Education Tech Research Dev (2025) 73:2425–2461
https://doi.org/10.1007/s11423-025-10485-y

DEVELOPMENT ARTICLE

Integrating cognition, self-regulation, motivation, and metacognition: a framework of post-pandemic flipped classroom design

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Accepted: 22 February 2025 / Published online: 28 March 2025
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Abstract
The adoption of blended and hybrid Flipped Classroom (FC) models increased dramatically during COVID-19 and is still highly valued and recommended for enhancing the quality, flexibility, and effectiveness of teaching and learning post-pandemic. While meta-analyses indicate a small yet meaningful effect size of the FC approach, examined studies often lack theoretical groundings and/or explicit design frameworks. As a result, there is an ever-increasing need for instructional design guidance for effectively integrating and facilitating online and in-person learning in the FC context. The current paper outlines a framework intended to guide educators, designers, and researchers to maximize the synergy of online and in-person learning as they design and implement FC. Grounded in (Merrill, First principles of instruction: Identifying and designing effective, efficient and engaging instruction, Pfeiffer, 2013) First Principles of Instruction, (Zimmerman and Schunk, Zimmerman and Schunk (eds), Handbook of self-regulation of learning and performance, Routledge, 2011) Self-Regulated Learning process, (Jones, Motivating students by design: Practical strategies for professors, CreateSpace, 2018) MUSIC Model of Academic Motivation, and (Flavell, American Psychologist 34:906, 1979) Metacognition theory, we first present a conceptual framework with flipped learning cycle, self-regulated learning cycle, and metacognitive FC orientation. Informed by these theories and our FC design experience across disciplines, we convert the conceptual framework into a procedural framework by organizing the design aspects and components into a generic FC learning process. Finally, we propose theoretically and empirically grounded design strategies for individual components of the FC process, which can be further validated and refined through iterative educational design research.

Keywords Flipped classroom · Blended learning · Hybrid learning · Design framework · First principles of instruction · Self-regulated learning · Motivation · Metacognition

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While the impact of COVID-19 brought an unprecedented disruption in education (United Nations, 2020), it also provided the opportunity for reimagining how teaching and learning could take place (Zhao, 2020; Zhao & Watterston, 2021). The adoption of blended and hybrid learning models accelerated during the pandemic to reduce in-person class time and class size in order to control the spread of virus (Pelletier et al., 2021). In particular, the flipped classroom approach offered effective solutions to providing safe and flexible learning environments while maintaining in-person instructor-to-student and student-to-student interactions (Divjak et al., 2022; Romanow et al., 2024). As we emerge from the pandemic, blended/hybrid and flipped learning methods are still highly valued and recommended for enhancing the quality, flexibility, and effectiveness of teaching and learning (Joosten et al., 2021; Pelletier et al., 2022; Singh et al., 2021). Further, with the accumulated online teaching and learning experience during COVID-19, educators and students become more and more likely to accept, test, and adapt to blended/hybrid and flipped learning in the post-pandemic era (Clark et al., 2022; Zhao & Watterston, 2021). Following this trend and the ever-increasing need for instructional design guidance, our paper presents a flipped classroom (FC) design framework that proposes theoretically grounded strategies for integrating online and in-person learning modes post-pandemic.

Originating in the high school chemistry classroom (Bergmann & Sams, 2012), FC has already been widely adopted as an innovative teaching and learning approach in both K-12 and higher education (Al-Samarraie et al., 2020; Bond, 2020; DeLozier & Rhodes, 2017; O'Flaherty & Phillips, 2015). FC is often defined as two interconnected components: (1) Pre-class direct instruction, where students learn with technology-based instructional materials at their own pace in an individual learning space, and (2) in-class active learning, where students engage in higher-order learning activities such as applying concepts and solving problems in a group learning space with instructor and peers (Bishop & Verleger, 2013; DeLozier & Rhodes, 2017; Flipped Learning Network, 2014). However, as FC practice emerging from the pandemic often involved reduced in-person class time and class size, its definition has evolved to blended/hybrid FC by reconsidering the distribution of goals, tasks, and time throughout pre-class, in-class, and after-class learning stages, creating the need for the development and sharing of new frameworks.

Reviews of FC literature before the pandemic already reveal a lack of theoretical grounding and/or explicit design framework(s) in FC design and research (Bond, 2020; Lo, 2018; O'Flaherty & Phillips, 2015). A majority of studies focus on the effects of this general approach through comparisons of student performance, engagement, and satisfaction with the traditional classroom, with relatively few emphasizing the theoretical framework or elaborating on the pedagogical design of the FC approach being used (Cheng et al., 2019). Meta-analyses of FC implementation indicate that the effect size of the FC approach on learning outcomes across studies has been small (e.g., Cheng et al., 2019; Låg & Sæle, 2019; van Alten et al., 2019). However, we argue that the varying qualities of FC design and implementation, due to the lack of operational design frameworks, could be one factor leading to the observed low effect size on learning outcomes.

However, a growing number of FC studies or reviews are moving beyond the basic FC characteristics of pre-class direct instruction and in-class active learning by creating theoretical frameworks to support FC design and investigation. Three general approaches have been taken to build frameworks: the first approach involves integrating a variety of pedagogical (e.g., knowledge construction, active learning, collaborative learning) and technological (e.g., seamless platforms, technology use) elements to create comprehensive FC models for at-home and in-class learning design (e.g., Blau & Shamir-Inbal, 2017; Chen et al., 2014; Hwang et al., 2015). The second approach

identifies and applies cognitive or social learning theories in the context of FC, such as first principles of instruction, cognitive apprenticeship, and community of inquiry (e.g., Kim et al., 2014; Lin et al., 2021; Lo et al., 2018; Yorganci, 2020). The third approach utilizes metacognitive and motivational theories, particularly self-regulated learning (SRL) and self-determination theories, to enhance FC design with SRL support and gamification strategies (e.g., Huang & Hew, 2018; Lai & Hwang, 2016; Liu et al., 2024; Ng, 2018; Zainuddin, 2018).

Although the aforementioned research has garnered positive findings, the extent to which these FC designs can be easily adopted by others across educational contexts is limited. Many of the frameworks are presented at a conceptual or theoretical level, supplemented with FC design descriptions that are heavily contextualized by the research setting. Few frameworks provide generalized design principles or strategies that can be transferred to different FC contexts and tested over time (e.g., Huang & Hew, 2018; Kim et al., 2014; Liu et al., 2024). Moreover, existing frameworks tend to be confined to the two traditional FC components of pre-class learning (also referenced as out-of-class learning, at home learning, or online learning) followed by in-class learning activities, making in-class learning the end of a flipped learning session. Although this reflects the original concept of "flipping", the implementation of student-centered pedagogies (e.g., knowledge integration, peer interaction, and learning reflection) often cannot be fully accomplished during limited in-class time, especially in blended/hybrid settings where in-class time is partially replaced with online learning. Additionally, most frameworks only recommend pre-class and in-class activity types that can be repeated throughout part of or an entire semester, without guidelines for introducing students to FC learning, giving them effective strategies, or helping them keep up with FC tasks.

We build upon the emerging trends in FC research by proposing a theoretically and empirically grounded framework that can provide practical guidance for FC design in the post-pandemic era that has further embraced blended/hybrid learning models. Below are three unique attributes.

First, to address the aforementioned limitations of existing frameworks, this framework is founded on interconnected theories, including First Principles of Instruction (Merrill, 2002, 2013), Self-Regulated Learning (Zimmerman, 2002, 2011), the MUSIC Model of Academic Motivation (Jones, 2009, 2018), and Metacognition (Flavell, 1979). We chose these theories because we believe that a successful flipped classroom requires not only effective and engaging instructions and activities (Lo et al., 2018), but also self-regulated and motivated learners with metacognitive awareness (Awidi & Paynter, 2019; Cheng et al., 2019; Liu et al., 2024).

Second, given the positive impact of blended/hybrid learning observed during the pandemic (Joosten et al., 2021; Pelletier et al., 2022; Singh et al., 2021), this framework integrates blended/hybrid concepts (Johnson et al., 2022) into FC design by highlighting the significant roles of online (pre-class), in-class, and after-class learning phases and their connections, which constitute the flipped learning cycles that can help educators and students build upon and revitalize their online and in-person teaching and learning strategies, as well as increasing the efficiency, flexibility, and effectiveness of post-pandemic education.

Third, the development of this framework is driven by the real-world challenges of implementing FC design across different higher education disciplines (see Appendix A) before, during, and after the pandemic. Those challenges gave us opportunities to apply the theoretical principles in various subject areas and at different pandemic stages, while generalizing design strategies across contexts. They also required us to consider the

semester-long FC teaching and learning process, and ultimately led us to situate the design strategies in a procedural framework that can be directly applied in real-world FC settings.

Theoretical perspectives

Cognition, metacognition, and motivation are three interdependent components for successfully completing any complex learning task (Mayer, 1998), which is particularly true in the FC environment. We believe that support from all these areas is needed to help students productively and efficiently engage in FC learning. The following section outlines the theoretical perspectives we identify as the foundation of our framework and how we adopt their principles and/or procedures applicable to FC learning.

First principles of instruction

Effective FC design should be guided by a robust instructional design framework grounded in learning theories (Lo, 2018). Merrill's (2002, 2013) First Principles of Instruction identifies five principles based on a variety of instructional design models and cognitive theories, including *Problem-Centered*, *Activation*, *Demonstration*, *Application*, and *Integration* principles. The *Problem-Centered* principle highlights the importance of acquiring knowledge and skills through real-world problem solving. The *Activation* principle advises activating learners' mental model through prior knowledge recall and/or new knowledge acquisition to provide the basis for learning new skills. The *Demonstration* principle suggests having learners observe a demonstration of the skills to be learned. The *Application* principle emphasizes engaging learners in applying their newly learned knowledge or skills to solve problems. The *Integration* principle recommends that learners integrate their new knowledge and skills by defending and sharing with others what they learned.

Although not widely adopted in FC studies, some researchers have applied these principles to the design of out-of-class and in-class learning activities and reported positive results (e.g., Hall et al., 2020; Lo et al., 2018; Yorganci, 2020). Since the ultimate goal of FC is to promote active learning and higher-order thinking skills (DeLozier & Rhodes, 2017), the *Problem-Centered* principle can serve as the overarching theme of FC design. The *Activation* and *Demonstration* principles prescribe direct instructional strategies, thus aligning well with pre-class learning. The *Application* principle can supplement pre-class learning design, however, due to its shared focus with the active learning component of FC, would be mainly applied to designing in-class and after-class activities. The *Integration* principle can be incorporated during class to reinforce new skills and after class through review, transfer, and further peer sharing.

Self-regulated learning

Given increased autonomy over learning, FC students are expected to possess a higher level of self-regulation skills (Cheng et al., 2019; van Alten et al., 2020), which were shown to impact their achievements in FC (e.g., Jovanovic et al., 2019; Sun et al., 2018). Zimmerman (2002; 2011) defines self-regulated learning (SRL) as a cyclical process that occurs across *Forethought*, *Performance*, and *Self-Reflection* phases. The *Forethought* phase focuses on task analysis through setting goals, planning strategies, and allocating resources for achieving those goals. The *Performance* phase involves monitoring and controlling the

implementation of the forethought plan through self-observation. The *Self-Reflection* phase requires evaluating self-observed performance against *Forethought* goals and adapting goals and strategies to inform planning in future SRL cycles.

