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ADVANCES IN PHYSIOLOGY EDUCATION

A PERSONAL VIEW

Developing a holistic approach to teaching biosciences using self-regulated learning theory

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NEW & NOTEWORTHY The proposed metacurriculum tackles the persistent "bioscience problem" by teaching students how to learn. It embeds self-regulated learning (SRL) strategies across all phases of the physiology learning cycle and uses low-stakes assessment and retrieval practice to reinforce learning. This approach is designed to improve self-efficacy, engagement, and achievement in bioscience.

INTRODUCTION

Despite being foundational to clinical reasoning and patient care, bioscience and physiology subjects are consistently reported as areas of difficulty for students across a range of health disciplines. Learners frequently describe these subjects as content heavy, conceptually dense, and anxiety provoking, which can reduce engagement and self-efficacy (1, 2). For educators, this persistent challenge, often referred to in nursing education as the "bioscience problem" (3, 4), raises important questions about how best to support student learning.

Although a variety of strategies have been explored to improve student outcomes, including flipped classrooms and active learning, a key factor often overlooked is how students learn to learn in these domains. Many health science students enter higher education with limited exposure to disciplinary science and few effective study strategies (5). Without explicit guidance, they may default to surface learning or inefficient techniques.

This article presents a discussion of the literature and proposes a metacurriculum approach that integrates instruction in self-regulated learning (SRL) strategies within the bioscience and physiology curriculum. Originally described by Weinstein (6), the metacurriculum involves embedding instruction in learning strategies alongside course content, with the goal of helping students develop both academic skills and content knowledge simultaneously. The SRL framework (7–9), grounded in social cognitive theory, provides an ideal structure for this integration.

By aligning bioscience instruction with the SRL cycle of forethought, performance, and self-reflection (8), educators can support learners in developing effective learning strategies, metacognitive awareness, and greater self-efficacy. Although the examples in this article are drawn primarily from nursing education, the principles and methods are broadly applicable to the teaching of physiology and bioscience in other health science programs.

BACKGROUND

The Bioscience Problem

Bioscience is widely recognized to be an important component of the nursing curriculum because of its foundational role in informing clinical practice (10–12). A strong understanding of bioscience is essential for nurses to apply physiological and pathophysiological knowledge effectively in patient care. However, despite its importance, bioscience has been persistently reported as an area of difficulty for students (4, 13–15).

Most research to address the bioscience problem has focused on four areas: *1*) factors that may be predictive of success, such as grade point averages and prerequisites (see Ref. 4 for review); *2*) teaching strategies, such as active learning and flipped classrooms; *3*) student characteristics; and *4*) student satisfaction. However, Jensen et al. (3) noted that there has been no clear explanation of why students find it difficult. Some researchers have suggested that these difficulties may be linked to students' perceptions of the relevance of bioscience to their future clinical practice. However, studies show that both nursing students and registered nurses report high relevance of bioscience content to their clinical practice (16).

In a review of first-year bioscience interventions, McVicar et al. (4) found that factors such as science prerequisites and specific teaching methods were inconsistently associated with student success. However, one area that consistently emerged as critical was the need to improve students' study skills (14, 17–22). McVicar et al. (4) concluded that although introducing science prerequisites for entry into nursing programs might be beneficial, student success will still "likely

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be contingent on innovative support early in Year 1 for study skills and the fundamentals of human bioscience." Similarly, Ralph et al. (23) note that "a persistent lack of strategies for learning and teaching this content in nursing hinders educational development in this important area."

Characteristics of Beginning Nursing Students Studying Bioscience

When designing any curriculum, it is important to understand the characteristics of the students who will be undertaking the learning. The characteristics of nursing students as learners have been studied both within nursing programs generally and specifically within biosciences. Generally, research indicates that nursing students may not be fully prepared for self-directed learning methods such as problem-based learning and flipped classrooms (17, 24, 25). In fact, compared to students in fields like teaching or social science, nursing students show lower readiness for self-directed learning and a higher preference for authoritative direction (26, 27).

