WHAT WORKS CLEARINGHOUSE™

Using Technology to Support Postsecondary Student Learning:

A Practice Guide for College and University Administrators, Advisors, and Faculty

EDUCATOR'S PRACTICE GUIDE
A set of recommendations to address challenges in classrooms and schools

ies NATIONAL CENTER FOR EDUCATION EVALUATION AND REGIONAL ASSISTANCE
Institute of Education Sciences

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U.S. DEPARTMENT OF EDUCATION

Using Technology to Support Postsecondary Student Learning

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Introduction to the Practice Guide on Using Technology to Support Postsecondary Student Learning

Despite increasing college enrollment[1] and growing diversity of the college student population,[2] college completion rates are low. Less than a quarter of students enrolled at public 2-year institutions complete their programs within 3 years.[3] At 4-year institutions, only 58 percent of students who enroll at public institutions and 69 percent of students who enroll at private institutions complete their programs at any institution within 6 years.[4] The first year of college is critical, with about 20 percent of first-time full-time students in 4-year institutions and more than 40 percent of first-time full-time students in 2-year institutions failing to return to that same institution for their second year.[5] Persistence and graduation rates are even lower for first-generation, low-income, and racial/ethnic minority college students.[6]

See the **Glossary** for a full list of key terms used in this guide and their definitions. These terms are underlined when first introduced in the guide.

Many colleges are exploring ways to leverage technology to improve student retention and increase the educational options for and success of their diverse student bodies. Technology is infused in almost every aspect of college life. In the general population, 77% of individuals own a smartphone, 73% own a laptop or personal computer, and 53% own a tablet.[7] Mirroring that trend, students have increasingly greater access to personal computing and communications technologies.[8] Web-based course or learning management systems and instructional technology centers can be found on almost every U.S. college campus. Colleges are even ranked based on the quality of their technology infrastructure and connectivity.[9] Off campus, technology allowed more than six million college students to take online courses in the 2015-2016 school year.[10] Colleges are using technology to improve the quality of student learning; make active and engaging learning available throughout institutional offerings; and help students become more successful learners.

This practice guide, developed by the What Works Clearinghouse™ (WWC) in conjunction with an expert panel, focuses on promising uses of technologies associated with improving postsecondary student learning outcomes. It provides higher education instructors, instructional designers, administrators, and other staff with specific recommendations for supporting learning through the effective use of technology.

Using Evidence to Develop the Recommendations

This practice guide makes five evidence-based recommendations around how to use technology to support postsecondary learning. Each recommendation includes examples of technologies and how to implement them, advice on how to overcome potential obstacles, and a summary of the research evidence that supports the recommendation. The panel created a practice guide protocol to guide the evidence search and review.[11] Findings from eligible studies (see **Box 1**) that meet evidence standards were summarized by trained and certified WWC reviewers for consideration by the expert panel.

BOX 1. STUDY ELIGIBILITY CRITERIA

Eligible research used a comparison group design, included an intervention that used technology to support student learning, involved college students in the United States, was published in 1997 or later, and reported on one or more outcomes in the following domains: (1) academic achievement; (2) college attendance; (3) credit accumulation and persistence; (4) attainment of a degree, certificate, or credential; (5) post-college employment and income; or (6) student engagement and motivation.

The expert panel, after considering the evidence, drafted the recommendations and assigned a level of evidence to each (see **Box 2**).

BOX 2. LEVELS OF EVIDENCE

Strong: There is consistent evidence that meets WWC standards and indicates that the practices improve student outcomes for a diverse population of students.

Moderate: There is some evidence meeting WWC standards that the practices improve student outcomes, but there may be ambiguity about whether that improvement is the direct result of the practices or whether the findings can be replicated with a diverse population of students.

Minimal: Evidence may not meet standards or may exhibit inconsistencies, but the panel determined that the recommendation must be included because the intervention is based on strong theory, is new and has not yet been studied, or is difficult to study with a rigorous research design.

The recommendations and the panel's strength of evidence assessment are shown in **Table 1** below.

Overarching Themes

Each recommendation focuses on using technology to support particular aspects of student learning. Taken together, the recommendations highlight five themes that cut across all of the advice in this guide.