Many FC studies have used quizzes to ensure the completion of pre-class learning (Låg & Sæle, 2019; van Alten et al., 2019); however, few provided systematic self-regulation support (e.g., Lai & Hwang, 2016; Ng, 2018; Yoon et al., 2021). We suggest that the three SRL phases be integrated with the recurring pre-class, in-class, and after-class learning activities to develop students' self-regulation skills required in FC. The *Forethought* phase can guide students to analyze FC tasks by setting goals, identifying learning strategies, and allocating resources. The *Performance* phase can guide students to monitor and control their FC learning behavior based on their planned goals, strategies, and resources. The *Self-Reflection* phase can guide students to periodically evaluate their learning performance, revisit learning goals, and adjust learning strategies to inform *Forethought* of upcoming FC learning. Iterative implementation of these phases will stimulate students' self-satisfaction with their learning progress that further enhances their SRL behaviors (Zimmerman, 2011).

The MUSIC model of academic motivation

Positive FC outcomes require motivating students to complete the before- and after-class activities (Huang & Hew, 2018) that often create an increased workload (Låg & Sæle, 2019; van Alten et al., 2019). Existing FC studies have applied self-determination theory (SDT) to enhance student motivation by embedding gamification elements in out-of-class activities (e.g., Huang & Hew, 2018; Zainuddin, 2018). In the current framework, we attempt to take a more holistic approach to designing motivational support for both out-of-class and in-class learning, utilizing Jones's (2009, 2018) MUSIC model of academic motivation, which integrates SDT with other motivation theories.

The MUSIC model components—*eMpowerment*, *Usefulness*, *Success*, *Interest*, and *Caring*—can be highlighted during self-regulated FC learning to foster student motivation. *eMpowerment* refers to giving students' control over some aspects of their learning. Pre-class direct instruction can be designed to empower students through self-paced learning, while SRL activities can engage students in taking ownership of their learning goals and strategies. *Usefulness* helps students understand how learning contributes to their long-term and short-term goals. It can be promoted as students reflect on their goals and values or solve real-world problems. *Success* is about establishing students' belief that they can succeed if they put forth effort. It can be implemented by clarifying FC expectations, providing feedback on performance, and encouraging reflection on learning outcomes. *Interest* refers to eliciting situational and personal interests that can attract student attention to learning. Pedagogical and technological strategies (e.g., providing real-world scenarios, using visual media) can be applied to stimulate student interest during FC learning. *Caring* gives students the feeling that the instructor and others in the class care about their learning and general well-being, which can be communicated through various social interactions, such as individualized assistance and peer sharing.

Metacognition

Metacognition, involving metacognitive knowledge (person, task, and strategy) and metacognitive experience (Flavell, 1979), plays an indispensable role in self-regulated learning

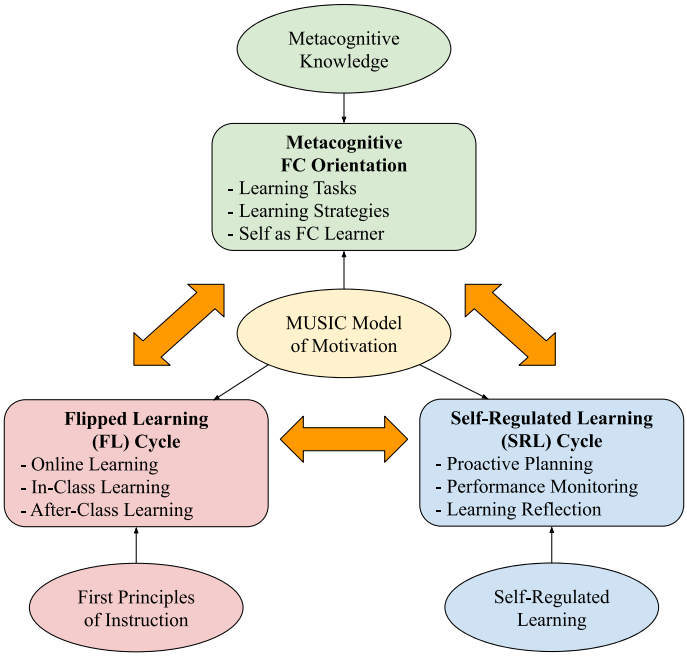


Fig. 1 Conceptual framework of flipped classroom design

(Schraw, 1998). Students with limited FC experience are likely to have inadequate knowledge about the FC learning tasks, useful strategies, and their strengths and weaknesses as FC learners, thus affecting the regulatory skills they adopt during SRL phases. Therefore, effective FC should first prepare students with the essential metacognitive knowledge about this learning format, followed by engaging them in guided SRL phases to continuously develop their metacognitive knowledge and experience related to FC.

Conceptual framework

Given the connections between these theoretical perspectives and the nature of FC, we created a conceptual framework of FC design in Fig. 1 with three main aspects: Flipped Learning (FL) Cycle, Self-Regulated Learning (SRL) Cycle, and Metacognitive FC Orientation. Next, we will first introduce each design aspect and then situate them in a generic FC learning process that serves as the foundation for the design strategies discussed later.

Flipped learning (FL) cycle

Borrowing from Caulfield's (2011) suggestion to use a repeatable and continuous learning cycle to help establish the rhythm of learning in hybrid/blended classes, our framework first conceptualizes the FC process as a set of FL cycles repeated throughout the semester. Each FL cycle includes online, in-class, and after-class learning stages that incorporate

First Principles of Instruction (Merrill, 2002, 2013) and motivational components from the MUSIC model (Jones, 2009, 2018).

In accordance with definitions of blended/hybrid learning models (Johnson et al., 2022), "Online Learning" is used instead of "Pre-Class Learning" to highlight self-paced online learning before coming to class as a formal step of the cycle that is equally important as in-class active learning. In-Class Learning extends online learning outcomes to focus on problem-centered applications with guidance and interaction. In blended/hybrid learning settings where a portion of the face-to-face instruction is replaced by online learning (Blended Learning Toolkit, 2011), the amount of class time can be reduced to compensate for online learning time, while also allowing large class sections to be divided into smaller sections that share the in-person class time with the instructor. This has been used as a strategy to reduce class size and enhance in-class interactions in large public universities (e.g., Spencer et al., 2022). Although there are mixed findings about whether the reduction of class time affects learning outcomes (van Alten et al., 2019), we argue that the decision should be made based on the benefits of reduced class size as a result of decreasing class time, the students' existing SRL skills, and the amount of SRL support available. Finally, After-Class Learning, essential to blended/hybrid classes with limited in-person class time, is included as a separate step to provide continued opportunities for review, application, peer sharing, and obtaining support beyond online and in-class learning, solidifying students' newly acquired knowledge and skills before they engage in the next FL cycle.

Self-regulated learning (SRL) cycle

To help students manage FC learning, a set of SRL cycles should be implemented in parallel with the FL cycles. Each SRL cycle consists of Proactive Planning, Performance Monitoring, and Learning Reflection stages that correspond to the *Forethought*, *Performance*, and *Self-Reflection* phases of SRL (Zimmerman, 2002, 2011), while being enhanced by the MUSIC model (Jones, 2009, 2018) components to further increase learning motivation.

We consider SRL cycles and FL cycles as separate but interconnected processes that could have the same or different rhythms of repetition, depending on the teaching and learning settings. When SRL cycle and FL cycle rhythms match (e.g., Lai & Hwang, 2016; Yoon et al., 2021), Proactive Planning begins prior to the FL cycle, with Performance Monitoring occurring throughout and Learning Reflection following the completion of the FL cycle. However, FC studies using such SRL support were often conducted in an experimental setting of several weeks, which may not be feasible for longer periods of learning due to the cumulative amount of SRL activities. We suggest that, in the context of semester-long learning, SRL cycles can be set less frequently by aligning one SRL cycle with multiple FL cycles to reduce excessive planning and reflection, thus avoiding SRL fatigue in FC (Robbins et al., 2020). The Proactive Planning stage can span a number of FL cycles, whereas the Learning Reflection stage can conclude those cycles and inform the planning for the next set of FL cycles, all while encouraging continuous Performance Monitoring.

Metacognitive FC orientation

Due to the differences between flipped and traditional learning, FC orientation is necessary for clarifying expectations to help students adapt to this new approach (Lee et al., 2017; O'Flaherty & Phillips, 2015). Metacognitive FC Orientation emphasizes developing students' metacognitive knowledge about the FL and SRL values, tasks, and strategies, as well

as themselves as learners in the FC environment. This knowledge can promote metacognitive awareness that helps students see value in the SRL cycle activities (Schraw, 1998). Meanwhile, students' later experience during the FL and SRL cycles can refine their initially developed metacognitive knowledge (e.g., strategy A works better for me than strategy B) to guide subsequent learning. Additionally, motivational components (e.g., *Usefulness*, *Success*, *Caring*) from the MUSIC model (Jones, 2009, 2018) can be integrated into the orientation to encourage reflection and sharing on longer-term goals, beliefs, and how they relate to FC learning to help students develop appropriate self-knowledge and attitudes.

Review of relevant FC studies

Due to the originality of this framework, there are no existing FC studies that have fully implemented the entire framework. However, we identified three representative FC studies that incorporated one or multiple design aspects discussed above, providing empirical evidence for the value and feasibility of the conceptual framework in supporting effective FC design.

Spencer et al. (2022) implemented a blended/hybrid FC design in a college level calculus course by first introducing this new format through an FC Orientation module that clarified the cyclical learning process and expectations and provided strategies for utilizing the course resources. Flipped Learning Cycles were created to guide students through steps of completing online lessons and assessments of basic concepts and skills, participating in in-class problem solving in small groups with guidance, and solving after-class problems independently to reinforce in-class learning. According to their results, students reported a high level of engagement and positive perceptions regarding the FC Orientation module, as it helped them understand the new course format. Student learning performances and perceptions in the FC format improved significantly from the traditional lecture format. Moreover, they found that better online learning outcomes tend to produce better in-class readiness, which further led to better after-class performances and exam grades, indicating that accumulative achievements throughout the flipped learning steps created fruitful cycles that ensured students' ultimate success in FC.

Lo et al. (2018) proposed an FC approach based on the First Principles of Instruction for designing out-of-class learning and in-class interactive learning, and applied it in high school courses of four subject areas. They used *Activation*, *Demonstration*, and *Application* principles in creating pre-class video lectures and follow-up exercises, and implemented all five principles, including *Integration* and *Problem-Centered* principles, through learning review, mini-lectures, and problem-solving activities during class. They reported greater student achievements in the flipped courses in three of the four subject areas, and attributed the results to self-paced learning of basic materials before class and group-based problem-solving activities during class. They also stressed the need to keep some amount of in-class lectures to explain and demonstrate the complex concepts while focusing on problem-centered learning activities. Based on their findings, they recommended grounding FC practice in this First Principles of Instruction-based model.