In the context of bioscience, nursing students often find studying for biosciences time-consuming and anxiety inducing (1, 28, 29). Although they are generally open to a range of teaching modalities, their preference leans toward direct instruction, particularly through didactic methods rather than through flipped learning (30, 31). This preference may stem from a lack of confidence in their knowledge and understanding, exacerbated by the content-heavy and conceptually challenging nature of biosciences (29, 32). Indeed, nursing students' perceived self-efficacy for learning biosciences has been reported as being generally low (13, 33).

Additionally, nursing students often rely on surface learning strategies, primarily aiming to reproduce information for examinations (34, 35). This reliance on authority figures for the "right answers" aligns with the dualism phase of intellectual development, as described by Perry (in Ref. 36). In this phase, students believe that knowledge consists of correct answers and that these come from authorities, a view that is common among beginning tertiary students. This perception may be reinforced by secondary science education, where science is frequently presented as a fixed "body of knowledge" (37–39). It may also be further reinforced in foundation-level tertiary subjects in bioscience, which also appear to value low-level factual recall (40).

Despite finding biosciences difficult, nursing students appreciate the importance of the biosciences to their future clinical practice (41, 42) and regularly report that they would like more instructional time spent on biosciences (43, 44). This suggests that difficulties with biosciences are not due to a lack of interest but rather stem from other factors.

SELF-REGULATED LEARNING FRAMEWORK

The early research on self-regulated learning (SRL) aimed to identify and understand the skills, processes, and attitudes that distinguish high-achieving students from their lower-achieving peers (45). Zimmerman and Martinez-Pons (46) were pivotal in this area, identifying 14 strategies used by high-achieving students (see Table 1 for list of strategies) to achieve their learning goals. The authors combined these strategies into a self-regulation "factor," which they report accounted for 80% of the variance in achievement (46). Self-regulated learning researchers contend that there are self-regulated learning strategies and skills that can be taught to students, and that doing so can lead to improvement in academic achievement (48, 49).

Although several models of self-regulated learning exist (50), this article describes a methodology for designing a bioscience SRL metacurriculum based primarily on Zimmerman's three-phase cyclical model of self-regulation (7, 8, 51) augmented with elements from Pintrich's conceptual framework (9, 52). Both models are grounded in social cognitive theory (50, 53) and share significant overlap, with Pintrich's framework consolidating key aspects of the major SRL models of the time (52).

A metacurriculum can therefore be structured around Zimmerman's three phases, forethought, performance, and self-reflection (8), and should include explicit instruction of cognitive, metacognitive, and resource management strategies as outlined in Pintrich's (52) framework. Research shows that bioscience students who effectively utilize strategies from all three phases tend to achieve higher academic

Table 1. *The 14 learning strategies used by high-achieving students classified into phase of the learning cycle and strategy type*

Zimmerman's Strategies[1]	Phase of Zimmerman's Cycle[2]	Strategy Type[3]
Goal setting and planning	Forethought	Metacognitive—self-regulation
Environmental structuring (principally avoiding distractions)	Forethought/performance	Metacognitive—self-regulation
Rehearsing and memorizing	Performance	Cognitive—rehearsal—superficial/passive
Review (notes, tests, textbook)[4]	Performance	Cognitive—rehearsal—superficial/active
Organizing and transforming	Performance	Cognitive—organization
Seeking information	Performance	Metacognitive—comprehension
Seeking help (peers, teacher, adults)[5]	Performance	Metacognitive—comprehension Resource management
Keeping records and monitoring	Performance	Metacognitive—comprehension
Reviewing tests	Self-reflection	Metacognitive—comprehension
Self-evaluation	Self-reflection	Metacognitive—comprehension
Self-consequences	Self-reflection	Metacognitive—self-regulation