- **Focus on how technology is used, not on the technology itself.** Technology evolves rapidly. Many of the technologies used in the research that supports this guide could change in the near future. Thus the expert panel elected to focus on how technology can be used to enhance and support teaching and learning. Keep this in mind throughout the guide: the specific technologies are less important than the ways existing or emerging technologies can be used effectively in college settings both now and in the future.
- **Technology should be aligned to specific learning goals.** Every recommendation in this guide is based on one idea: finding ways to use technology to engage students and enhance their learning experiences. That is, the focus of this guide is not on using technology

Table 1. Recommendations and corresponding levels of evidence

	LEVEL OF EVIDENCE		
Practice Recommendation	**Minimal**	**Moderate**	**Strong**
1. Use communication and collaboration tools to increase interaction among students and between students and instructors.	●		
2. Use varied, personalized, and readily available digital resources to design and deliver instructional content.		●	
3. Incorporate technology that models and fosters self-regulated learning strategies.		●	
4. Use technology to provide timely and targeted feedback on student performance.		●	
5. Use simulation technologies that help students engage in complex problem-solving.	●		

as a mechanical tool, for computation or word processing, for example. Instead, this guide is about using technology to engage students more deeply in learning content, activate their learning processes, and provide the social connections that are key to succeeding in college and in life after college. To do this effectively, any use of technology suggested in this guide must be aligned with learning goals or objectives. Instructors should explore the wide range of technologies available to help them meet their instructional goals. Then they should select technologies that best align with the pedagogical approach in their individual course(s).

- **Pay attention to potential issues of accessibility.** Despite the pervasiveness of technology and internet-enabled devices, technology is not higher education's panacea. Smartphone ownership is not universal, and some students in rural areas have spotty or nonexistent internet access. The issue of student access to technology has several facets. The Pew Research Center (2018a) has been tracking internet access annually in the United States for the past 15 years. It finds that about 89 percent of all households have internet access. However, there are disparities based on age, income, race, region, and broadband capability. Generally older, minority, and immigrant populations have less access than younger, white households.

  Pew Research Center (2018a) reports broadband access, which is highly desirable for using and delivering media-rich material, is in approximately two-thirds of American households. This percentage is much lower among poorer populations and especially those in rural parts of the country. Thus colleges and universities with large minority commuter populations such as community colleges likely will have disproportionate numbers of students who have limited access to the internet in their homes.

  Students with special needs or disabilities can find it difficult to use or interact effectively with technology. For them, the issue of accessibility is critically important. Hundreds of colleges have been the subject of federal investigations regarding noncompliance with the Americans with Disabilities Act (Wang, 2017) because of limited access capabilities for students with special needs. Instructional designers increasingly must be aware of the service requirements for that student population. They need to ensure that learning materials on course websites and course/learning management systems can accommodate students who are visually and/or hearing impaired.

- **Technology deployments may require significant investment and coordination.** Implementing any new intervention takes training and support. That is true even more so in an environment where students might be more comfortable with technology than are their instructors and where resources are scarce. Effective implementation of new technologies that have the potential to support student learning outcomes requires support from administrators and teaching and learning centers. Further, sufficient information technology investments and infrastructure are necessary to roll out new technologies. Institutions should provide clear incentives and opportunities for professional development to encourage successful implementation. Finally, a commitment to collaboration among technology developers, instructional designers, higher education administrators, and instructors can promote effective implementation of new technologies.

  Instructors at smaller institutions that may lack established teaching and learning centers can obtain technology-related materials and instructional strategies from widely available sources. Those sources include Multimedia Educational Resource for Learning and Online Teaching (MERLOT), Creative Commons, the Online Learning Consortium, and EDUCAUSE, all described later in this guide. Instructors at any institution can benefit from having access to appropriate resources on campus to help them navigate issues such as software licensing and accessibility for all students.

- **Rigorous research is limited and more is needed.** Though the panel believes technology can be used to improve postsecondary student learning, the recommendations made in this practice guide are supported by *moderate* or *minimal* evidence. Despite technology's ubiquity in college settings, rigorous research on the effects of technological interventions on student outcomes is rather limited. More rigorous research on new technologies and how best to support instructors' and administrators' uses of technology is needed.

Who Might Find This Guide Useful?

This guide is designed to be used by instructors, administrators, and advisors at 2- and 4-year colleges and universities seeking ways to support instructional practices and student learning with technology. The recommendations in this guide will also be useful for technology developers, instructional designers, and staff at campus-based teaching and learning centers. Strategies for instructional design, application development, and deployment must all be considered to implement technology-based practices successfully in educational settings. This statement holds whether the technology is face-to-face, blended, or online. Where possible, this guide's suggestions for how to carry out a recommendation address all those audiences.