To support self-regulated learning in FC, particularly pre-class learning, Yoon et al. (2021) suggested three design principles based on Zimmerman's (2002) *Forethought*, *Performance*, and *Self-Reflection* phases of SRL, including having students set learning goals for a pre-class session, using visualizations to show their progress and performance after each session, and asking students to transfer what they learned from the session to

new contexts. In the setting of facilitating SRL in a three-week flipped learning unit of a pre-service teacher course on technology integration, they applied these design principles by creating (1) a dashboard module that visualized students' activity completion progress and quiz scores of the pre-class session and (2) a reflection module that prompted students to assess their pre-class session performance, set a learning goal for the next session, as well as thinking about ways to apply what they learned from the session materials. They reported that the experimental group using the two modules exhibited higher levels of SRL skills, behavioral and cognitive engagement, and learning performance than the control group.

To summarize, Spencer et al. (2022) employed a preliminary version of this framework that considered the FC Orientation and the cyclical FL process that included online, in-class, and after-class learning. Lo et al., (2018) intentionally applied First Principles of Instruction in out-of-class and in-class learning design based on the original concept of FC. They proposed and validated more detailed design strategies than Spencer et al. (2022), but did not mention after-class reinforcement activities, which could be due to the different expectations in high school vs. higher education. Yoon et al. (2021) integrated the cyclical process of SRL in FC by providing support for all three SRL phases and presented opportunities for using technology-based visual feedback to guide FC learning, which complemented the other two studies with the SRL dimension of FC design. However, given the short study duration and the limited focus on pre-class learning, more systematic SRL support integrated with the full FC process in longer-term should be explored further. Overall, all three studies indicated positive learning outcomes as a result of adopting their theoretically and/or empirically grounded FC design, giving us confidence in the value of our conceptual framework that encompassed the same design aspects. Still, these are independent studies that cannot provide a coherent set of FC design strategies that seamlessly integrate FC Orientation, FL Cycles, and SRL Cycles, suggesting the need for building upon the conceptual framework to develop concrete FC design guidelines.

Procedural framework and design strategies

To make the conceptual framework more pragmatic, we converted it into a procedural framework (see Fig. 2) by organizing the design aspects and components into a generic FC learning process. The process begins with an FC orientation to develop students' initial metacognitive knowledge about FL/SRL tasks and strategies, and themselves as FC learners. Students then engage in a number of SRL cycles organized by learning milestones (e.g., content topics, exams, projects) and repeated throughout the semester or chosen time frame. They start each SRL cycle with proactive planning for FL goals and strategies, and end the cycle with learning reflection that enhances their metacognitive knowledge and informs future planning. During each SRL cycle, students go through one or multiple FL cycles while monitoring their learning behavior and performance using the planned goals and strategies. Each FL cycle is structured with online, in-class, and after-class learning steps that incorporate teaching and learning activities based on the First Principles of Instruction. In summary, FC orientation prepares students to effectively engage in this new approach of learning; repeated FL cycles guide students through the entire process of cognitive learning; repeated SRL cycles help students intentionally manage their learning across the FL cycles.

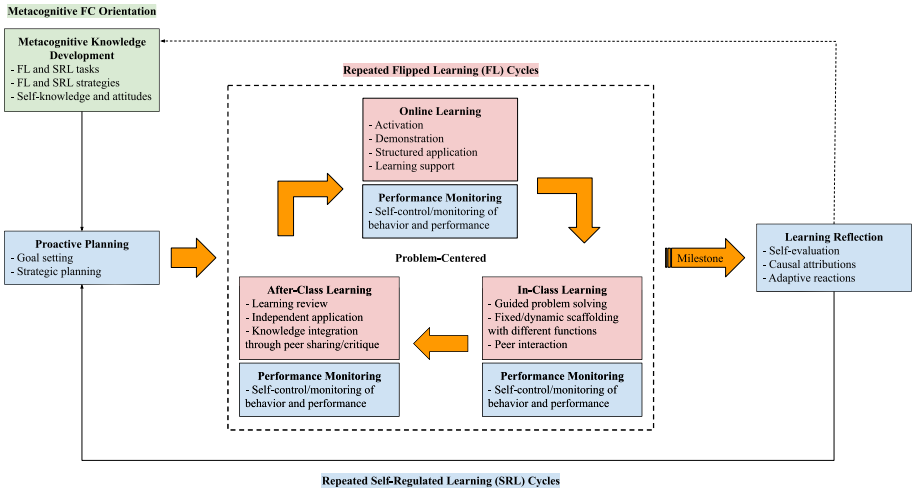


Fig. 2 Procedural framework of flipped classroom design

In the next sections, we discuss three sets of design strategies for FL Cycle, SRL Cycle, and Metacognitive FC Orientation respectively. Originated from the conceptual framework, these strategies (see Table 1) elaborate on the ways to approach the individual design components and have been fully or partially applied in the FC courses listed in Appendix A.

FL cycle design strategies

Creating FL cycles

1.1 Define the FL cycle length, steps, and learning tasks to clarify expectations To promote *Success* (Jones, 2018), effective FCs should have explicit expectations that are clearly communicated to students (Lee et al., 2017). Central to this is defining the FL cycle itself. A generic FL cycle can first be delineated by its typical length, key steps, and types of learning tasks associated with each step, and then be applied to individual FL cycle design.

Defining the cycle length based on a regular class schedule makes the FL cycles easier to plan. Depending on how often the class meets, the FL cycle can be set around each class day, a week, or other regular schedules. Cycles should be as consistent in length and steps as possible, each encompassing online, in-class, and after-class learning. Learning tasks of each cycle step should be designed by selectively applying the First Principles of Instruction to address the intended learning outcomes as well as to leverage the advantages of the accompanied learning environment (e.g., using the *Application* principle for in-class learning where instructor guidance and peer interactions are readily available). The FL cycle structure should be presented to students at the beginning of FC and reflected in the organization of the materials and activities to reinforce expectations.

1.2 Gradually increase the challenge level along the FL cycle Challenge levels of learning activities should match students' abilities in order to create a state of flow (Csikszentmihalyi, 1990) that motivates them to learn and promotes *Success* (Jones, 2018). Similarly, the

Table 1 Flipped classroom design strategies

Design aspects	Design components	Design strategies
Flipped Learning (FL) Cycle	1. Creating FL Cycles	1.1 Define the FL cycle length, steps, and learning tasks to clarify expectations 1.2 Gradually increase the challenge level along the FL cycle 1.3 Provide regular and specific feedback throughout the FL cycles
	2. Designing Online Learning	2.1 Create online learning to support initial mental model development 2.2 Apply multimedia learning principles to designing online materials 2.3 Complement online learning with dialogue-based learning support
	3. Designing In-Class Learning	3.1 Engage students in solving whole problems with supplementary instructions 3.2 Guide problem solving using different scaffolding types and functions 3.3 Facilitate peer interaction during problem solving to support integration
	4. Designing After-Class Learning	4.1 Foster learning review and new problem solving with reduced support 4.2 Encourage after-class peer sharing and critiquing to reinforce integration
Self-Regulated Learning (SRL) Cycle	5. Creating SRL Cycles	5.1 Define iterative SRL cycles encompassing the FL cycles 5.2 Provide internal and external feedback support during SRL cycles
	6. Designing Proactive Planning	6.1 Start each SRL cycle with goal setting 6.2 Guide strategic planning for task, time, environment, and help-seeking
	7. Designing Performance Monitoring	7.1 Support self-control by making planned strategies easily accessible 7.2 Facilitate self-monitoring of strategy use and learning outcomes
	8. Designing Learning Reflection	8.1 Guide self-evaluation by comparing with appropriate references 8.2 Steer causal attributions toward controllable factors and elicit adaptive reactions
Metacognitive FC Orientation	9. Developing Task and Strategic Knowledge	9.1 Develop task knowledge of FC rationale, process, and expectations 9.2 Develop strategic knowledge of approaching FL and SRL tasks
	10. Developing Self-Knowledge and Attitudes	10.1 Guide students to reflect on their cognitive and motivational beliefs 10.2 Develop proper attitudes through peer interactions and instructor feedback

Problem-Centered principle also suggests situating learning in a progression of simple-to-complex problems to help students develop their mental model (Merrill, 2013).

Online, in-class, and after-class learning tasks should be designed to match students' incremental skill levels throughout a cycle. All knowledge types and cognitive processing levels (Anderson & Krathwohl, 2001) can be considered in each stage, yet, the complexity level of the learning tasks should be calibrated based on students' growing capabilities. Online learning should focus on introductory tasks that can be completed asynchronously with minimal real-time interactions (e.g., watching problem-solving demonstrations, solving well-structured problems with automated feedback, sharing or discussing initial ideas on discussion forums). In-class learning should transition to more complex tasks that require students to actively retrieve and apply the newly acquired knowledge and skills to solve less structured real-world problems with appropriate scope for in-class completion. Instructor guidance and peer interaction during class can tailor the challenge levels to individual needs. After-class learning tasks should further increase the challenge by asking students to solve new problems, at sustained or increased complexity levels (e.g., challenge assignments, comprehensive projects), with reduced support and improved autonomy, as well as sharing their achievements with others. Individual assistance (e.g., tutoring, office hours) should be offered when the challenge levels are likely to be above any particular student's abilities.

1.3 Provide regular and specific feedback throughout the FL cycles Jones's (2018) *Success* strategies recommend providing regular feedback about levels of competence to help students determine how well they are performing and whether their learning strategies are effective. Such feedback helps shape students' self-perception of competence which sustains motivation along the FL cycle steps.

To make feedback specific and effective, intrinsic and corrective feedback can be used following application tasks (Merrill, 2013). Online learning, with an emphasis on the basic concepts and skills, should use corrective feedback (e.g., correct answer with explanation and/or further demonstration) to reinforce the intended level of understanding and application. As productive failures are effective for developing advanced application skills (Kapur, 2008), in-class learning should first let students observe the intrinsic feedback from their own application (e.g., initial attempts to solve a problem without assistance) followed by corrective instructor/peer feedback. Since after-class learning requires more autonomy in application, corrective feedback (e.g., solution notes, instructor comments) should be available to compensate for reduced guidance. Feedback from each FL cycle step can enhance students' self-competence (Jones, 2009) as they engage in the ensuing steps and cycles.

Designing online learning

2.1 Create online learning to support initial mental model development Students need to develop an initial mental model of new knowledge and skills (Merrill, 2013) through online learning in order to retrieve and apply them during class. This can be addressed by procedurally implementing the *Activation*, *Demonstration*, and *Application* principles, while incorporating the *Problem-Centered* principle.

Online learning materials, delivered using text and visual media, should first activate students' prior knowledge and provide a framework of reference (e.g., advanced organizer). Next, new knowledge and skills are presented, followed by demonstrations of ways to

apply them. Well-defined problems can serve as the context for *Activation* and *Demonstration* to help students see the *Usefulness* of what they learn (Jones, 2018), while observing the problem-solving process they need to master.