[1]Zimmerman and Martinez-Pons (46); [2]Zimmerman (7); [3]Weinstein et al. (47); [4]grouping of strategies 12–14 as per Zimmerman and Martinez-Pons (Ref. 46, p. 681); [5]grouping of strategies 9–11 as per Zimmerman and Martinez-Pons (Ref. 46, p. 681).

outcomes than those who do not (54). The instruction must be integrated within the context of the bioscience content and leverage student-centered teaching strategies to maximize the self-motivational beliefs of Pintrich's framework, such as intrinsic and extrinsic motivation, control of learning beliefs, task value, and self-efficacy for learning.

Self-efficacy is a critical component of Bandura's (53, 55, 56) social cognitive theory and, by extension, self-regulated learning theory. It is also an important characteristic of nursing students that needs to be developed in a bioscience context (5, 33). Bandura (53) identifies four primary sources of self-efficacy beliefs: mastery experiences, where the student experiences success; vicarious experiences, observing peers' success; verbal persuasion, which involves credible feedback from instructors; and emotional and physiological states, which can either enhance or undermine performance (for example, anxiety can decrease perceived self-efficacy). Schunk and Ertmer (57) suggest that SRL programs should include components to enhance students' self-efficacy for learning and implementing SRL skills, given the reciprocal effects of these two factors. Additionally, Bandura (58) highlights the importance of social learning through observation and imitation, particularly in the context of modeling.

To effectively implement a bioscience metacurriculum, educational strategies should include instructor modeling and collaborative learning in informal small groups during workshops or laboratory sessions (49, 59). Instructor modeling is important for making expert thinking processes visible to learners, which also aligns with the core concept central to cognitive apprenticeship theory. Cognitive apprenticeship emphasizes the importance of situating learning in authentic contexts where instructors demonstrate not only the skill but also the thought processes and self-regulatory strategies experts use in practice (60).

INTEGRATING SELF-REGULATED LEARNING INTO BIOSCIENCE EDUCATION

Self-regulated learning encompasses the use of cognitive, metacognitive, and resource management strategies across a cyclical process of forethought, performance and monitoring, and self-reflection to reach one's learning goals. Designing a metacurriculum involves two steps (see Fig. 1). First, consider each content module as a separate "learning cycle," consisting of a forethought phase, a performance phase, and a self-reflection phase. Second, within each phase, provide explicit instruction and modeling of cognitive, metacognitive, and resource management strategies directly with the bioscience content being taught. This approach ensures that students learn how to effectively manage the learning process as they learn the content.

Step 1: Aligning Phases of the Self-Regulated Learning Cycle with the Content Modules

Higher education subjects are generally divided into instructional time, which may consist of lectures, tutorials, workshops, and/or laboratory sessions where students have instruction from academic staff, and independent study time.

During the instructional time for each of the content modules, the three phases of Zimmerman's cyclical model should be explicitly modeled by the instructor. At the completion of the self-evaluation phase for each module, students should be instructed to undertake the three phases again during their independent study time (see Fig. 2). It can be useful to provide either a formative or a low-stakes summative assessment task at the conclusion of each module so that students have a measure of success against the learning outcomes. These tasks provide students with feedback to support preparation for higher-stakes assessment and reinforce SRL strategies in a supportive, low-pressure context, reducing any test anxiety associated with high-stakes exams. They also provide opportunities for retrieval practice, which is an empirically supported method for strengthening long-term retention (61). Doing this exposes the students to multiple self-regulatory cycles across the study period, which may raise their perception of the value of these strategies (57).

Forethought (planning).

