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Eight Recommendations to Promote Effective Study Habits for Biology Students Enrolled in Online Courses

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To achieve meaningful learning experiences in online classrooms, students must become self-regulated learners through the development of effective study habits. Currently, there is no set of recommendations to promote study habits in online biology learning environments. To fill gaps in our understanding, a working group associated with a research coordination network (Equity and Diversity in Undergraduate STEM, EDU-STEM) convened virtually in June 2021. We identify student barriers to self-regulated learning in online environments and present eight practical recommendations to help biology educators and biology education researchers apply and advance evidence-based study habits in online courses. As higher education institutions continue to offer online learning opportunities, we hope this essay equips instructors with the knowledge and tools to promote student success in online biology coursework.

KEYWORDS self-regulated learning, scaffolding, learning objectives, feedback, formative assessments, interactive software, learning management systems, self-assessment, spacing, digital natives

PERSPECTIVE

The global spread of COVID-19 forced universities to rapidly shift from face-to-face instruction to virtual learning. During this time, students completed their coursework online, and had limited access to their peers, instructors, and other learning supports (1). Students expressed stress related to learning in this environment, citing challenges with completing coursework as well as a negative perception of online learning (1). While some students thrived with the increased level of autonomy offered by online learning, others viewed it negatively and struggled with time management, motivation, and focus (1, 2). These challenges indicate that students need more guidance and support to achieve meaningful learning experiences in online classrooms. Consistent with this, a survey distributed to faculty in 672 U.S. institutions at the start of the pandemic indicated that the rapid shift to online learning left faculty, many of whom who had no prior experience with teaching online, with limited information on how to best support their students (3). Specifically, faculty desired more information for students on how to succeed in online learning environments (3).

Prior to the pandemic, students drove increasing enrollments in online courses across the United States due to their accessibility, flexibility, and convenience (4). However, students frequently emphasize their preference for face-to-face courses over online courses due to belief that face-to-face courses provide explicit instruction necessary to be academically successful, especially in classes that students perceive as difficult (5). According to Jaggars (2014), students perceived learning less in online classes and resorted to reading from the textbook to obtain information (5). Thus, to best support students who enroll in online courses, faculty must understand the perceptions, strategies, and barriers students encounter in these environments.

One of the largest barriers to student success in online courses is self-regulated learning (SRL). SRL refers to how

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TABLE 1
Challenges students experience when attempting to prepare and study for online biology classes

Challenge	Description
Low motivation and low self-efficacy	Decreased motivation to learn and decreased perception of ability to learn
Anxiety and depression	Excessive worrying and hypervigilance; persistent feelings of hopelessness and sadness that affects student motivation and concn
Zoom fatigue	Mental and physical exhaustion experienced after participating in prolonged periods of virtual meetings
Isolation from peers	Lack of opportunities to engage with peers
Work-life balance	Inability to manage the expectations of work, school, and home

students proactively transform their mental abilities to academic skills through self-generated thoughts, feelings, and behaviors (6). Students who lack the SRL necessary for online courses experience negative academic outcomes (7–10). According to Zimmerman's framework of SRL, there are three critical components by which self-regulated learners engage in their own learning: metacognition, motivation, and behavior (6, 11). For example, self-regulated learners may have the ability to monitor their own learning (metacognition), have intrinsic interest in their studies (motivation), and employ effective study habits (behavior) (5, 6, 11). In this essay, we focus on the application of appropriate study habits because students report significant struggle in this area, particularly in online environments that demand high-SRL skills (12, 13). *Study habits* encompass a variety of behaviors that include what strategies students use to learn, understand, and retain course content, how much time is spent studying, and how students distribute their study time over the course of a semester (12, 14). As the transition to emergency remote learning demonstrated, these skills are underdeveloped in students, particularly those enrolled in large, introductory classes, and many students developed a negative attitude toward online learning as a result (1, 2). How can faculty equip their students with the cognitive tools necessary to study effectively and succeed in the online environment?