Students should also be given the opportunity to apply new knowledge and skills through structured activities or simplified problem-solving exercises targeting the component skills (e.g. quiz questions on particular concepts or skills, discussion activities on well-defined topics, assignments of solving problems similar to those in the demonstration), as opposed to comprehensive applications. Such practice allows students to self-assess their initial mental model after completing online learning, as well as receiving feedback from available sources (e.g. quiz feedback, answer keys, peers' responses) that can guide them to revise their mental model, and help them decide if they need to revisit the learning materials or seek additional help.

2.2 Apply multimedia learning principles to designing online materials As suggested by Merrill (2002), Mayer's (2001) multimedia learning principles offer more detailed guidance of using relevant media in designing *Activation* and *Demonstration* materials. They help capture students' *Interest* in the materials (Jones, 2018) while ensuring the effectiveness of learning.

Based on Mayer's (2001) principles, online materials should be relevant to the learning goals without extraneous information (*Coherence* principle), starting from introducing the component concepts or skills to showing more complex models (*Pre-Training* principle). Verbal or visual organizational cues (e.g., outlines, concept maps) should be incorporated to direct students' attention and activate their mental framework (*Signaling* principle). Materials presenting new knowledge and skills, particularly lecture videos, should be broken into small and sequentially presented segments that allow students to control the pacing and deepen their learning (*Segmenting* principle). Moreover, online materials should use narrated visual media with proper amounts of text information (e.g., bullet points, labels), to make the materials easy-to-understand while best utilizing students' cognitive capacity (*Modality*, *Multimedia*, and *Redundancy* principles). Social cues such as conversational words (e.g. you, I) and the real instructor's voice in videos can contribute to students' feeling of relatedness (*Personalization* and *Voice* principles).

2.3 Complement online learning with dialogue-based learning support Online learning creates a high transactional distance between instructor and students that requires high learner autonomy (Moore, 1993). Increasing instructor-student and student–student dialogue helps reduce the transactional distance and autonomy requirement (Moore & Kearsley, 1996). In the FC context, these types of dialogue can complement individual online learning with dynamic learning support from the instructor or peers, resulting in reduced transactional distance (Caulfield, 2011; Chen et al., 2014) and increased sense of *Caring* beyond the learning materials (Jones, 2018).

Asynchronous dialogues can be facilitated using technology tools such as discussion forums, whereas synchronous or in-person dialogues can be conducted through office hours, study groups, or at the beginning of each class. To encourage student participation in these dialogues, the available learning support options should be clarified and integrated into the FL cycles steps (e.g., direct students to ask questions in a discussion forum after presenting the online materials and activities). Students should also be encouraged to reflect on the effectiveness of the different learning supports in resolving their online learning challenges.

Designing in-class learning

3.1 Engage students in solving whole problems with supplementary instructions In-class learning transitions from asynchronous online instruction to in-person active learning (DeLozier & Rhodes, 2017). Regardless of which active learning methods are used (e.g. class discussion, pair-and-share activities, group collaboration), students should participate in problem-centered application activities during class, with appropriate levels of guidance. The *Problem-Centered* principle suggests using "whole problems" that are representative of problems learners will encounter after learning (Merrill, 2013). Solving authentic whole problems not only helps develop situated and transferable knowledge and skills, but also stimulates students' *Interest* in the learning context and helps them recognize the *Usefulness* of what they learn (Jones, 2018).

While online learning involves the application of component skills, in-class learning should require students to use the acquired component skills comprehensively to solve whole problems. Challenges from in-class application problems, alongside peer interactions and instructor feedback, help students check the adequacy of their existing mental model (Merrill, 2013) and create a collaborative zone of proximal development (Goos et al., 2002). However, additional activation and demonstration should be provided as supplementary instructions (e.g., mini lectures, just-in-time teaching) if the whole problem requires complex knowledge and skills not fully covered during online learning.

3.2 Guide problem solving using different scaffolding types and functions To help students achieve their zone of proximal development (Vygotsky, 1978), adequate levels of scaffolding should be provided in the learning environment to support students in solving whole problems using their new knowledge and skills (Merrill, 2013). Fixed and dynamic scaffolds, typically provided by technology and instructor/peers respectively, can be designed to implement the four scaffolding functions of open learning environments, including procedural, conceptual, metacognitive, and strategic scaffolding (Hannafin et al., 1999).

Procedural scaffolding (e.g., steps of completing a task) guides students through the in-class problem-solving process, whereas conceptual scaffolding (e.g., prompts for retrieving learned concepts) prompts retrieval of relevant concepts and skills from online learning to apply during class. Both procedural and conceptual scaffolding should be integrated with the whole problem to give students contextualized support and help them see connections between online and in-class learning. However, to prevent the piecemeal approach of using procedural and conceptual scaffolding (Sharma & Hannafin, 2007), metacognitive and strategic scaffolding are needed for developing autonomy and forming a deeper understanding. Metacognitive scaffolding (e.g., reflection questions, checklists) encourages planning, monitoring, and evaluating the problem-solving process, while strategic scaffolding (e.g., ideation resources, examples) offers suggestions and alternative perspectives of problem analysis and solutions. All four scaffolding functions can be provided through fixed scaffolds in the form of digital templates with guiding prompts and resource links, as well as being augmented with dynamic scaffolds emerging from interactions with the instructor and peers.

3.3 Facilitate peer interaction during problem solving to support integration Peer interactions through discussion, collaboration, or critiquing can initiate the *Integration* process in conjunction with knowledge/skill application, as they require students to consolidate new and old knowledge/skills by explaining their modified mental models to

others and defending them when challenged (Merrill, 2013). They also give students opportunities to showcase their increasing competencies and receive feedback, which can enhance their self-efficacy and peer relatedness.

In-class problem-solving activities can be organized in pairs or small groups to facilitate peer collaboration and critiquing. To maximize the benefits of peer interactions, problem-solving activities should start with individual application using students' own mental models, and then move on to collaborative discussion to help group members adjust their mental models through explanation and argumentation. Students from other groups can be invited to critique the group's solution or product and prompt them to revise or defend their work. This process allows students to continuously reflect on and revise their mental models, making them more flexible for solving new problems (Merrill, 2013). To prevent uneven participation, instructors should provide protocols or guidelines of the collaboration process to ensure all students are actively engaged.

Designing after-class learning

4.1 Foster learning review and new problem solving with reduced support Since in-class learning has limited time and focuses on guided application, students need after-class learning to complete the *Integration* process (Wang, 2019). Reviewing online and in-class learning helps students make connections between the new and prior knowledge/skills and reflect on their problem-solving strategies. With their reorganized mental model after learning review, students should then solve whole problems in new contexts in order to develop better conditioned knowledge/skills (Merrill, 2013). In contrast to guided in-class application, after-class problem solving can be the starting point for fading scaffolds and giving students choices regarding which problems to solve and how to solve them, with the intention to *eMpower* students with autonomy in application (Jones, 2018). However, students should still have access to problem-solving support asynchronously or in-person (e.g., help forums, office hours) to allow help-seeking when needed.

4.2 Encourage after-class peer sharing and critiquing to reinforce integration Peer sharing and critiquing of new knowledge/skills can be extended after class using asynchronous communication tools such as discussion forums. Students can show proofs of their competency level by demonstrating the process and outcomes of problem solving via digital formats (e.g., text, images, screencasts, videos). Exchanges of problems solved in new contexts could be even more beneficial for after-class peer sharing, as they require knowledge/skills with relatively high autonomy. Peers can review each other's work and comment on the strengths and weaknesses based on criteria consistent with the learning objectives. Instructors can provide additional guidance by answering questions or redirecting conversations. As students respond to peer and instructor feedback, they are likely to defend their work and/or further modify their mental model, thus reinforcing knowledge/skill integration. Similar to in-class peer interactions, these activities can also create a sense of relatedness and *Caring* that enhance motivation (Jones, 2018).

SRL cycle design strategies

Creating SRL Cycles

5.1 Define iterative SRL cycles encompassing the FL cycles While FL cycles foster academic skill development, SRL cycles facilitate the "self-directed process by which learners transform their mental abilities into academic skills" (Zimmerman, 2002, p. 65). Proactive Planning (*Forethought*) and Learning Reflection (*Self-Reflection*) should occur in between the FL cycles, whereas Performance Monitoring (*Performance*) can be integrated within the FL cycles to encourage monitoring and controlling processes while students work on FL tasks.

Given the cyclical nature of the SRL process, SRL cycles should iterate multiple times throughout FC learning to allow students to utilize self-regulatory experience from previous cycles. The length of an SRL cycle is best defined by the learning milestones that provide feedback on learning outcomes (e.g., exams, projects). Assessment feedback helps students reflect on their progress toward goals, the effectiveness of their learning strategies, and the adequacy of their efforts, which can assist them in planning and monitoring their learning and performance in the following SRL cycle and the associated FL cycle(s).

5.2 Provide internal and external feedback support during SRL cycles Feedback from internal or external sources is an inherent catalyst for SRL activities (Butler & Winne, 1995) and an essential supporting factor for *Success* (Jones, 2018). Internal feedback is self-generated by students as they compare their current state with their goals or criteria, make judgements about their level of success, and develop affective reactions that influence subsequent engagement. Students should be encouraged to revisit their goals and plans from Proactive Planning as they engage in FL cycle tasks to generate internal feedback that helps them monitor progress and adjust actions. Students should also be prompted to reassess their initial goals and plans during Learning Reflection, the feedback from which can guide them to make adaptations to reduce any discrepancy between their goals and performance.

External feedback is provided by external sources such as instructor, peers, or technology tools. Elaborated external feedback, containing a profile of cues (e.g., time spent, completed activities, accuracy levels) predicting final performance, can be useful in guiding self-regulation (Butler & Winne, 1995). Instructors can highlight the predictive cues by sharing exemplary profiles of self-regulated FC learning, and giving comments and suggestions on individual students' profiles. Peer sharing and discussion of each other's self-regulation experience in FC (e.g., study schedule before/after class, online learning strategies, ways to get help) can offer personalized feedback and encourage co-regulation (Hadwin et al., 2017). Moreover, with the advent of learning analytics tools, many predictive cue data can be easily recorded and visualized by technology to provide feedback for students to monitor their progress and consider the next steps (e.g., Appendix B; Pérez-Sanagustín et al., 2021; Silva et al., 2018; Yoon et al., 2021).

Designing proactive planning

6.1 Start each SRL cycle with goal setting According to Zimmerman (2011), goal setting is a major source of motivation for self-regulation. A well-organized goal system involves

"short-term goals serving as proximal paths to more distal outcome goals" (Zimmerman, 2011, p. 56). Proactive Planning at the beginning of each SRL cycle helps set the short-term goals that are stepping stones to the longer-term goals of the entire semester.

Two types of goals are mentioned in goal orientation theories (Dweck & Leggett, 1988; Elliott & Dweck, 1988): learning goals to increase competence (acquiring or improving skills) and performance goals to prove competence (getting good grades). Students should first be guided to set learning goals as the competency levels they aim to achieve regarding the upcoming FL cycle learning outcomes (e.g., Which competency level regarding ____ do I want to be at?). They can also be given the option to set performance goals (e.g., I am aiming to achieve a ____ score in the test/exam) if they have high self-perceptions of their current competency levels, or skip performance goal setting if they have low self-perceptions. By setting these goals, students are more likely to become motivated to strive toward *Success* and demonstrate persistence as they engage in the nested FL cycles (Jones, 2018).