In the forethought phase of self-regulated learning, students perform a task analysis and set goals (7). This includes

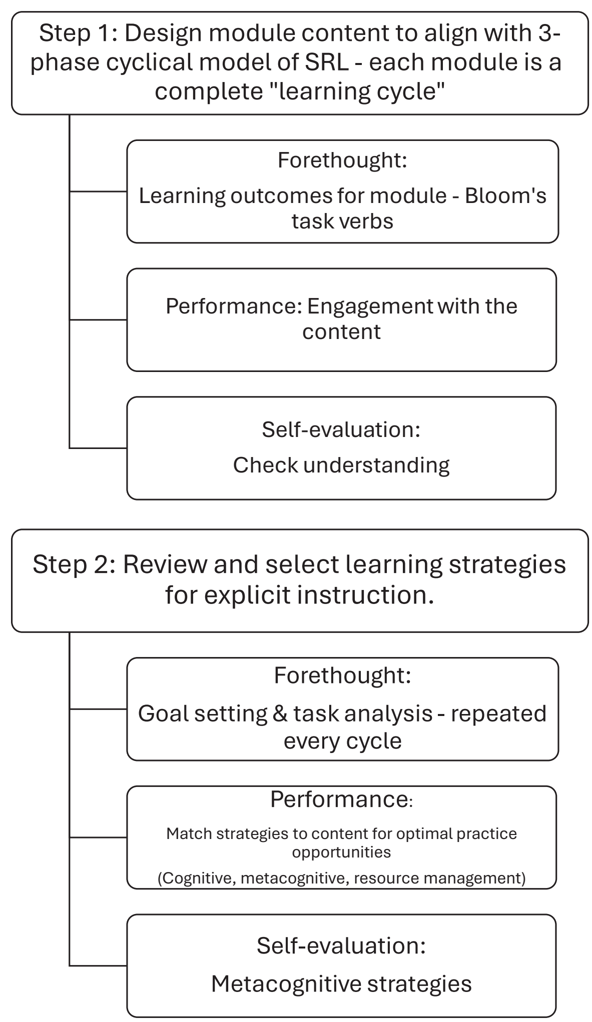

Figure 1. Outline of the process of developing a metacurriculum to embed explicit instruction of self-regulated learning (SRL) strategies and skills within the bioscience content.

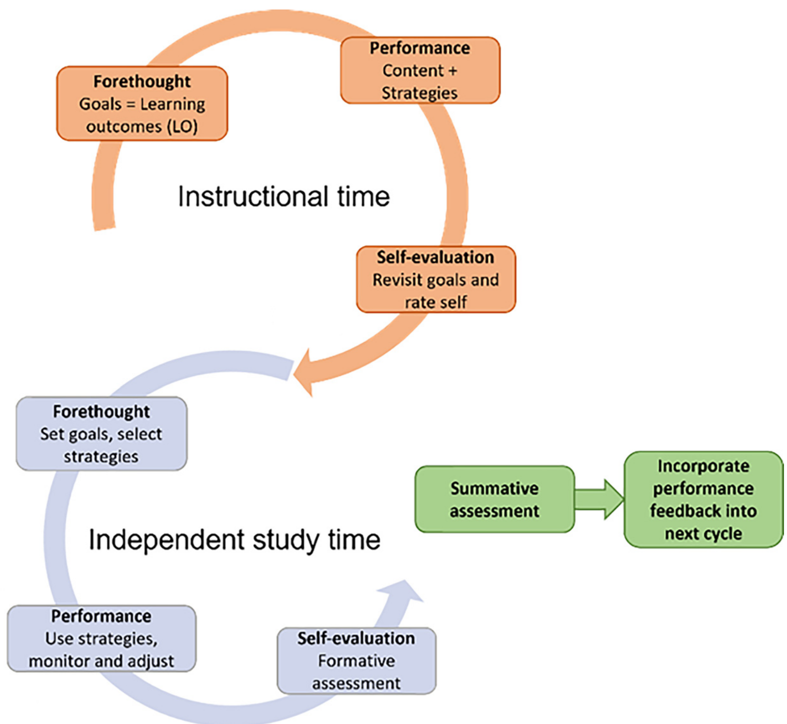

Figure 2. The phases of the cyclical model of self-regulated learning (SRL) during instruction and independent study time.

selecting appropriate cognitive strategies for processing the information, appropriate metacognitive strategies for monitoring and maintaining their progress, and appropriate resource management strategies (for example, allocating the time available). Factors such as self-efficacy for learning the content, task value, and goal orientation can affect students' motivation to get started and to persevere when difficulties arise (53). The goals set in the forethought phase must be revisited again in the self-evaluation phase, so that students can make an assessment on whether the goals were met.