To address this question, faculty must first understand why students relied on ineffective study habits during online learning. In this paper, we present a framework for challenges and solutions related to the promotion of study habits in the online environment. We explored these ideas during a breakout discussion of participants from a Research Coordination Network, Equity and Diversity in Undergraduate STEM (EDU-STEM) in June of 2021. During this breakout session, a group of faculty who represent a variety of institutional types, including community colleges, private undergraduate colleges, research-intensive institutions, and minority serving institutions gathered to discuss experiences with emergency remote teaching and identify best practices for supporting students in the online learning environment. The goal of this session was to come to a consensus regarding student challenges and best practices to promote successful study habits in online instruction. During the pandemic, we taught large enrollment introductory biology classes through asynchronous or synchronous Zoom sessions and used a variety of learning management systems (LMS) (e.g., Canvas, Moodle, Blackboard) to distribute course-related information to students.

Here, we identify challenges for student development of effective study habits in online courses and offer eight recommendations for instructors to help students overcome these challenges and develop the tools necessary to be successful in biology.

CHALLENGES FOR STUDENT DEVELOPMENT OF EFFECTIVE STUDY HABITS IN ONLINE COURSES

A goal of college courses is to teach students how to be self-regulated learners, or students who actively participate in their own learning by adjusting their efforts, approaches, and behaviors to achieve their learning goals (6, 11, 12). Students often enter college with underdeveloped self-regulatory skills (11, 12, 15). Specifically, students lack the ability to effectively assess their learning and often feel that they learn more from cognitively superficial study habits such as re-reading the textbook or their lecture notes (11). This outcome is particularly common among students enrolled in online coursework. Due to limited instructor–student interaction, online courses require students to assume greater responsibility for their learning, to actively monitor their performance, and to apply appropriate study strategies to be academically successful (9, 16). However, despite the importance of this skill, students enrolled in online classes may be unaware of how to effectively implement SRL or face serious challenges out of their control that result in poor performance outcomes in online courses (4, 17).

Below we summarize discussions among the contributing authors, who are biology instructors from a Research Coordination Network (Equity and Diversity in Undergraduate STEM, or EDU-STEM) about central challenges students face in their efforts to study and prepare for biology courses. These include: (i) low motivation and low self-efficacy; (ii) depression and anxiety; (iii) Zoom fatigue; (iv) inability to access network of peers; and (v) work/life balance (Table 1).

Low motivation and low self-efficacy

Students reported that the abrupt shift from face-to-face learning to online learning environments resulted in difficulties with SRL (1). Self-efficacy (student perception that they are capable of learning) and motivation (intrinsic motivation to learn) have been identified as factors that contribute to SRL development in online environments (1, 16, 17). Students who have high self-efficacy and are highly motivated tend to appropriately control their learning process and utilize appropriate study strategies in order to achieve their learning goals. However, students who have low self-efficacy or lack motivation fail to use these strategies and experience negative academic outcomes as a result (e.g.,-spending more time on assignments, failing to submit assignments on time, and submitting poor quality work) (1, 18). Research into online learning environments corroborates previous research; specifically, Landrum (2020) found student confidence in their ability and motivation to learn in an asynchronous, online environment in the absence of peers and instructors to be a predictor of student performance and persistence (19).

