learning. Perception of blended learning significantly affects students' online synchronous $(\beta = 0.128,\ p = 0.047)$, online asynchronous $(\beta = 0.201,\ p < .001)$, and face-to-face learning preference $(\beta = -0.171,\ p < .01)$ and attitude toward HyFlex learning $(\beta = 0.138,\ p = 0.014)$. The effect size of perception of blended learning was considerably smaller than that of online synchronous $(f^2 = 0.005)$, online asynchronous $(f^2 = 0.014)$, and face-to-face learning preference $(f^2 = 0.010)$ and attitude toward HyFlex learning $(f^2 = 0.012)$.

The last was student preferences regarding the learning mode effect on attitudes toward HyFlex learning. Students who preferred face-to-face, online asynchronous, or synchronous learning showed no differences in attitude toward HyFlex learning.

11 Discussion

This section discusses the findings of this study. First, the study confirms that students' technological skills drive them to have positive attitudes toward new learning technology (Mishra et al., 2017; Broadbent et al., 2020), including HyFlex learning. Maximizing the use of online learning such as HyFlex learning requires good technological competence (Broadbent et al., 2020). The utilization of technology broadens the range of opportunities available to students, enabling them to actively participate in learning by offering diverse avenues and means of access (Attard and Holmes, 2022). This result agrees with a study conducted by Rhema and Miliszewska (2014). They found that students who possess superior proficiency in and better access to technological resources generally manifest more favorable attitudes toward e-learning. This notion is further supported by existing scholarly work. They posit that the degree of technological accessibility and its dependability significantly influences students' propensity to utilize Information and Communication Technologies (ICTs) for their educational objectives (Rhema and Miliszewska, 2014).

The association between students' technological skills and attitudes toward HyFlex was partially mediated by online self-regulated learning and students' perception of blended learning. This result is in line with that of a previous study by Broadbent et al. (2022), who found that technological skills and media may enhance students' self-regulated learning. Students' technological proficiency allows them to effectively utilize the features and functionalities of online learning platforms, enabling them to navigate through different tools, access resources, and engage in various learning activities (Lee et al., 2019; Alfadda and Mahdi, 2021).

Students with better technological skills are more likely to possess better self-regulation abilities in an online learning environment. They can effectively manage their time, set goals, monitor their progress, and adjust their learning strategies accordingly (Brown et al., 2022). Their proficiency in using technology enables them to access and organize learning materials, collaborate with peers, and seek additional resources independently (Gocotano et al., 2021). Self-regulation contributes to overall learning success and engagement (Lawrence et al., 2019).

The results also show that students' technological skills affect their perceptions of blended learning. Studies have indicated that students' proficiency in digital literacy has a beneficial impact on their involvement in digital educational materials and their general outlook on online and blended learning (McGuinness and Fulton, 2019; Sari and Wahyudin, 2019). Students' technological skills also increase their likelihood of choosing online asynchronous and synchronous learning and reduce their likelihood of choosing face-to-face learning as their learning preference. The reason behind these behaviors is that students' lack of technological knowledge prevents them from using technology in their learning (Son et al., 2017). In other words, students with poor technological skills tend to choose face-to-face learning modes that minimize their use of technology.

These findings indicate that SRL affects students' attitudes toward HyFlex learning. The role of feedback and social support in SRL influences students' attitudes toward new learning technologies. Feedback that guides students' next steps in learning and supports their self-regulation can contribute to a positive attitude and increased acceptance of technology (Brown et al., 2016). Additionally, evidence strongly suggests that students' online self-regulated learning encourages them to have positive perceptions of blended learning. This result is in line with a study conducted by Tsai (2010), who found that students engaged in web-based SRL expressed positive perspectives on the arrangement of their blended courses.