When setting goals, students need to know what the criteria for success are and what level of performance they want to achieve (62) so that they can gauge their progress. If students do not know or do not understand the criteria for success, it can be difficult for them to set realistic goals. In addition, students often default to vague or global goals, such as "passing the subject" rather than setting specific, actionable goals tied to the learning process. A more effective approach is to break the subject down into smaller, short-term goals linked directly to each learning outcome.

Learning goals are the intentions or aims that guide a student's efforts in learning, whereas learning outcomes are educator-defined statements of what students should know or be able to do by the end of a learning cycle. Learning outcomes provide the reference point from which students can derive meaningful goals. However, it should not be assumed that students know how to convert learning outcomes into learning goals. If students are unfamiliar with how to perform a task analysis on a learning outcome to break it into its component knowledge, skills, and actions, they are unlikely to plan effective learning strategies.

Schunk and Ertmer (57) found that college students provided with specific learning goals rather than general performance goals (e.g., "try your best") developed higher self-efficacy and were better at evaluating their learning progress. Helping students link their personal learning goals to specific learning outcomes may therefore improve both motivation and metacognitive regulation.

Clear learning outcomes should be given at the start of each module, presented in terms of the types of understanding or Bloom's level of thinking (as modified by Ref. 63) required for each one (64–67). Ensure that students are given definitions of the common task verbs that will be used throughout the subject and explicitly shown how to undertake a task analysis using the task verbs early in the study period. This can help them transform each learning outcome into concrete, achievable learning goals.

Performance.

During the performance phase of the learning cycle, students implement their plans and monitor their understanding (7). There is an element of monitoring during the performance phase; if students perceive that a learning strategy they have selected is not working, then they should adjust the strategy as they go. As such, the performance phase involves the use of different cognitive and metacognitive strategies to enable the student to interact with the material in a meaningful way for processing information for understanding and committing it to long-term memory and also for checking their comprehension as they progress. The literature on the study techniques of nursing students in bioscience suggests that these students often begin with a limited repertoire of skills on which they can draw for this phase (5, 17, 68). Therefore, when designing a metacurriculum, it is essential to include explicit instruction in a wide range of learning strategies to help students to develop a more comprehensive set of learning strategies that are useful within the bioscience context.

Explicit instruction of the learning strategies must include details on each strategy's declarative (what the strategy is), procedural (how the strategy is implemented), and conditional (when the strategy is likely to work best) use (69). Instruction should involve modeling by the instructor during the lectures and laboratories or workshops, with opportunities for students to practice using the strategy under guidance, with bioscience content (59, 70).

Self-reflection (self-evaluation).
To properly conclude a learning cycle, self-evaluation of performance against success criteria should be undertaken. In Zimmerman's model (8), this involves self-judgment and self-reaction. At this time, students may make causal attributions, for example, "I worked really hard to succeed," "I am too dumb," "the lecturer is too disorganized" (7, 52), and they may also give themselves small rewards or punishments (71, 72).

At the end of each module, revisit the learning outcomes set as goals in the forethought phase and prompt students to make a judgment of learning for each outcome (73, 74). However, caution students against relying solely on "feelings of learning" (75), as these can often be illusions: either a false sense of understanding when information is present in context or an illusion of difficulty based on the effort required of them. Instead, offer ample opportunities for retrieval practice (76, 77) to provide feedback to guide students in planning their independent study. Students should independently engage in the three phases of the learning cycle, planning, performing, and self-evaluation, to develop personal short-term study goals and select learning strategies that they determine will prepare them for a low-stakes summative assessment task to complete each module.