6.2 Guide strategic planning for task, time, environment, and help-seeking Strategic planning, as another beginning step of self-regulation, refers to selecting or creating strategies that can guide cognitive learning, direct actions, and manage emotions during the learning process (Zimmerman, 2011). Four types of strategies, including task, time, environment, and help-seeking, support the SRL cycle goals.

Task strategies help improve the efficiency and effectiveness of cognitive learning. Students should be familiar with what task strategies to use and why/when/how to use them during the FL cycle (e.g., when watching online videos, pause or rewind the player to allow time for notetaking and/or deeper processing). *Time management* strategies, a significant predictor of performance (Zimmerman, 2011), should be planned by setting aside sufficient time for completing online learning tasks before in-class learning, and completing after-class learning tasks before starting the next FL cycle (e.g., Pérez-Sanagustín et al., 2021). *Environmental structuring* strategies "make the physical surroundings more attractive for task completion" (Zimmerman, 2011, p. 57), such as setting up a productive learning space with little distractions, enough safety and privacy, convenient access, and plenty of workspace for outside-of-class learning. *Help-seeking* involves reaching out for assistance from other individuals to meet one's learning needs. Students should recognize their need for help during the FL cycle and be aware of the types of help available to them.

Proactive Planning of these strategies sets the stage for Performance Monitoring. However, students should be given the choice to select which strategies to adopt or adapt based on their learning needs and preferences, in order to *eMpower* them with ownership in learning and increase their autonomy (Jones, 2018).

Designing performance monitoring

7.1 Support self-control by making planned strategies easily accessible Performance Monitoring of the SRL cycle requires students to execute self-control as they implement their planned strategies during the nested FL cycle(s) to achieve their goals. To facilitate self-control, students should be reminded about intentional strategy use, either through provided materials or interactions with the instructor and/or peers. These prompts should be highlighted during the initial FL and SRL cycles where students are exploring various strategies, but can fade as students develop autonomy in using them.

Task strategies can be embedded within the online, in-class, and after-class learning materials or activities. For example, strategies or prompts of how to learn effectively

using videos (e.g., pause and rewind, take notes, self-check understanding levels) can be added next to or embedded within the video (e.g., van Alten et al., 2020). Strategies of collaborating with peers during in-class activities (e.g., think through a problem individually before working with peers) can be included in activity instructions and/or facilitated by the instructor. *Time management* and *environmental structuring* strategies can be reinforced using technology tools such as an online calendar, which helps students set up planned study time and space, as well as sharing their plans with peers to form study groups. *Help-seeking* strategies, including when/where to get help and how to ask questions, should be organized as resources that students can easily reference. Easy access to planned strategies encourages students to apply them during the FL cycle tasks and allows them to assess the *Usefulness* of different strategies (Jones, 2018).

7.2 Facilitate self-monitoring of strategy use and learning outcomes Monitoring strategy use and its outcomes can elicit increased effort from the student to promote *Success* (Jones, 2018; Zimmerman, 2011). Monitoring involves self-recording of learning behaviors, conditions, effects, and performance (Zimmerman, 2011). During the SRL cycle, students should be guided to monitor their strategy use related to learning task, time, and environment, as well as monitoring their interim learning outcomes to help detect the need for seeking help.

Since strategies for task completion, time management, and environmental structuring are planned ahead of time, they can be recorded in a spreadsheet template (e.g., Appendix C) or other tools (e.g., Pérez-Sanagustín et al., 2021; Yoon et al., 2021) that allow students to keep track of the frequency and/or effectiveness of each strategy employed during a FL cycle. Based on their judgments of effectiveness, students can adjust their behavior or strategy use throughout the FL and SRL cycles. As students develop autonomy in using certain strategies, they may stop intentional monitoring but resume when necessary.

As help-seeking is initiated by detecting a lack of understanding or competency (Karabenick & Berger, 2013), students should be guided to first monitor their knowledge and skill levels in each FL cycle, and then monitor the actions they take and the usefulness of any help they receive, using a similar spreadsheet template (e.g., Appendix D) or other tools designed for help-seeking purpose. Specifically, to self-monitor cognitive competencies, students can be directed to revisit the learning objectives/outcomes covered in the FL cycle, along with assessment examples, to self-assess their confidence levels. Once gaps are identified, students should be prompted to select appropriate help-seeking strategies and monitor their effectiveness.

Designing learning reflection

8.1 Guide self-evaluation by comparing with appropriate references Learning Reflection requires students to self-evaluate their performance at the end of the cycle with a standard or goal, leading to affective reactions that can increase or decrease one's self-satisfaction (Zimmerman, 2011). Students should be guided to evaluate their competencies with appropriate references in order to generate positive emotional reactions and develop *Success* beliefs that can enhance their motivation to learn (Jones, 2018).

Prior knowledge and skill levels can serve as one type of self-evaluation reference. Students can look back at what they knew or could do at the beginning of an SRL cycle to assess the amount of progress they have made (e.g., Pérez-Sanagustín et al., 2021). This will likely help students see the incremental growth of their competencies and create some

level of self-satisfaction. As another type of reference, students could compare their competencies with the learning and/or performance goals they set during Proactive Planning to assess where they are in meeting their goals (e.g., Onodipe et al., 2020). When encountering gaps between goals and current competencies or performance, students should be guided to manage negative reactions while focusing on making adjustments during goal setting and strategic planning for the next SRL cycle.

8.2 Steer causal attributions toward controllable factors and elicit adaptive reactions

Self-regulatory processes prior to the Learning Reflection phase have significant impact on causal attribution factors (Zimmerman, 2011). Students who have engaged in accurate and effective Performance Monitoring are already likely to attribute their success or failure to controllable factors that can initiate adaptive reactions of adjusting strategies.

To ensure effective causal attributions, students can be first directed to reflect on their implementation of strategies, their time management for online and after-class learning, the physical spaces they used for study outside of class, and the timing, type, and amount of learning help they requested. Such reflections can draw students' attention to the controllable factors when making causal attributions of their learning outcomes afterward (e.g., not setting aside enough study time made it difficult to reach my learning goals). Causal attribution should be followed by prompting students to suggest the changes they would make to their strategies or implementation tactics as adaptive reactions for the next SRL cycle. Moreover, individualized instructor feedback or recommendations on adaptive reactions can show students the *Caring* from the instructor about their learning (Jones, 2018), and can encourage them to use their reflection from the current SRL cycle to inform future learning.

Metacognitive FC orientation design strategies

Developing task and strategic knowledge

9.1 Develop task knowledge of FC rationale, process, and expectations To prepare students for self-regulated FC learning, it is necessary to develop their task knowledge of this approach, including the task goals, demands, and how the task should be managed (Flavell, 1979). Specifically, the FC orientation should start by explaining the rationale of using this approach, with an emphasis on the benefits for the intended learning outcomes, to help students see the *Usefulness* (Jones, 2018). Comparison with the non-flipped version might further demonstrate the purposes and advantages of using FC.

Moreover, the orientation should introduce the FL and SRL cycles to help students understand the FC learning process and expectations. The generic FL cycle can be introduced first to provide declarative knowledge about the repeated learning steps, tasks, and pacing (e.g., Spencer et al., 2022), followed by the generic SRL cycle phases, activities and their roles in supporting FC learning. Two types of visuals would be helpful: (1) a micro-diagram of the generic FL cycle aligned with its typical length, such as a week, can show students which days are designated for online, in-class, and after-class learning respectively (e.g., Appendix E); and (2) a macro-diagram displaying all FL and SRL cycles of the semester can help students see the big picture and recognize the connections between the two types of cycles (e.g., Appendix F). Well-designed visuals could stimulate students'

situational *Interest* (Jones, 2018) in learning about the FC format and help them develop procedural knowledge of how to complete the self-regulated FC learning tasks.

9.2 Develop strategic knowledge of approaching FL and SRL tasks Students need knowledge about the cognitive and metacognitive strategies to effectively engage in self-regulated FC learning, including the declarative, procedural, and conditional knowledge of those strategies (Flavell, 1979; Schraw, 1998). The FC orientation should prepare students regarding what the FL and SRL strategies are, why they are being used, and when/how to use them.

FL strategies are the task strategies discussed earlier for enhancing cognitive learning (see strategy 6.2). The declarative and procedural information of these strategies can be organized by the online, in-class, and after-class learning steps of the FL cycle to help students understand which strategies can be used for which tasks. To develop conditional knowledge, orientation activities can give students scenarios of typical FC learning challenges (e.g., I had difficulty solving the homework problem) and let them select appropriate actions based on the task strategies (e.g., review notes of in-class problems before attempting the homework problem), followed by feedback on their choices.

Although SRL strategies, including goal setting, time management, environmental structuring, and help-seeking, are essentially the SRL cycle tasks, they should be highlighted in the orientation materials to explain what they mean and why they are beneficial (declarative knowledge), as well as how and when they should be applied throughout the SRL cycle tasks (procedural and conditional knowledge). In the meantime, tools (e.g., planners, tracking tools, progress dashboard) and resources (e.g., available learning spaces, help-seeking options) supporting the SRL strategies should be introduced or demonstrated to help students use them strategically from the beginning.

Developing self-knowledge and attitudes

10.1 Guide students to reflect on their cognitive and motivational beliefs Self-knowledge refers to beliefs about the nature of oneself as a cognitive processor (Flavell, 1979). Here we expand it to students' cognitive and motivational beliefs about themselves as FC learners. Since the FC format creates different levels of challenges for different learners, students should be guided to reflect on their strengths and weaknesses in approaching the FC tasks and incorporate those self-understandings into initial Proactive Planning. Moreover, to help students recognize their motivational beliefs, the FC orientation should also guide them to reflect on their long-term goals for academic study or future career, their self-efficacy and interest in the subject area, and their perceived value of FC. By exploring the connections between the FC format and their self-knowledge about what motivates them to learn, students are more likely to use the learning strategies persistently (Jones, 2009).

However, initial reflection during the orientation, before engaging in any FL and SRL cycles, may only elicit a limited amount of self-knowledge. Both cognitive and motivational beliefs can be reinforced or refined through periodic Learning Reflection at the end of each SRL cycle by asking students to identify the causes of their outcomes and suggest ways to improve.

10.2 Develop proper attitudes through peer interactions and instructor feedback FC research has shown mixed findings in student satisfaction (Låg & Sæle, 2019; O'Flaherty & Phillips, 2015), indicating that students are likely to bring a mixture of positive and nega-

tive attitudes toward FC due to different beliefs about this new way of learning (e.g., "I can learn at my own pace using the videos" vs. "I have to teach myself using the videos"). FC orientation should engage students in peer interactions after they have reflected on their individual cognitive and motivational beliefs. Instructors can prompt students to share and discuss their FC related beliefs and self-knowledge, exposing them to various perspectives about the values and challenges of FC learning, which may help transform negative attitudes while immersing students in a *Caring* culture that can increase motivation (Jones, 2018). Moreover, personalized feedback from the instructor regarding individual students' goals and beliefs not only demonstrates that the instructor cares about their FC learning experience and attitudes, but also serves as a good opportunity to point students to strategies or resources for overcoming the challenges and concerns they have about the FC approach.