How to Use This Practice Guide

For each of the five recommendations in this guide, we include the following:

- **Recommendation:** Details about the recommended practice, example technologies, Level of Evidence, and a description of how the recommended practice supports student learning. **Appendix C** contains a detailed rationale for the Level of Evidence and information on the individual studies that support each recommendation. Each recommendation also includes a ***"Spotlight on Implementation"*** that provides additional implementation detail from one of the studies that supports the recommendation. All figures and examples in this guide are offered as examples and should not be read as endorsements of specific products or approaches.
- **How to Carry Out the Recommendation:** Guidance on how to implement the recommended practice. This guidance is informed by the studies that support the recommendation, as well as the expert panel's expertise and knowledge of resources and strategies available to help implement the recommendation.
- **Potential Obstacles:** Advice from the panel about challenges and how to overcome them.
- **Tools and Resources:** Examples related to the guidance for how to carry out the recommendation.

The guidance on how to carry out each recommendation is presented in a sequence. However, not every step will be appropriate to every audience, nor is every step required in order to implement a recommendation successfully. Users of this guide are encouraged to use the advice provided here in ways that fit best into the varied contexts in which they work. Recommendations 1 and 2 focus on interventions that might be applied broadly across a postsecondary institution, though they can also be implemented in individual courses. Recommendations 3, 4, and 5 focus on pedagogical strategies for using technologies in postsecondary courses, whether face-to-face, blended, or online.

Though this guide does not provide step-by-step instructions for implementation, readers will find resources mentioned throughout providing more details about how to apply particular practices.

Recommendation 1: Use communication and collaboration tools to increase interaction among students and between students and instructors.

When used effectively, communication and collaboration tools can increase engagement by allowing students to communicate about course content and their learning experiences. The relationships that college students form with their instructors and with one another enable them to create connections around common learning goals, build knowledge and identity, and develop a sense of belonging.[12] These relationships and interactions are believed to foster student engagement and belonging, which may influence postsecondary students' performance and persistence.[13]

Communication and collaboration tools can help build a sense of community and foster social learning. Social learning occurs when people learn from one another via observation, imitation, and modeling, and it can lead to established groups founded around common learning goals. Effective social learning in online courses is associated with better motivation and learning outcomes.[14]

Instructors and administrators in postsecondary settings can facilitate communication and collaboration among students and between students and instructors through the use of technology both inside and outside the classroom, whether those classrooms are traditional, blended, or exclusively online.

The vast majority of students have access to affordable personal devices—including mobile phones, tablets, and laptops. They give students ready access to tools that can connect them with their peers both virtually and in person, encourage cooperation, permit continuation of discussions outside of class, and open up new avenues for engaging with instructors. Instructors should, however, be mindful of potential equity gaps. They need to think creatively about how they are maximizing learning opportunities for *all* students, including those who may not have access to personal devices.

WWC staff and the expert panel assigned a minimal level of evidence based on three studies of the effectiveness of communication tools designed to foster collaboration and build community. One of the studies meets WWC group design standards without reservations,[15] and the two other studies do not meet WWC group design standards.[16] See **Appendix C** for a detailed rationale for the Level of Evidence for Recommendation 1.

This section describes strategies, examples, and tools that can support instructors in effectively using communication and collaboration tools in their courses.

How to Carry Out the Recommendation

The guidance below is informed by the studies that support the recommendation, as well as the expert panel's expertise and knowledge of resources and strategies available to help implement the recommendation.