Anxiety and depression

Prior to the COVID-19 pandemic, institutions across the United States were reckoning with a growing mental health crisis, with an increasing number of students seeking mental health treatment for anxiety and depression (20, 21). Anxiety is a common mood disorder that is characterized by excessive worrying and hypervigilance. It is often associated with depression, which is characterized by persistent feelings of sadness and hopelessness (21–23). These feelings can be accompanied by loss of energy, difficulty concentrating, and difficulty sleeping (21). Given that mental health can affect student motivation and concentration, it has been identified as a leading barrier to academic success (21, 24). During COVID-19 online learning, the pandemic lockdown exacerbated mental health issues such as depression in undergraduate students due, in part, to concerns about their own well-being, as well as the health of their friends and family, less interaction with others, and less community support (24–29). Women, students of color, LGBTQ+ students, and students from lower-than-average socio-economic backgrounds were disproportionately affected by lockdown and reported higher levels of anxiety and depression (20, 25, 30, 31). Many students reported that the transition to online classes and difficulty with online learning were major stressors that resulted in higher rates of anxiety and depression (1, 20, 24). Consequently, students reported increased workloads, more difficulty in completing academic tasks due to physical isolation from instructors or teaching assistants, and struggling to concentrate (1, 24). Consistent with these findings, undergraduate and postgraduate students reported that mental health difficulties negatively affected their ability to study (32). Despite the urgent need for increased mental health support, previous research showed students perceived barriers to seeking help from professionals or peers due to fear of judgment (21, 24). Interestingly, despite the difficulties reported with online coursework, some students reported the use of effective study habits (e.g., setting a study schedule) as a coping mechanism for their anxiety (24).

Zoom fatigue

The COVID-19 pandemic caused a rapid rise in the use of video conferencing systems, such as Zoom, Google Meet, Blackboard Ultra, and Microsoft Teams. For example, Zoom video conferencing increased from approximately 10 million daily Zoom meeting participants in December 2019 to 200 million in March 2020 and 300 million in April 2020 (33). The increase in screen and sitting time caused many users to experience fatigue or burnout. A new phrase, Zoom fatigue, or Zoom burnout, paralleled the growth in Zoom usage peaking in popularity in late April 2020 and July 2021 respectively (data source: Google Trends [https://www.google.com/trends]).

Zoom fatigue refers to the mental and physical exhaustion people feel after participating in prolonged periods of virtual meetings. It is caused by excessive amounts of closeup eye gaze, cognitive load, increased self-evaluation from staring at video of oneself, and constraints on physical mobility and communication (34). Users reported increases in physical, behavioral, and psycho-emotional problems (35, 36), including difficulty concentrating, physical exhaustion, anxiety, irritability, headache, eye strain, and increased pessimism. Furthermore, Zoom fatigue has been attributed to the fatigue associated with concerns regarding self-presentation (i.e., being watched on camera enhances need to manage impression and turns focus inward) (37). Ultimately, this limits participant engagement with the virtual meeting (37).

Unsurprisingly, Zoom fatigue has resulted in students reporting moderate to considerable difficulty with online learning. Learning, even in online environments, requires active engagement, and students have not received training on how to actively engage in asynchronous or synchronous Zoom sessions (38). As a result, students reported increased distractions and struggled with remembering the materials presented during asynchronous or synchronous sessions due to the passive intake of information and lack of engagement in the content that would promote deeper learning (38). As a result, students may rely heavily on passive strategies (e.g., re-reading the textbook, re-watching lecture videos) during their study periods to fill the gaps in their knowledge.

Isolation from peers/ability to access network of peers

Past research highlights how undergraduate students rely on their peers to teach and learn disciplinary content related to coursework (39, 40) and employ effective study

habits (41, 42). Research on *information seeking behavior*, or the way people search for and utilize information (43), has demonstrated that students and the public actually prefer to obtain information from human sources (44). For example, students' information seeking behavior may involve actively finding relevant information about the syllabus from a peer to prepare for an exam.

During face-to-face instruction, students are immersed in classrooms with other students and plenty of opportunities exist to interact with peers before, during, and after class in such a way that supports collaborative learning. In online learning environments, however, instructors or course developers must implement virtual structures that support collaborative learning with peers. The lack of default opportunities to engage in discussions with peers represents a potential obstacle for students, who will not reap the benefits of these interactions in their learning. These obstacles may be particularly high for first-year students, transfer students, or those who are unfamiliar with others who are in the class. Previous research documented how students' studying for exams in large active learning organismal biology classes differed 1 week and 1 month after a university's decision to transition to emergency remote instruction due to COVID-19 (45). They found that at both time points, one of the largest concerns reported by students related to a lack of access to their in-class assigned groups. One student acknowledged, "I was unable to study with friends and had no way of knowing if my knowledge had holes in it." This reflection speaks to the importance of student access to their network of peers in preparing for in-class assessments.