Conclusion and implications

This paper proposed an FC design framework grounded in theories related to cognition, self-regulation, motivation, and metacognition, as well as being informed by our experience of designing FC courses across disciplines. We first created a conceptual framework based on relevant theories, then converted it into a procedural framework that identifies the design components, and finally proposed the FC design strategies for each component. Our framework builds upon the trend of strengthening FC design with pedagogical theories (e.g., Huang & Hew, 2018; Kim et al., 2014; Lai & Hwang, 2016; Lin et al., 2021; Lo et al., 2018; Yorganci, 2020) and goes a step further by contributing pragmatic FC design strategies that can be applied to or adapted for various contexts.

With growing interest in blended and hybrid learning models since the pandemic, this framework provides practical guidance for educators, designers and researchers who strive to maximize the synergy of online and in-person learning during the post-pandemic era. Derived from diverse theoretical underpinnings, the design strategies can guide FC designers to consider a variety of factors essential to successful learning in the FC environment, particularly the metacognitive knowledge for getting ready to engage in FC and the self-regulated learning skills for managing online and in-person learning, which are often overlooked in FC design and research (Cheng et al., 2019). This framework also highlights the emerging direction of blended/hybrid FC that starts a flipping cycle with a considerable amount of online learning and transitions to in-class learning that may have reduced class time and size, followed by after-class reinforcement of online and in-class learning. This direction could provide opportunities and insights for post-pandemic FC design, particularly in large public universities.

Despite our internal evaluation of the FC courses (see Appendix A) that implicitly influenced this framework, rigorous research studies are needed to examine the framework by validating and refining the design strategies. We believe our framework can be used to initiate educational design research, which involves iterative development of practical solutions and consecutive investigations to build theories (McKenney & Reeves, 2019), in the inextricable fields of FC and blended/hybrid learning. Researchers can use this framework as a starting point for FC design and conduct iterative evaluations of the learning outcomes, processes, and attitudes to test and elaborate on the strategies for FL cycle, SRL cycle, and FC orientation design. Results from a series of empirical investigations can help us better understand the values and challenges of such learning models and provide evidence

for proving or revising the design framework and strategies. Through further research and implementation efforts, we anticipate that this framework will continue to evolve and positively impact theories and practices in blended/hybrid FC learning.

Appendix A Flipped classroom courses designed using this framework

Course Title	Course Setting	FL Cycle Design	SRL Cycle Design	FC Orientation Design
Applied Web-based Client–Server Computing	Class meets two days per week with 60–90 students in one section	27 FL cycles were set up based on class days. Each day involved (a) online conceptual learning of 2–3 interactive mini lessons with self-check exercises, (b) in-class coding demo and guided coding activities, (c) after-class individual project tasks, and (d) after-class team project tasks	3 SRL cycles were set up based on the major course stages (Stages 1&2, Stage 3, and Stage 4). Students planned for and reflected on the SRL elements at the beginning and end of each cycle using Moodle quizzes. Students monitored activity completion using a Moodle course roadmap (See Appendix B)	The FL cycle steps and tasks were presented. Strategies for learning, project management, and help-seeking were introduced. Students reflected on their long-term goals in relation to this course and identified the learning strategies that they intended to use through a Moodle quiz

Course Title	Course Setting	FL Cycle Design	SRL Cycle Design	FC Orientation Design
College Physics I	Class meets 2–3 days per week with 100 + students per section, 3–4 sections per semester	24–37 FL cycles were set up based on class days. Each day covered 1–3 modules that each involved (a) online conceptual learning using videos and basic exercises, (b) in-class guided problem solving using active learning journals (Google Docs), and (c) after-class independent problem solving and sharing as homework	3 SRL cycles were set up based on 3 midterm exams. Students planned for and reflected on the SRL elements at the beginning and end of each cycle using Moodle quizzes. They monitored activity completion using a Moodle course roadmap	The FL cycle steps and tasks were presented. Learning strategies were introduced for each step. Students reflected on their long-term goals and related back to the course learning objectives through a Moodle quiz
Computer Methods in Biological Engineering	Class meets one day per week with 40–50 students in one section, plus a weekly lab with about 25 students per section	15 FL cycles were set up based on week-long modules. Each module involved (a) online learning of Excel or R skills, online problem-solving demo and practices, (b) in-class problem solving using planning templates (Google Docs), along with instructor guidance and peer interactions, (c) lab problem solving using a simplified planning template, and (d) individual homework	2 SRL cycles were set up based on the Excel and R topics taught in class. Students planned for and reflected on the SRL elements at the beginning and end of each cycle using Moodle quizzes. Every week, they reported the learning strategies that worked well for them and their confidence levels in the learning objectives using the Moodle choice tool. They monitored activity completion using a Moodle course roadmap	The FL cycle steps and tasks were presented. Learning strategies were introduced. Students reflected on their long-term goals in relation to this course and identified the learning strategies that they don't naturally use but would be beneficial through a Moodle quiz

Course Title	Course Setting	FL Cycle Design	SRL Cycle Design	FC Orientation Design
Foundations of Interactive Game Design	Class meets two days per week with 100 + students in one section	14 FL cycles were set up by weeks. Each week involved (a) online theoretical learning using interactive videos and readings, (b) experiential learning through playing games online and sharing thoughts in class, with journal reflections after class, (c) game design project activities using a guided template, with group collaboration inside and outside of class, and (d) standalone online learning of game engine tutorials	2 SRL cycles were set up by grouping the milestones of the semester-long game design project (plan & design vs. implement & test). Students planned for and reflected on the SRL elements at the beginning and end of each cycle using Moodle quizzes. Learning strategy callouts were integrated with relevant activities. Students monitored activity completion using a Moodle course roadmap	Weekly FL cycle steps and tasks were presented. Learning strategies were introduced. Students reflected on their long-term goals in relation to this course and identified the learning strategies that they don't naturally use but would be beneficial through a Moodle quiz

Course Title	Course Setting	FL Cycle Design	SRL Cycle Design	FC Orientation Design
General Biochemistry	Class meets two days per week with 100 + students in one section	14 FL cycles were set up by weeks. Each week covered 1–2 modules organized as (a) online learning using videos and quizzes, (b) in-class active learning using activity worksheets, with group collaboration and instructor walkthrough, and (c) after-class textbook learning using readings, review questions, and challenge problems	3 SRL cycles were set up based on the 3 midterm exams. Students planned for and reflected on the SRL elements at the beginning and end of each cycle using Moodle quizzes. Students monitored activity completion using a Moodle course roadmap	Weekly FL cycle steps and tasks were presented. Learning strategies were introduced for each step. Students reflected on their long-term goals in relation to this course through a Moodle quiz
Information System Management	Class meets one day per week (reduced from two days per week) with 70–80 students per section, 8–10 sections per semester	10 FL cycles were set up by weeks. Each week involved (a) online learning using videos, readings, demos, and practices, (b) in-class problem solving with peer interactions and instructor guidance, and (c) after-class review and homework problem solving	N/A	Weekly FL cycle steps and tasks were presented

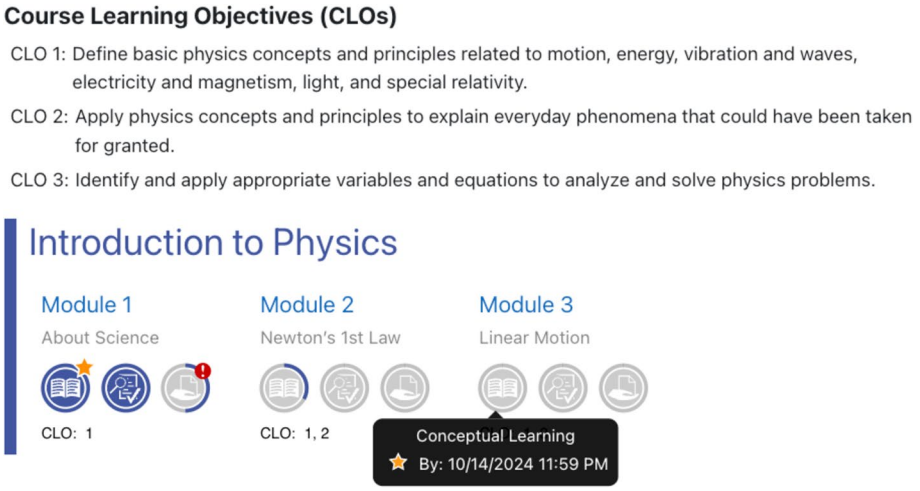
Course Title	Course Setting	FL Cycle Design	SRL Cycle Design	FC Orientation Design
Introductory Biology	Class meets two days per week with 100 + students per section, 1–2 sections per semester	14 FL cycles were set up by weeks. Each week covered 1–3 modules that each involved (a) conceptual learning using interactive videos and self-check quizzes, (b) in-class guided application using active learning logs (Google Docs), with peer interactions and instructor walkthrough, and (c) after-class independent applications as homework	2 SRL cycles were set up based on course topics (Units 1&2 vs. Units 3&4). Students planned for and reflected on the SRL elements at the beginning and end of each cycle using Moodle quizzes. Every week, they reported the learning strategies that worked well for them and their confidence levels in the learning objectives using Moodle choice tool. They monitored activity completion using a Moodle course roadmap	The FL cycle steps and tasks were presented. Learning strategies were introduced. Students reflected on their long-term goals in relation to this course and identified the learning strategies that they don't naturally use but would be beneficial through a Moodle quiz

Course Title	Course Setting	FL Cycle Design	SRL Cycle Design	FC Orientation Design
MATLAB Programming	Class meets one day per week with 250 + students in one section, plus a weekly lab with about 40 students per section	10 FL cycles were set up by weeks. Each week covered 1–2 modules organized as (a) online learning using videos and basic applications, (b) in-class exercises with peer interactions and instructor walkthrough, and (c) after-class and lab learning through individual coding exercises, problems, and projects	3 SRL cycles were set up based on the high-level course topics and tests. Students planned for and reflected on the SRL elements at the beginning and end of each cycle using Moodle quizzes. Students monitored activity completion using a Moodle course roadmap	Weekly FL cycle steps and tasks were presented. Learning strategies were introduced for each step. Students reflected on their long-term goals in relation to this course through a Moodle quiz