1. Select communication and collaboration tools that will best support learning objectives.

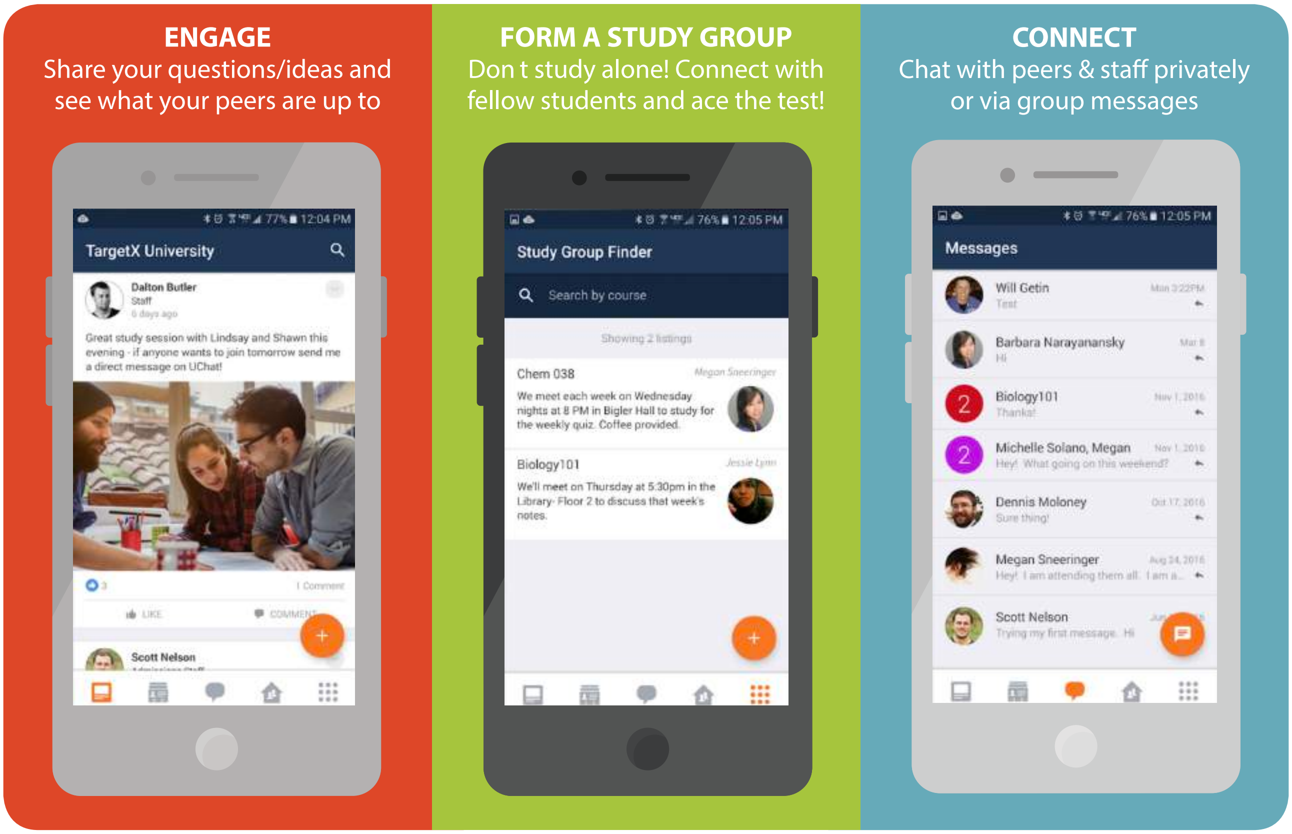
When selecting technologies to support communication and collaboration, instructors should consider which tools are best suited to help students meet the objectives for the course or for individual activities within the course. Among several types of technologies to choose from, instructors might find it helpful to use one or more of the following types of communication and collaboration tools:

	ASYNCHRONOUS	SYNCHRONOUS	SOCIAL NETWORKING
The tool allows users to…	Interact in a time-independent fashion without participants needing to be present at the same time. Can promote collaboration and facilitate group work if tool has features that allow for commenting on and creating and revising of multiple drafts.	Interact in real or same time, and requires all participants to be present at the same time, either face-to-face or virtually.	Form communities or groups around similar interests or goals, and share content both within and outside of their groups.
The tool can be used…	For one-to-one, one-to-many, or many-to-many communications.	To increase communication between students and instructors when they are not physically present in the same location. Can also facilitate remote collaboration among students assigned to work in small groups.	To structure social interaction among users. Communication with these tools can take place synchronously or asynchronously.
Examples	Email, online discussion forums, blogs, wikis, Google Docs, and microblogs such as Twitter or Instagram.	LiveBoard, Google Hangouts, and Zoom. Tools that allow for live or virtual sessions in which users can interact from afar, such as screen sharing, tele- and video-conferencing, shared remote whiteboards, broadcasts of live simulations, and immersive, virtual worlds.	Schools App, Course Networking, Commons In A Box (CBOX), Facebook, and Twitter. Most learning management systems also include features that allow social media–like communication and collaboration tools to be embedded.

For example, Schools App (see **Figure 1.1**) is a social networking tool that allows students on a particular campus to collaborate and communicate during college. Features include a study group finder, group and private messaging, and announcements from the institution.

Instructors should ensure that the use of these tools is not distracting students from their learning goals. Instructors should also check whether any institutional policies restrict the use of social networking tools in the classroom.