Work-life balance

Students in online learning environments may experience challenges in managing the expectations of work, school, and home (46). In traditional face-to-face learning environments, there are firm barriers between learning time, family time, work time, and leisure time that allow students to schedule and complete activities associated with each task (e.g., setting up dedicated study time) (46). However, as online learning became increasingly prevalent during the COVID-19 pandemic, these boundaries between school, family, work, and leisure time began to blur and students struggled with adjusting their behaviors to balance each of these domains (1, 46). The pandemic highlighted the sizeable population of students for whom college was not their only focus. Such students may hold one or two jobs to cover tuition costs and other living expenses. Others may have family responsibilities such as caring for a younger sibling, elderly parent(s), or caring for their own family and children.

EIGHT RECOMMENDATIONS TO DEVELOP STUDENT STUDY HABITS IN ONLINE BIOLOGY COURSES

After discussing challenges for students and why some might rely on ineffective study habits during online learning, we explored recommendations for instructors during a breakout discussion of participants from Research Coordination Network EDU-STEM. While each recommendation will profit from more research in the context of undergraduate biology, they represent the opinions of experienced faculty who teach biology from a range of institutions and serve as a starting point into empirical work on these topics. The eight recommendations aimed at promoting effective study habits include (i) establish content (and digital) learning objectives; (ii) align assessments and assignments with learning objectives; (iii) high quality feedback; (iv) increase scaffolding; (v) incorporate multiple due dates; (vi) incorporate online formative assessments; (vii) provide resources outside of textbook and recorded lectures; and (viii) facilitate student-content engagement with interactive instructional materials (Table 2).

Recommendation 1: establishing content (and digital) learning objectives

We recommend that online instructors select and articulate not only biology content and science process learning objectives, but also digital learning objectives that develop the skills and confidence of students in the effective use of the digital technology that supports their learning. In the beginning weeks of a course, instructors can easily create digital objectives for navigating the LMS (e.g., "students will be able to access course announcements"). However, students need continuous practice using these online tools and it is important for instructors to incorporate their content objectives with digital objectives. For example, instructors who wish for their students to gain core knowledge may articulate low-level Bloom's objectives and select a quizzing strategy through adaptive learning programs that allow students to practice factual knowledge. In this instance, it is equally important for instructors to name the learning objective for the digital output (e.g., "students will demonstrate proficiency in timed online multiple-choice quizzing") and provide adequate training for how to use this platform of practice effectively (e.g., "treat the answer choices as multiple true-false statements for extra practice"). Similarly, instructors may wish for their students to apply recently learned content to a real-world scenario and may require students to complete the assignment in online collaborative groups. Thus, for this assignment the digital objective would be "students will demonstrate proficiency in accessing student groups on the LMS and contacting groupmates." In doing so, student content learning and digital skills are made as explicit as the modality in which they will demonstrate those outcomes. Class time may be used to model effective online learning study skills calibrated to the learning objectives and digital mode, and students may be assigned and encouraged to use and transfer these skills independently as they grow in their metacognitive awareness and self-regulation.

Although low-level Bloom's objectives are commonly utilized in online spaces (47), higher order skills may be assessed using alternative assessment styles in the digital space. For example, conceptual models may be assessed in a drawing app

TABLE 2
Recommendations for developing effective study habits

Recommendation	Rationale	Study habits developed
Establish content (and digital) learning objectives	Students struggle with using digital tools for academic purposes	• Making diagrams • Explaining concepts • Self-assessment • Consistent and spaced study time
Aligning learning objectives and assessments	Students struggle with constructing meaning from online content and identifying concepts to study	• Self-assessment • Explaining concepts
High quality feedback	Students struggle with constructing meaning from online content and identifying concepts to study	• Self-assessment
Scaffolding	Students cite poor time management and inability to assess learning as barriers to online learning	• Consistent and spaced study time • Synthesizing notes • Making diagrams • Explaining concepts • Self-assessment
Multiple due dates	Students frequently express issues with procrastination and turning work in on time despite having a clear due date	• Consistent and spaced study time
Incorporating online formative assessments	Students struggle with constructing meaning from the lectures posted by instructors	• Self-assessment
Provide resources outside of recorded lectures and textbook	Students struggle with using digital tools for academic purposes	• Synthesizing notes • Use of and completion of problem sets • Explaining concepts • Self-assessment
Facilitate student-content engagement with interactive instructional materials	Students feel that online learning is less engaging and motivating than face-to-face learning	• Use of and completion of problem sets • Making diagrams • Explaining concepts • Self-assessment