Step 2: Informed Selection of Learning Strategies

There is a common conception in the literature that adult learners "possess a basic repertoire of useful strategies" (69, 78, 79). However, research continually shows that students rely on a limited number of ineffective study strategies such as rereading notes or passively reviewing material (80, 81). In addition, instructors sometimes inadvertently reinforce these unproductive habits by advising students to use strategies that are less effective, such as encouraging rote memorization rather than promoting deeper cognitive engagement (82).

Furthermore, students are very good at judging the difficulty or effort required of a strategy, but not the beneficial effect of the strategy, and often give up on strategies they find difficult (83, 84). To address these issues, it is recommended to include explicit instruction in a variety of cognitive strategies in workshops or tutorials. These sessions should provide opportunities for students to practice the strategies with the bioscience content, ask questions, and receive feedback, helping to increase students' repertoire of effective learning strategies.

The 14 learning strategies identified by Zimmerman and Martinez-Pons (46) can serve as a foundation for selecting cognitive, metacognitive, and resource management skills essential for self-regulated learners. These 14 strategies are identified in Table 1, where they have been categorized into both the phases of learning cycle and the strategy type as described by Weinstein et al. (47). Weinstein's classification system is included because of its broad recognition in the learning strategy literature and its use in Pintrich's conceptual framework.

A review of the literature on "learning-to-learn" interventions was undertaken to identify specific, empirically supported cognitive, metacognitive, and resource management strategies to include in a bioscience metacurriculum. For example, Zimmerman's strategy of "organizing and transforming" (Table 1) is not a single strategy; rather, it can be divided into several cognitive strategies, such as concept mapping or constructing a flowchart. Additionally, the review of the literature sought to identify empirically validated methods for teaching these strategies. The following section outlines several strategies that can be included and some of the approaches for embedding them into a bioscience metacurriculum.

Cognitive learning strategies are mental processes used to learn, understand, and commit to memory content that supports students in reaching their academic goals. Weinstein and Meyer (85) highlight that cognitive learning strategies are goal directed, intentionally invoked, effortful, and situation specific; intrinsic factors such as the subject, task, or context will impact the usefulness of a particular cognitive learning strategy, as will extrinsic factors such as time available and competing priorities.

In their early work, Weinstein and Mayer (86) categorized cognitive learning strategies into three groups: rehearsal, elaboration, and organization (see Table 2). Rehearsal strategies are often viewed as surface-level learning techniques used for rote memorization. However, there is "an important distinction between memorizing without understanding first [rote learning]... and memorization when you have understood [meaningful memorization]" (Marton, Wen, and Wong in Ref. 87). Therefore, rehearsal learning strategies are not inherently undesirable for student learning.

Shuell (88) proposed an early model suggesting that that different learning strategies become more and less important and effective at different points on a student's learning journey, particularly when learning a complex body of knowledge. This idea was later reinforced by Hattie and Donoghue (87) following a synthesis of 228 meta-analyses investigating learning strategies. They suggest that strategies such as summarizing, note-taking, and mnemonics are effective in the initial stages of acquiring new knowledge, followed by review, deliberate practice, and repetition. These strategies align with the rehearsal and basic elaboration cognitive strategies shown in Table 2. Importantly, more complex elaboration and organization strategies are less effective if used too early but become more valuable once students have achieved some "surface" understanding. At this stage, these strategies help students identify relationships between ideas and concepts advancing them to "deeper" understanding. Therefore, strategies from all cognitive categories should be included in the metacurriculum.