Course Title	Course Setting	FL Cycle Design	SRL Cycle Design	FC Orientation Design
Precalculus	Class meets two days per week (reduced from three days per week) with 60 students per section, 2–3 sections per semester	13 FL cycles were set up by weeks. Each week covered 2 modules organized as (a) online learning using videos and self-check exercises, (b) in-class Q&A on lecture topics, (c) in-class problem solving with peer interactions and instructor walk-through, and (d) after-class review and homework problems	3 SRL cycles were set up based on the 3 midterm tests. Students planned for and reflected on the SRL elements at the beginning and end of each cycle using Moodle quizzes. Students monitored activity completion using a Moodle course roadmap	Weekly FL cycle steps and tasks were presented. Learning strategies were introduced for each step. Students reflected on their long-term goals in relation to this course through a Moodle quiz
Python Programming	Class meets one day per week (first 30 min being optional Q&A) with 100 + students in one section, plus a weekly lab with about 30 students	14 FL cycles were set up by weeks. Each week covered 1–2 modules organized as (a) online conceptual learning using videos and basic application exercises, (b) in-class exercises and coding problems with peer interactions and instructor guidance, (c) lab coding problems with peer interactions and TA guidance, and d) after-class coding problems and projects completed individually	4 SRL cycles were set up based on the course topics. Students planned for and reflected on the SRL elements at the beginning and end of each cycle using Moodle quizzes. Every week, they reported their usage and effectiveness of the learning strategies and their confidence levels in the learning objectives using Google Sheets. They monitored activity completion using a Moodle course roadmap	Weekly FL cycle steps and tasks were presented. Strategies for learning tasks, learning management, help-seeking were introduced by specifying why, how, and when to use each strategy

Course Title	Course Setting	FL Cycle Design	SRL Cycle Design	FC Orientation Design
Sports Management	Class meets two days per week with 60–80 students per section, 2 sections per semester	14 FL cycles were set up by weeks. Each week covered 1–2 modules organized as a) conceptual learning using videos, readings, and quizzes, (b) in-class active learning through discussions and case studies with instructor guidance, and (c) tasks from a semester-long career exploration game for in-class discussions and after-class homework	N/A	Weekly FL cycle steps and tasks were presented
Technology in Society and Culture	Class meets two days per week with 60–70 students in one section	15 FL cycles were set up based on weeks. Each week involved (a) online mini-lectures, readings, and sharing initial thoughts, (b) in-class discussion of theoretical concepts and examples, (c) watching film as a class and discussing relevant concepts, with after-class reflections, and (d) in-class essay planning and workshopping, with data collection, data analysis, and essay writing tasks after class	2 SRL cycles were set up based on the major course units (Units 1&2 vs. Units 3&4). Students planned for and reflected on the SRL elements at the beginning and end of each cycle using Moodle quizzes. Students monitored activity completion using a Moodle course roadmap and discussed their strategy use with peers in selected class sessions	The FL cycle steps and tasks were presented. Learning strategies were introduced for each step. Students reflected on their long-term goals in relation to this course and identified the learning strategies that they intended to use through a Moodle quiz

Appendix B Moodle course roadmap tool for visualizing student progress



The Moodle course roadmap visually organizes the major phases (e.g., Introduction to Physics) and the flipped learning cycles (e.g., Module 1, Module 2, Module 3) of a course. Each roadmap icon represents a step in the flipped learning cycle (e.g., Conceptual Learning) and is connected to the activities associated with that step. Students can see their progress of the step (filling in the outside ring), whether they completed on time (with a star icon), and if the expected completion date and time is approaching (with an exclamation mark). This tool is designed based on the proposed framework and will be released in the Moodle Plugins directory.

Appendix C Strategy tracking tool for task completion, time management, and environmental structuring

Categories	Learning Strategies (see details)	Tracking	If not tracking, why?	Weeks 2-3 Usage	Weeks 2-3 Effectiveness
Study Strategies (SS)	SS1 - Pause and/or rewind the lecture videos to self-pace your learning.	☑		Fully used	Highly effective
	SS2 - Review the Conceptual Learning materials within 24 hours after initial learning.	☑		Slightly used	Somewhat effective
	SS3 - Take notes while working on the class or lab exercises.	☑		Partially used	Slightly effective
	SS4 - Revisit or redo the class/lab exercises that you made mistakes in or struggled with.	☑		Not used	N/A
	SS5 - Self-assess your knowledge/skill levels using the LOs and associated exercises.	☑		Fully used	Highly effective
Learning Management (LM)	LM1 - Set aside sufficient study time before and after class to work on assigned activities.	☑			
	LM2 - Use a productive space to study for this course.	☐	I already use it spontaneously.	Fully used	
	LM3 - Start early to work on the Conceptual Learning tasks before class.	☑		Partially used	
	LM4 - Start early to work on the homework and project tasks.	☑		Slightly used	
				Not used	

Strategies for task completion, time management, and environment structuring, as recommended by the instructor and former students, are listed in the Google Sheet for current students to selectively track based on their self-regulated learning skills. On a weekly or bi-weekly basis, students rate their usage frequency and effectiveness levels of the strategies they track to self-monitor their learning and develop autonomy over time.

Appendix D Strategy tracking tool for help-seeking

Weeks	Modules	LO #	Learning Objectives (LO)	Confidence Level	Need Support?	Next Step (Optional if you feel confident)
Week 3	Module 4	LO 4.1	Describe what functions are, and why we need functions.	Extremely confident		
		LO 4.2	Use function terminologies to describe how to define and execute functions.	Extremely confident		
		LO 4.3	Use appropriate built-in and imported functions to solve given problems, and use the Python online documentation to look up the syntax of the functions.	Somewhat confident		
		LO 4.4	Create and use user-defined functions.	Unconfident	Yes	Go to office hours
		LO 4.5	Identify the scope of a variable.	Extremely confident		
		LO 4.6	Determine the value of global variables and local variables from given code.	Somewhat confident		
		LO 4.7	Trace and write code that uses nested function calls.	Slightly confident	Maybe	Ask questions on Piazza
		LO 4.8	Document the purpose of user-defined functions.	Extremely confident		
		LO 4.9	Test the correctness of user-defined functions.	Unconfident	Yes	Do more review and practice

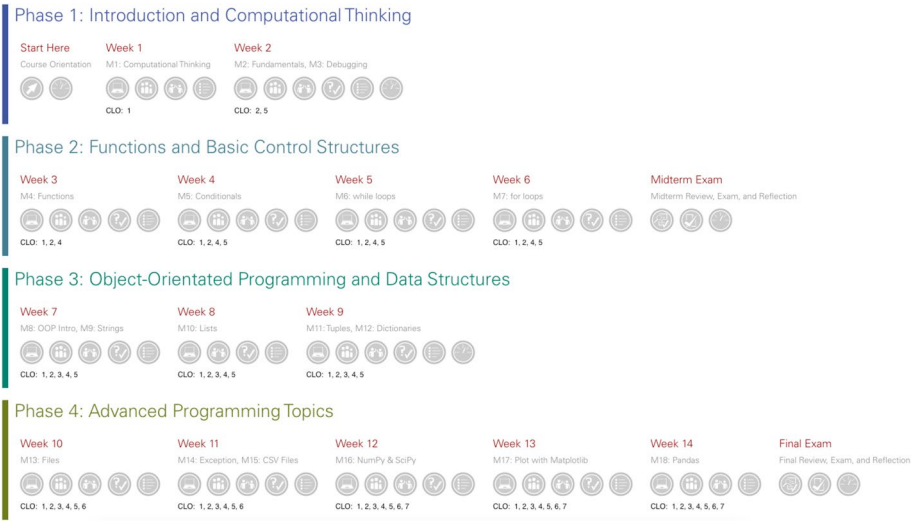
Module learning objectives are listed in the Google Sheet for students to self-assess their confidence levels at the end of that module in order to determine whether they need additional support and what help-seeking actions they would take.

Appendix E Sample micro-diagram of a generic FL cycle



In this example, the week-long generic FL cycle starts on Sundays and ends on Saturdays. Students complete online learning during the first four days of the week, with the option to attend the in-person Q&A session on Tuesdays. Students attend in-person class on Thursdays to participate in guided problem-solving activities, and then complete homework activities after class on Fridays and Saturdays. They are encouraged to get help throughout the FL cycle.

Appendix F Sample macro-diagram of all FL and SRL cycles



This diagram is generated using the Moodle course roadmap tool to visualize the organization of FL cycles (by weeks) and SRL cycles (by phases) in a course. In this example, under the *Start Here* section, the arrow icon represents the FC orientation, whereas the scale icon represents initial SRL planning activities for Phase 1. The scale icons at the end of each phase represent activities of reflecting on the previous phase and planning for the next phase. The first four icons of each week represent the four FL cycle steps: online conceptual learning (computer icon), in-class problem solving (three figures icon), lab problem solving (two figures icon), and homework projects (question mark and check mark icon). The bulleted list icons at the end of each week represent SRL monitoring activities within the FL cycles.

Acknowledgements We are grateful to all NC State instructors who collaborated with us to explore, apply, and assess this framework in their subject areas through NC State DELTA Grant projects from 2017 to 2024. We thank our DELTA colleagues Stephen Bader, David Tredwell, Ben Huckaby, and Jeff Williford for their contributions in developing the tools and graphics we shared as examples in the appendices.

Data availability Not applicable.

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References

Al-Samarraie, H., Shamsuddin, A., & Alzahrani, A. I. (2020). A flipped classroom model in higher education: A review of the evidence across disciplines. *Educational Technology Research and Development, 68*, 1017–1051.

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Longman.

Awidi, I. T., & Paynter, M. (2019). The impact of a flipped classroom approach on student learning experience. *Computers & Education, 128*, 269–283.

Bergmann, J., & Sams, A. (2012). *Flip your classroom: Reach every student in every class every day*. International Society for Technology in Education.

Bishop, J., & Verleger, M. A. (2013, June). The flipped classroom: A survey of the research. In *2013 ASEE Annual Conference & Exposition* (pp. 23–1200).

Blau, I., & Shamir-Inbal, T. (2017). Re-designed flipped learning model in an academic course: The role of co-creation and co-regulation. *Computers & Education, 115*, 69–81.

Blended Learning Toolkit (2011). *What is Blended Learning?* University of Central Florida, Center for Distributed Learning (CDL). https://blended.online.ucf.edu/2011/06/07/what-is-blended-learning/

Bond, M. (2020). Facilitating student engagement through the flipped learning approach in K-12: A systematic review. *Computers & Education, 151*, 103819.

Butler, D. L., & Winne, P. H. (1995). Feedback and self-regulated learning: A theoretical synthesis. *Review of Educational Research, 65*(3), 245–281.

Caulfield, J. (2011). *How to design and teach a hybrid course: Achieving student-centered learning through blended classroom, online and experiential activities*. Stylus Publishing.

Chen, Y., Wang, Y., & Chen, N. S. (2014). Is FLIP enough? Or should we use the FLIPPED model instead? *Computers & Education, 79*, 16–27.

Cheng, L., Ritzhaupt, A. D., & Antonenko, P. (2019). Effects of the flipped classroom instructional strategy on students' learning outcomes: A meta-analysis. *Educational Technology Research and Development, 67*, 793–824.

Clark, R. M., Kaw, A. K., Lou, Y., & Scott, A. R. (2022). The flipped classroom during the remote period of COVID: student perceptions compared to pre-COVID times. *International Journal of Mathematical Education in Science and Technology, 55*(5), 1204–1225. https://doi.org/10.1080/0020739X.2022.2052198

Csikszentmihalyi, M. (1990). *Flow. The Psychology of Optimal Experience*. HarperPerennial.

DeLozier, S. J., & Rhodes, M. G. (2017). Flipped classrooms: A review of key ideas and recommendations for practice. *Educational Psychology Review, 29*, 141–151.