(Google JamBoard) or problem-solving, and argumentation skills may be assessed using video apps. Regardless of the digital output, the core tenet of explicitly stating the digital learning objectives and outputs along with the desired content and scientific skill objectives is key.

Recommendation 2: aligning assessments and assignments with learning objectives

Alignment of course activities and assessment methods with learning objectives is critical for effective course design across in-person and online learning environments (48–53). Through this alignment, instructors can clearly communicate to students what is expected of them, and work shows that students find properly aligned objectives helpful in highlighting what they are expected to know (54). Additionally, undergraduate science students believe that learning objectives are a helpful tool to narrow down and organize their studying while preparing for exams (54). But how do students use learning objectives to study? In a study conducted by Osueke et al. (2018), students indicated that they use learning objectives for self-assessment (e.g., answering the learning objectives as questions or self-testing using the learning objectives) and as a resource for studying (e.g., using the learning objectives as a study guide) (54).

Given that online students may not know how to use learning objectives as a resource for their learning, we recommend that instructors not only clearly define and explicitly communicate learning objectives to students, but also provide explicit instruction on how to use learning objectives for self- assessment.

Recommendation 3: high quality feedback

In large foundational face-to-face STEM courses, students commonly receive formal instructor feedback only a few times

throughout the semester, generally after large consequential exams that account for a significant part of the students' grades. However, it's easier for instructors to engage in informal dialogue and gauge student understanding in face-to-face settings, and students may benefit from unstructured or unplanned feedback on assignments, assessments, or other important information. In some online learning environments, such as those where the instructor is teaching an online class of black screens, it is more difficult to 'read the room' and know when students need clarification on a topic. In these online contexts, providing high quality feedback becomes a crucial element of the learning process (55). Student reports also show instructor feedback is used as a method for improving learning or study strategies (56). Students struggle with constructing meaning from online content and identifying concepts to study, underlining the need for instructors to provide high quality feedback on student assignments and assessments. This fosters student motivation and can provide information to help shape learning (55).

Recommendation 4: scaffolding

The incorporation of specific design elements, such as active learning strategies, student engagement, and assessment strategies, guide students in how to manage their time, self-assess their understanding of material, and promote satisfaction in learning. These design elements, also known as scaffolding, refer to the teacher-generated support a learner is given to accomplish a specific task (57). For example, an instructor can teach students how to engage with recorded lectures by providing guided note taking sheets (58). Additionally, instructors can encourage students to self-assess by providing frequent short practice tests and quizzes (58). As a learner achieves mastery in a specific task, the teacher may remove the support and pass the responsibility of learning on to the learner (57). Interestingly, scaffolds also allow students to think deeply about the content and are particularly effective in helping students develop study strategies and time management skills (17).

Prior to and during the pandemic, students commonly reported that online learning was subpar compared to face-to-face learning and that they simply did not learn as much in their online classes (1, 58). Students also cited poor time management, inability to assess learning, and lack of access to supporting resources as barriers that contributed to their negative experience and poor academic outcomes (1, 45). However, by including scaffolds in their learning management systems, instructors can elicit appropriate study habits from students.