Another result also implies that students' perceptions and experiences of blended learning affect their attitudes toward HyFlex learning. Students' perceptions of blended learning were built based on their blended learning experience during the COVID-19 pandemic. Several studies have shown that attitudes can be driven by past experiences and behaviors (Terry et al., 1999; Reza Jalilvand and Samiei, 2012; Andretta et al., 2014). Students' perception of blended learning also tends to increase their likelihood of choosing online asynchronous learning and reduce their likelihood of choosing face-to-face learning as their learning preference. Positive perceptions of blended learning may be linked to its perceived effectiveness and engagement in online learning. Students' positive attitudes toward blended learning and its components, such as synchronous and asynchronous learning, influence their behavior or preference for specific learning modes (Shamsuddin and Kaur, 2020). Students who have positive experiences with blended learning may perceive online learning as equally or even more effective than face-to-face learning (Bouilheres et al., 2020) because they perceive it as more engaging and interactive (G. Dada et al., 2019). They may also appreciate the interactive and multimedia elements of online learning platforms, which can enhance their engagement and motivation (Ma and Lee, 2021). In addition, blended learning often incorporates online discussion forums, group projects, and collaborative activities, which can foster social interaction and peer learning (Gulnaz et al., 2019). Students who value these collaborative aspects of blended learning may be more likely to choose online learning options that allow synchronous or asynchronous interactions with their peers.

Finally, student-preferred modes of learning did not affect their attitude toward HyFlex learning. HyFlex learning comprises face-to-face, online synchronous, and asynchronous online modes of learning (Abdelmalak and Parra, 2016). Hyflex provides flexibility and equity to students (Abdelmalak and Parra, 2016; Saenen et al., 2023). All learning modes were accommodated in HyFlex learning, leading to an insignificant effect of student-preferred learning modes on their attitude toward HyFlex learning.

11.1 Theoretical contributions

In the context of our study on the relationship between students' technological skills and their attitudes toward HyFlex learning in Indonesia, the theoretical contributions are as follows.

11.1.1 Technological skills and educational attitudes framework

This study contributes to the development of a theoretical framework that specifically explores the relationship between students' technological skills and their attitudes toward HyFlex learning. These findings suggest that technological skills play a pivotal role in shaping

attitudes, offering insights into the cognitive and affective dimensions of this relationship. This framework can serve as a foundation for future studies to explore the role of technological skills in other educational contexts and learning modalities.

11.1.2 Extended knowledge-attitude-behavior for HyFlex learning

Building on established models such as knowledge-attitude-behavior (KAB), this study extends the theoretical understanding of technology acceptance to the unique context of HyFlex learning. By demonstrating the direct and indirect influences of technological skills on attitudes, this study enriches the KAB with elements specific to flexible learning environments. This extension enhances our understanding of the factors that influence students' acceptance of and adaptation to innovative educational modes.

11.1.3 Mediating mechanisms in educational technology adoption

The identification of mediating factors, such as online self-regulated learning and blended learning experiences, contributes to a more nuanced theoretical understanding of the mechanisms that influence the adoption of educational technology. This study suggests that the relationship between technological skills and attitudes toward HyFlex learning is not only direct but is also mediated by students' perceptions and experiences. Integrating these mediating factors into theoretical models can enhance predictions and interventions in technology-adoption scenarios.

11.1.4 Cultural adaptation In educational technology models

By focusing on the Indonesian context, this study provides insights into how cultural factors may influence the relationship between technological skills and attitudes toward innovative learning modes. These theoretical contributions extend beyond a generic understanding of technology adoption, emphasizing the need for culture-sensitive models. This acknowledgment of cultural nuances contributes to a broader conversation about adapting educational technology models to diverse global contexts.

11.1.5 The role of preferred learning modes in educational attitudes

Although the study did not find a mediating role for student-preferred learning modes, this finding contributes to the discourse on the complex interplay between individual preferences and attitudes in educational contexts. The theoretical contribution lies in recognizing that the impact of technological skills on attitudes is not universally mediated by preferred learning modes. Future theoretical frameworks may need to explicitly consider individual differences when examining technology adoption in education.

12 Conclusion, implications for practice, and future research

By employing structural equation modeling, this study provides strong evidence of the direct and indirect contributions of students' technological skills to their attitudes toward HyFlex learning in Indonesia. The findings indicate that students' technological skills significantly affect their attitudes toward new learning modes, such as HyFlex learning. Hence, adequate technological skills may encourage students to have a positive attitude toward HyFlex learning. As attitude is important in new learning adaptation, HyFlex learning adaptation requires student technological skills.

The study also investigated the mediating role of online self-regulated learning, perceptions based on blended learning experiences, and students' preferred learning modes. The study noted that enhancing students' online self-regulated learning and blended learning experiences can create strong servitudes between students' technological skills and their attitude toward HyFlex learning. The mediating role of student-preferred learning modes was also examined. However, the results showed that they did not mediate the relationship between students' technological skills and HyFlex learning.