Application of cognitive strategies.
Bioscience subjects are typically delivered early in nursing education programs (44, 89), so students may have had limited exposure to the discipline-specific vocabulary used during teaching and learning activities. Therefore, a useful early rehearsal strategy is the use of flash cards for

Table 2. *Taxonomy of learning strategies*

Category		Examples	Useful for
Cognitive	Rehearsal	Flash cards, mnemonics (passive—repetition) Highlighting information then reviewing again (active—additional opportunities for further processing)	Discrete information, e.g., vocabulary, names of things (anatomy)
	Elaboration—actively processing	Basic—paraphrasing and summarizing—Putting into own words is cognitive work. More complex—analogies, compare-contrast	Connecting to prior knowledge
	Organization—translating or transforming information into a new configuration	Outlines, concept maps, concept matrices (tables), flowcharts (organizing into categories, hierarchies or sequences)	Making connections between concepts Looking for trends (reduce the amount of material to learn)
Metacognitive	Metacognitive self-regulation	Goal setting, planning, implementing, monitoring, evaluating	Fine-tune strategic approaches—manage cognitive, motivation, emotional and environmental factors
	Metacognition—comprehension monitoring	Self-testing	Comprehension monitoring

Adapted from Weinstein, Jung, and Acee (47).

the internalization of vocabulary (47, 87). Providing a list of essential glossary terms for each module can further support this process.

Elaboration and organization strategies are deep-level strategies that require more cognitive effort than rehearsal strategies and lead to a more meaningful understanding of concepts. The primary goal of elaboration strategies is to connect new information with prior knowledge. Weinstein et al. (47) emphasize that this category of learning strategies is diverse and that active processing of information, rather than the specific strategy, is important. It is important to include explicit instruction in a variety of elaboration strategies, such as making analogies between known and new material and identifying similarities and differences between concepts to deepen understanding. The ability to recognize patterns and distinctions is an advanced skill vital for applying learning to new situations (87).

Organization strategies aim to transform information into a format that is easier to understand and remember. According to Weinstein et al. (47), the benefit of organization strategies arises from both the active processing of information and the creation of products, like concept maps, summary tables, and flowcharts, that can be used for future revision. Within nursing education research, there is substantial evidence that developing skills in concept mapping increases achievement and critical thinking (90–92).

Schraw et al. (93) include problem-solving and critical thinking as advanced cognitive strategies involving analysis, evaluation, and application of information (69). In a bioscience context, developing critical thinking is crucial for applying physiological concepts effectively (32), especially given concerns about nursing students' clinical application of bioscience knowledge (94). Teaching frameworks such as Halpern's (95) provide practical guidance on cultivating critical thinking skills. Halpern discusses seven general skills that students should develop to become better at evaluating information critically. Four of these are fit easily within a bioscience context: understanding how cause is determined (cause and effect thinking), providing reasons to support a conclusion (justifying answers), integrating isolated data into a wider framework (making connections between concepts), and using analogies to solve problems.

Finally, student-centered teaching methods should be employed to actively engage students in the learning process and facilitate collaborative meaning-making with peers. Student-centered learning is often synonymous with active learning (96), which encourages students to take an active role in their education rather than passively receiving information. Active learning approaches, such as the "lectorial" format described by Thalluri and Penman (96), integrate direct instruction with interactive elements such as clicker questions and small-group discussions to reinforce learning (61, 97).

Application of metacognitive learning strategies.
Schraw et al. (93) describe metacognition as a hierarchy comprising two subcomponents: knowledge of cognition and regulation of cognition. Knowledge of cognition encompasses students' knowledge of the cognitive strategies available to them, as well as their own strengths and weakness as learners. Knowledge of cognition is further divided into declarative knowledge (knowing what), procedural knowledge (knowing how), and conditional knowledge (knowing when). To effectively regulate their cognition, students must practice a variety of learning strategies in a range of situations to develop a robust knowledge of cognition (69, 85, 98).