Recommendation 5: multiple due dates

Students prefer clear and consistent due dates for assignments in online courses, and previous work shows this relates to their self-perceived learning and learning satisfaction (58). However, during the COVID-19 pandemic, students frequently expressed issues with procrastination and turning work in on time despite having a clear due date (1). This, along with a perceived increase in workload and inability to construct meaning from recorded lectures, can result in students using ineffective study habits (e.g., "cramming") during their study time. To limit these issues, we recommend that instructors move due dates to multiple times during the week instead of requiring students to submit all of their assignments on one day (17, 59). Setting multiple due dates allows students to work in smaller, manageable time increments. Additionally, this easy change models the highly effective study strategy of spacing (i.e., studying across multiple sessions instead of cramming) for students. Specifically, setting multiple due dates encourages students to work on assignments at multiple points during the week and ultimately promotes greater long-term learning (12, 17).

Recommendation 6: incorporating online formative assessments

Due to Zoom fatigue and other factors affecting focus, students have struggled with constructing meaning from the lectures posted by instructors. Interestingly, prior studies have demonstrated that online formative assessments are essential for gaining, refocusing, and extending student attention following STEM lectures (58). Therefore, to assist students in understanding the content presented, it is recommended that instructors incorporate frequent, low-stakes online formative assessments (i.e., activities that are a small portion of students' grades and are intended to generate feedback on learning progress) (60). Formative assessments encompass a variety of activities such as weekly quizzes, homework assignments, group discussions, and in-class polling. While frequent, low-stakes formative assessments are important for students in all classroom contexts, they are especially important for online learners who may struggle with self-regulated learning because they provide students with immediate feedback and explanations that students can use to modify their learning (58). Thus, instructors should incorporate online formative assessments into their LMS. These assessments can be created through various learning management systems such as Canvas, Blackboard, or Moodle. Alternatively, instructors can use tools such as EdPuzzle (www.edpuzzle.com), Quizizz (www.quizizz.com), Kahoot! (https://kahoot.com/), or Quizlet (www.quizlet.com) to create formative assessments for their students.

Recommendation 7: providing resources outside of textbook and recorded lectures

In an institutional survey given to students enrolled in online STEM courses, students indicated that they enjoyed course-related videos that allowed for greater understanding of course content (58). While some students are considered to be digital natives, or those who were exposed to computers and digital technology from an early age, many students struggle with using digital tools, such as navigating