Lastly, as the HyFlex learning mode becomes an alternative learning mode giving students equity and control in their learning, countries throughout the world, including Indonesia, should prepare their students with the required technological skills, enhance their self-regulated learning, and give them the best experience in online or blended learning before adopting HyFlex.

12.1 Limitations and future research directions

Our study on the relationship between students' technological skills and attitudes toward HyFlex learning in Indonesia has several limitations that warrant consideration. The first and foremost is the issue of generalizability. Our research was geographically confined to the unique educational landscape of Indonesia, and caution must be exercised when extending the findings to other cultural or educational contexts. The distinct characteristics of the Indonesian educational system, sociocultural factors, and technology infrastructure might limit the external validity of the study, emphasizing the need for additional research in diverse settings to ascertain the broader applicability of our results.

The second limitation pertains to the cross-sectional design adopted in our study. By capturing a single snapshot of the relationship between technological skills and attitudes at a specific point in time, our research is constrained by its ability to establish causal relationships or discern how these associations may evolve over time. A longitudinal approach could provide a more dynamic understanding of the interplay between technological skills and attitudes toward HyFlex learning, allowing for the identification of trends and changes in these dynamics.

Furthermore, our reliance on self-report measures introduces a potential source of bias, which must be acknowledged. The subjectivity inherent in self-reporting technological skills and attitudes may lead to inaccuracies, as participants may be inclined to either overstate or understate their capabilities and perceptions. This limitation emphasizes the importance of triangulating data using alternative assessment methods, such as performance-based evaluations or observations, to enhance the reliability and validity of our findings.

In recognizing these limitations, we underscore the need for caution when interpreting our results. Future research endeavors could address these constraints by employing more diverse samples, incorporating longitudinal designs, and utilizing a mix of assessment methods to provide a more comprehensive understanding of the complex relationship between technological skills and attitudes toward HyFlex learning.

13 Practical recommendations

The findings of this study have practical implications for educators, institutions, policymakers, and other stakeholders involved in HyFlex learning implementation. These practical implications are essential in creating an environment that maximizes the benefits of HyFlex learning for students. The practical implications of this study are as follows.

13.1 Technology integration in curriculum

Educational institutions should integrate technology into their curriculum to enhance students' technological skills. This can be achieved through the development of courses or modules specifically designed to improve digital literacy, coding abilities, and proficiency in the relevant software. Integrating technology into various subjects will ensure that students develop the skills necessary to navigate HyFlex learning environments.

13.2 Professional development for educators

Educators play a pivotal role in HyFlex learning success; therefore, institutions should invest in professional development programs to enhance educators' technological proficiency and pedagogical strategies in online and blended learning. Training sessions, workshops, and ongoing support can empower educators to create HyFlex learning experiences that align with students' needs and expectations.

13.3 Support systems for online self-regulated learning

Institutions should establish support systems to foster self-regulated online learning among students. Providing resources such as online tutorials, study guides, and interactive platforms can help students to develop effective self-regulation skills. Educators and support staff can also play a role in guiding students toward successful self-regulated learning practices.

13.4 Blended learning best practices

Incorporating blended learning experiences into traditional classrooms can positively impact students' attitudes toward HyFlex learning. Institutions should identify and implement best practices for blended learning by leveraging the strengths of both online and in-person instruction. This may include creating interactive online materials, encouraging collaborative projects, and optimizing the balance between face-to-face and virtual interactions.

13.5 Technological infrastructure and accessibility

Policymakers and educational institutions must invest in a robust technological infrastructure to ensure equitable access to HyFlex learning for all students. This includes addressing issues related to Internet connectivity, providing devices for students who may not have them, and creating a supportive environment for learning both on- and off-campus. By addressing these infrastructure concerns, institutions can minimize disparities in access and promote inclusivity.

13.6 Continuous assessment of technological preparedness

Institutions should establish mechanisms for the continuous assessment of students' technological preparedness. Regular evaluations can help to identify areas where additional support is needed to inform targeted interventions. This ongoing assessment also allows institutions to adapt their strategies to the evolving landscape of educational technology.

Data availability statement

The datasets presented in this study can be found in the following online repository: https://doi.org/10.6084/m9.figshare.23677653.v1.

Author contributions

AA: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Project administration, Resources, Supervision, Writing – original draft. SS: Data curation, Investigation, Validation, Visualization, Writing – review & editing. WS: Data curation, Formal analysis, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

Publisher's note

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