Regulation of cognition, in contrast, involves planning, monitoring, and evaluating the learning (93). These processes are not static but are applied dynamically throughout the different stages of learning, allowing students to adjust their strategies as needed. Effective regulation ensures that students not only choose appropriate learning strategies but also evaluate their effectiveness in real time. This aligns with the skills and strategies of the self-regulated learning models of Pintrich and Zimmerman, where regulation plays an important role in all phases of the learning cycles. Without active regulation, students may continue using ineffective strategies.

In adults, the processes of self-regulation may not always be conscious because they often become automated over time and develop without deliberate effort (93). Consequently, some students may be unaware of these processes or unable to articulate them when prompted. Therefore, instructor modeling of the processes used during the forethought and self-reflection phases of the learning cycle is an important educational strategy to make these processes visible (49, 59). By making implicit processes explicit, instructors can help students refine their self-regulation skills, fostering more deliberate and effective learning.

During the forethought phase, instructors should model the breakdown of learning outcomes. Learning outcomes are typically written with Bloom's taxonomy of thinking verbs (63). Instructors could use a visual representation of the taxonomy to illustrate the different cognitive levels (e.g., remember, understand, apply, analyze, evaluate, create). For each level, the instructor should detail what students should be able to do with respect to each specific learning outcome. This modeling helps students understand how to approach and achieve the learning goals.

In the performance phase, ongoing monitoring is essential. Students need to continuously assess both their comprehension of the content and the effectiveness of their chosen learning strategies. Having received explicit instruction and practice with a range of learning strategies in class, students are equipped to actively engage with the material, adjust strategies, and seek feedback.

In the self-reflection phase at the end of each module, discussion should focus on the knowledge covered and how metacognitive strategies were applied. For example, have students review the content provided in the module and attempt to relate it back to each of the learning outcomes. This process assists students to identify and extract key concepts, monitor their understanding, and determine the extent to which their learning strategies were effective. As part of this reflection, students should be encouraged to engage in self-evaluation, reflecting on what they did and how effective it was in terms of their performance against the learning outcomes. Retrieval practice and low-stakes formative assessments support this process by providing concrete evidence of learning and highlighting gaps in understanding. Because these evaluative and reflective processes do not come naturally to all learners, they should be taught explicitly and embedded intentionally throughout the curriculum. Instructors can scaffold this process by modeling reflective questions, integrating structured prompts into class activities, or including self-assessment tools.

CONCLUSIONS

In conclusion, addressing the persistent challenges of learning bioscience and physiology in health professions education demands a comprehensive approach, one that not only delivers content but also equips students with the skills to engage meaningfully with it. Manchester and Roberts (10) highlight the importance of understanding not only what to teach but also how to teach it effectively. Although active learning methods that rely on students' ability to self-direct their learning are common in bioscience education, their success depends on students' use of self-regulated learning skills and strategies (99). This article has proposed an integrated metacurriculum, grounded in self-regulated learning theory, as a holistic response to this need.

By embedding explicit instruction in learning strategies within the teaching of bioscience content, educators can foster deeper cognitive engagement, improve student self-efficacy, and support the development of transferable learning skills. The self-regulated learning framework provides a robust structure for guiding students through iterative cycles of planning, performance, and reflection, key processes for effective and independent learning.

Although the examples presented draw on nursing education, the principles and strategies described are applicable across disciplines where physiology and bioscience are taught. Implementing a metacurriculum aligned with SRL offers a promising path forward: it not only addresses the learning challenges common in these subjects but also empowers students to approach their studies with greater autonomy and confidence. Ultimately, this integrated approach prepares future health professionals to apply their scientific knowledge more effectively in clinical and professional practice.

Future research in this area should examine the implementation and effectiveness of this metacurriculum with a mixed-method approach. Quantitative measures should include students' self-efficacy for both the bioscience content and the SRL strategies, while qualitative data could be gathered through reflective writing, learning journals, or metalearning assessment tasks (100).

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

V.D. prepared figures; V.D. and J.C. drafted manuscript; V.D. and J.C. edited and revised manuscript; V.D. and J.C. approved final version of manuscript.

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