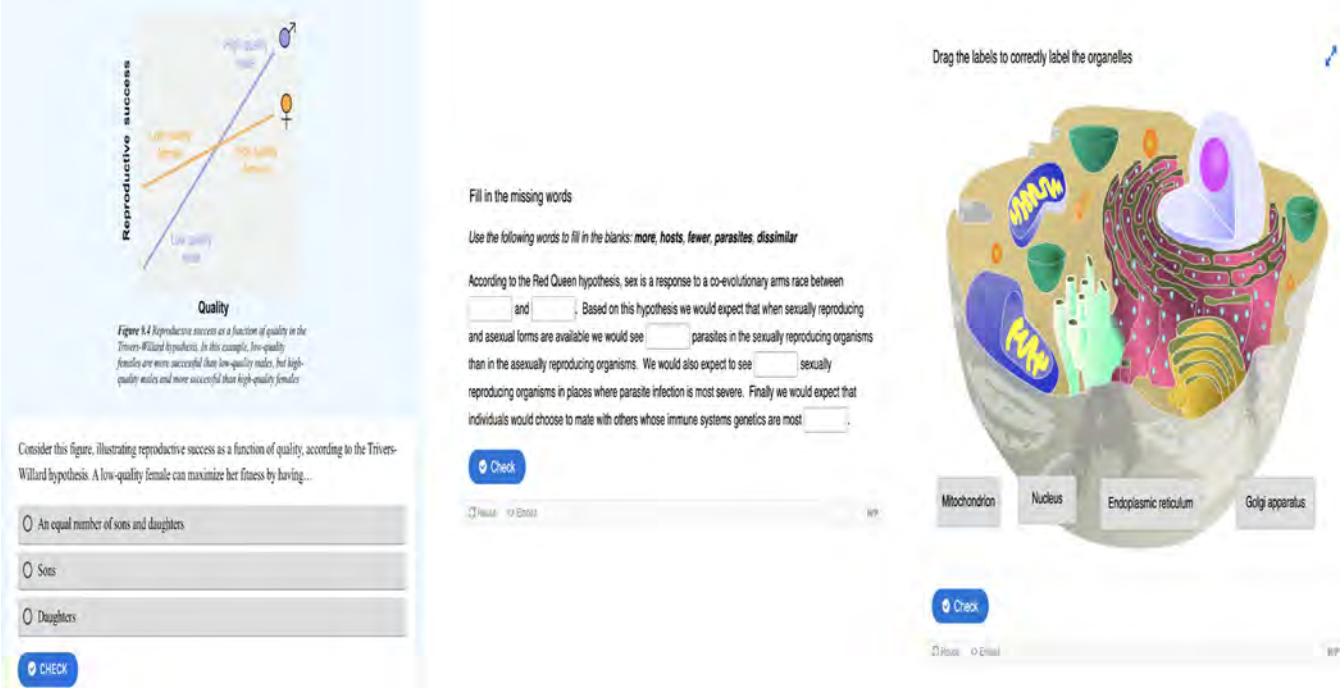

FIG 1. Examples of interactive activities on H5P from Cotner and Wassenberg (72).

learning management systems, for academic purposes. This means that the tools provided to students intended to enhance their learning may inadvertently serve as a barrier to learning. We suggest that instructors provide links to other resources (e.g.,- YouTube videos, instructor generated guided notes, simulations) that provide students with different ways to engage with and conceptualize the content (17).

Recommendation 8: facilitate student-content engagement with interactive instructional materials

Learner interaction with content has previously been identified as a key factor that supports learning in online courses (61). This interaction can take a number of forms (e.g., watching instructional videos, interaction with multimedia, and searching for information) and requires instructors to take an active role in facilitating sustained engagement with the course material (61, 62). Thus, online instructors are encouraged to invest time in searching for interactive instructional materials (62). However, during the COVID-19 pandemic, instructors were forced to rapidly shift to online teaching, and many had to do so without previous online teaching experience. As a result, like many newcomers to online teaching, instructors simply replicated their traditional classroom model to an online platform without alteration to account for the new instructional context (63). This left some students struggling to effectively engage with and study the content, which may contribute to the perception that all online learning was less interactive (64) and less motivating (65) than face-to-face instruction. Instructors can address some of these concerns by creating interactive, online content compatible with asynchronous or synchronous environments. Interactivity can enhance student motivation by increasing autonomy, such that the user must make choices and direct the pace of their own learning, and a sense of competence, such that lessons can be scaffolded so that novel concepts are not introduced until initial concepts are mastered (66–68).

Several tools exist for creating interactive content—tools that go beyond what is native to an existing LMS. Tools that are either free or relatively low-cost include Edpuzzle (https://edpuzzle.com/), Quizizz (www.quizizz.com), Kahoot! (https://kahoot.com/), Quizlet (www.quizlet.com), Nearpod (www.nearpod.com), Wordwall (https://wordwall.net/), and H5P (https://h5p.org/). These tools allow the instructor to create activities (e.g., multiple choice quizzing, interactive video presentations, simulations) that are scaffolded, tailored to course content, and aligned with course outcomes (Fig. 1). Further, these tools can be embedded into several existing LMS platforms such Canvas, Moodle, and Blackboard, and shared easily with colleagues.

SUMMARY

The goal of this essay was to identify challenges students face studying for online biology courses and to provide recommendations for instructors to foster the development of effective study strategies. Our recommendations were informed by our experiences with teaching online biology courses and by the current state of knowledge regarding best practices for online teaching. As instructors communicate expectations to students through pedagogical choices (e.g., use of instructional time, assignments, course

structure, scaffolding, and organization), students will adjust to these situational and environmental cues with explicit training and modeling for how to study and master the material in the online learning space. We hope that iterative, high-structure, and developmental approaches in the online learning space will result in similar positive impacts as previously reported in physical classrooms (69–71).

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