Divjak, B., Rienties, B., Iniesto, F., Vondra, P., & Žižak, M. (2022). Flipped classrooms in higher education during the COVID-19 pandemic: Findings and future research recommendations. *International Journal of Educational Technology in Higher Education, 19*, 9.

Dweck, C. S., & Leggett, E. L. (1988). A social-cognitive approach to motivation and personality. *Psychological Review, 95*(2), 256.

Elliott, E. S., & Dweck, C. S. (1988). Goals: An approach to motivation and achievement. *Journal of Personality and Social Psychology, 54*(1), 5.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist, 34*(10), 906.

Flipped Learning Network. (2014). *What Is Flipped Learning?* https://flippedlearning.org/wp-content/uploads/2016/07/FLIP_handout_FNL_Web.pdf

Goos, M., Galbraith, P., & Renshaw, P. (2002). Socially mediated metacognition: Creating collaborative zones of proximal development in small group problem solving. *Educational Studies in Mathematics, 49*, 193–223.

Hadwin, A., Järvelä, S., & Miller, M. (2017). Self-regulation, co-regulation, and shared regulation in collaborative learning environments. In B. Zimmerman & D. Schunk (Eds.), *Handbook of self-regulation of learning and performance* (pp. 83–106). Routledge.

Hall, J. A., Lei, J., & Wang, Q. (2020). The first principles of instruction: An examination of their impact on preservice teachers' TPACK. *Educational Technology Research and Development, 68*, 3115–3142.

Hannafin, M., Land, S., & Oliver, K. (1999). Open learning environments: Foundation, methods, and models. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: A new paradigm of instructional theory* (Vol. II, pp. 115–140). Lawrence Erlbaum.

Huang, B., & Hew, K. F. (2018). Implementing a theory-driven gamification model in higher education flipped courses: Effects on out-of-class activity completion and quality of artifacts. *Computers & Education, 125*, 254–272.

Hwang, G. J., Lai, C. L., & Wang, S. Y. (2015). Seamless flipped learning: A mobile technology-enhanced flipped classroom with effective learning strategies. *Journal of Computers in Education, 2*, 449–473.
Johnson, N., Seaman, F., & Poulin, R. (2022). Defining different modes of learning: Resolving confusion and contention through consensus. *Online Learning, 26*(3), 91–110.
Jones, B. D. (2009). Motivating students to engage in learning: The MUSIC model of academic motivation. *International Journal of Teaching and Learning in Higher Education, 21*(2), 272–285.
Jones, B. D. (2018). *Motivating students by design: Practical strategies for professors* (2nd ed.). CreateSpace.
Joosten, T., Weber, N., Baker, M., Schletzbaum, A., & McGuire, A. (2021). *Planning for a Blended Future: A Research-Driven Guide for Educators.* [Report] Every Learner Everywhere Network. Retrieved June 13, 2023 from https://www.everylearnereverywhere.org/resources/planning-for-a-blended-future/
Jovanovic, J., Mirriahi, N., Gašević, D., Dawson, S., & Pardo, A. (2019). Predictive power of regularity of pre-class activities in a flipped classroom. *Computers & Education, 134*, 156–168.
Kapur, M. (2008). Productive failure. *Cognition and Instruction, 26*(3), 379–424.
Karabenick, S. A., & Berger, J.-L. (2013). Help seeking as a self-regulated learning strategy. In H. Bembenutty, T. J. Cleary, & A. Kitsantas (Eds.), *Applications of self-regulated learning across diverse disciplines: A tribute to Barry J. Zimmerman* (pp. 237–261). IAP Information Age Publishing.
Kim, M. K., Kim, S. M., Khera, O., & Getman, J. (2014). The experience of three flipped classrooms in an urban university: An exploration of design principles. *The Internet and Higher Education, 22*, 37–50.
Låg, T., & Sæle, R. G. (2019). Does the flipped classroom improve student learning and satisfaction? A systematic review and meta-analysis. *AERA Open, 5*(3), 2332858419870489.
Lai, C. L., & Hwang, G. J. (2016). A self-regulated flipped classroom approach to improving students' learning performance in a mathematics course. *Computers & Education, 100*, 126–140.
Lee, J., Lim, C., & Kim, H. (2017). Development of an instructional design model for flipped learning in higher education. *Educational Technology Research and Development, 65*, 427–453.
Lin, Y. N., Hsia, L. H., & Hwang, G. J. (2021). Promoting pre-class guidance and in-class reflection: A SQIRC-based mobile flipped learning approach to promoting students' billiards skills, strategies, motivation and self-efficacy. *Computers & Education, 160*, 104035.
Liu, L., Hew, K. F., & Du, J. (2024). Design principles for supporting self-regulated learning in flipped classrooms: A systematic review. *International Journal of Educational Research, 124*, 102319.
Lo, C. K. (2018). Grounding the flipped classroom approach in the foundations of educational technology. *Educational Technology Research and Development, 66*, 793–811.
Lo, C. K., Lie, C. W., & Hew, K. F. (2018). Applying "First Principles of Instruction" as a design theory of the flipped classroom: Findings from a collective study of four secondary school subjects. *Computers & Education, 118*, 150–165.
Mayer, R. E. (1998). Cognitive, metacognitive, and motivational aspects of problem solving. *Instructional Science, 26*, 49–63.
Mayer, R. E. (2001). *Multimedia learning*. Cambridge University Press.
McKenney, S., & Reeves, T. C. (2019). *Conducting educational design research*. Routledge.
Merrill, M. D. (2002). First principles of instruction. *Educational Technology Research and Development, 50*, 43–59.
Merrill, M. D. (2013). *First principles of instruction: Identifying and designing effective, efficient and engaging instruction*. Pfeiffer.
Moore, M. G. (1993). Theory of transactional distance. In D. Keegan (Ed.), *Theoretical principles of distance education* (pp. 22–38). Routledge.
Moore, M. G., & Kearsley, G. (1996). *Research on effectiveness, distance education: A systems review*. Wadsworth.
Ng, E. M. (2018). Integrating self-regulation principles with flipped classroom pedagogy for first year university students. *Computers & Education, 126*, 65–74.
O'Flaherty, J., & Phillips, C. (2015). The use of flipped classrooms in higher education: A scoping review. *The Internet and Higher Education, 25*, 85–95.
Onodipe, G., Keengwe, J., & Cottrell-Yongye, A. (2020). Using a learning management system to promote self-regulated learning in a flipped classroom. *Journal of Teaching and Learning with Technology, 9*, 3–18.
Pelletier, K., Brown, M., Brooks, D.C., McCormack, M., Reeves, J., Arbino, N., Bozkurt, A., Crawford, S., Czerniewicz, L., Gibson, R., Linder, K., Mason, J. & Mondelli, V. (2021). *2021 EDUCAUSE Horizon Report Teaching and Learning Edition*. Boulder, CO: EDU. Retrieved June 13, 2023 from https://www.learntechlib.org/p/219489/.

Pelletier, K., McCormack, M., Reeves, J., Robert, J., Arbino, N., Al-Freih, w.M., Dickson-Deane, C., Guevara, C., Koster, L., Sanchez-Mendiola, M., Skallerup Bessette, L. & Stine, J. (2022). *2022 EDUCAUSE Horizon Report Teaching and Learning Edition*. Boulder, CO: EDU. Retrieved May 16, 2023 from https://www.learntechlib.org/p/221033/.

Pérez-Sanagustín, M., Sapunar-Opazo, D., Pérez-Álvarez, R., Hilliger, I., Bey, A., Maldonado-Mahauad, J., & Baier, J. (2021). A MOOC-based flipped experience: Scaffolding SRL strategies improves learners' time management and engagement. *Computer Applications in Engineering Education, 29*(4), 750–768.

Robbins, M. M., Onodipe, G. O., & Marks, A. (2020). Reflective writing and self-regulated learning in multidisciplinary flipped classrooms. *Journal of the Scholarship of Teaching and Learning, 20*(3), 20–32.

Romanow, D., Cline, M. K., & Napier, N. P. (2024). A response to COVID: From traditional to remote learning using a flipped classroom pedagogy and its impact on BI skills attainment. *Journal of Information Systems Education, 35*(1), 99–111.

Schraw, G. (1998). Promoting general metacognitive awareness. *Instructional Science, 26*, 113–125.

Sharma, P., & Hannafin, M. J. (2007). Scaffolding in technology-enhanced learning environments. *Interactive Learning Environments, 15*(1), 27–46.

Silva, J. C. S., Zambom, E., Rodrigues, R. L., Ramos, J. L. C., & de Souza, F. D. F. (2018). Effects of learning analytics on students' self-regulated learning in flipped classroom. *International Journal of Information and Communication Technology Education, 14*(3), 91–107.

Singh, J., Steele, K., & Singh, L. (2021). Combining the best of online and face-to-face learning: Hybrid and blended learning approach for COVID-19, post vaccine, & post-pandemic world. *Journal of Educational Technology Systems, 50*(2), 140–171.

Spencer, D., Willis, C., Shen, Y., Fenn, M., & Viel, S. (2022). Utilizing a blended + flipped learning approach in a calculus for life and management sciences classroom. *Primus, 33*(6), 670–690.

Sun, Z., Xie, K., & Anderman, L. H. (2018). The role of self-regulated learning in students' success in flipped undergraduate math courses. *The Internet and Higher Education, 36*, 41–53.

United Nations. (2020, August). *Policy brief: Education during COVID-19 and beyond.* https://www.un.org/development/desa/dspd/wp-content/uploads/sites/22/2020/08/sg_policy_brief_covid-19_and_education_august_2020.pdf

van Alten, D. C., Phielix, C., Janssen, J., & Kester, L. (2019). Effects of flipping the classroom on learning outcomes and satisfaction: A meta-analysis. *Educational Research Review, 28*, 100281.

van Alten, D. C., Phielix, C., Janssen, J., & Kester, L. (2020). Self-regulated learning support in flipped learning videos enhances learning outcomes. *Computers & Education, 158*, 104000.

Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Harvard University Press.

Wang, F. H. (2019). On the relationships between behaviors and achievement in technology-mediated flipped classrooms: A two-phase online behavioral PLS-SEM model. *Computers & Education, 142*, 103653.

Yoon, M., Hill, J., & Kim, D. (2021). Designing supports for promoting self-regulated learning in the flipped classroom. *Journal of Computing in Higher Education, 33*(2), 398–418.

Yorganci, S. (2020). Implementing flipped learning approach based on 'first principles of instruction' in mathematics courses. *Journal of Computer Assisted Learning, 36*(5), 763–779.

Zainuddin, Z. (2018). Students' learning performance and perceived motivation in gamified flipped-class instruction. *Computers & Education, 126*, 75–88.

Zhao, Y. (2020). COVID-19 as a catalyst for educational change. *Prospects, 49*, 29–33.

Zhao, Y., & Watterston, J. (2021). The changes we need: Education post COVID-19. *Journal of Educational Change, 22*, 3–12.

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory into Practice, 41*(2), 64–70.

Zimmerman, B. J., & Schunk, D. H. (2011). Motivational sources and outcomes of self-regulated learning and performance. In B. Zimmerman & D. Schunk (Eds.), *Handbook of self-regulation of learning and performance* (pp. 49–64). Routledge.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

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