FIGURE 1.1. FEATURES OF A SAMPLE MOBILE APP THAT SUPPORTS COMMUNICATION AND COLLABORATION: SCHOOLS APP



SOURCE: https://www.targetx.com/solutions/schools-app/

2. Consider student preferences and levels of access when adopting new technology.

Instructors should consider student preferences and experience when selecting tools to adopt in their courses. Key considerations to keep in mind include the following:

- Students in general are frequent users of mobile phones, tablets, and laptops, but different groups of students might have different preferences and varying degrees of access to these devices.
- Some students might prefer social media technologies such as Twitter to institutional learning management system technologies because they are more familiar with social media technologies.
- Other students might be apprehensive about mixing their personal and academic lives online.

At the beginning of the semester, instructors can survey students on their use of technologies. Survey responses can help instructors to incorporate the tools students are already using or to plan time for students to get used to any unfamiliar technologies selected for the course. Instructors should carefully consider the implications of using communication and collaboration applications that students already use for non-academic purposes. For example, will the distractions of Facebook or Twitter in class outweigh the benefits of using the tool to support learning? Lastly, when instructors tailor course instruction and materials, they should remember the technologies—whether hardware or software—should always support learning goals and objectives.

3. Articulate expectations for when and how students should use communication and collaboration tools, both inside and outside the classroom.

When introducing communication and collaboration tools—even those familiar to students—instructors must be clear about the purpose of using these tools within their course. Instructors should explain that these tools are meant to connect formal and informal learning by extending communication beyond the classroom. And that they can also foster collaboration around similar learning goals and tasks.

Instructors should design discussion tasks to be relevant and integrated with course material, not perfunctory exercises in student participation. Specifically, technology-based communication and collaboration spaces should be treated as important components of the course. Students will benefit from clear expectations about when and how they should use those spaces. When use of these tools factor into instructors' assessments of student performance, grading criteria and rubrics should be shared with students at the beginning of the course.

Instructors should also provide guidelines for interacting respectfully and protecting privacy in communication and collaboration spaces. See **Figure 1.2** for a sample set of guidelines students can receive at the beginning of the course to ensure they are aware of the norms for engaging in respectful behavior and dialogue and for protecting student information and privacy.

FIGURE 1.2. SAMPLE STUDENT GUIDELINES FOR INTERACTING ONLINE AND PROTECTING PRIVACY

- ✓ Be mindful of what you post. Anything posted will be permanently recorded online, so consider the impact that your words will have on others.
- ✓ Protect your own information. Carefully review your privacy settings and consider how these settings affect who can and cannot view your content. Make adjustments to your settings as needed, and revisit your settings frequently.
- ✓ Protect the information of others. Be mindful of any posted content that may reveal information about others. This can include students' names and more general information such as their majors, addresses, social activities, and religious/political affiliations.
- ✓ Respect the diversity of the student and faculty body. Remember that other students and faculty will have different viewpoints on religious, political, and social issues. Try to be as objective as possible and respectful when discussing these issues.
- ✓ Give credit to others for their ideas and work. Also, remember to appropriately reference any direct quotes used from other sources. Not doing so is considered plagiarism.
- ✓ Notify your instructor if you see posts or content that you think is disrespectful or makes you feel uncomfortable in any way.
- ✓ Familiarize yourself with campus resources and policies on protecting student and faculty privacy and security.

SOURCE: Adapted from SANS.org guidelines on securely using social media: https://www.sans.org/security-awareness-training/resources/top-tips-securely-using-social-media

4. Seek information about communication and collaboration technologies currently available on campus, and determine whether there is guidance and support for using them.

Instructors should check with other instructors and staff at their institution for existing resources, such as teaching and learning centers. Instructors can ask instructional designers about the availability of technologies that support communication and collaboration, as well as which are most popular among students and other instructors. For example, instructors can request learning management system usage data to help determine whether they should use communication functions within the system or look for alternative tools.

Instructional designers might know whether the university has resources available to acquire additional technology that may be of use to instructors and students. They should also be able to tell instructors about any available guidance or training related to the effective use of such technologies to support teaching and learning.

5. Monitor student participation, and provide facilitation and feedback as needed.

Communication and collaboration tools that enable discussion forums and blogging can be used to provide students the opportunity to write reflectively, discuss learning experiences, and react to the experiences of classmates. Instructors can model desired behaviors; then if students are not engaging or contributing as expected, instructors can redirect them or provide additional support.

When monitored and supported by instructors, communication and collaboration tools can facilitate knowledge building and knowledge sharing and also be effective in supporting active learning.[17] In addition, such tools provide students with additional options to communicate with one another and the instructor, making them more likely to engage in conversations. Instructors should encourage contributions from all students and discourage negative exchanges, such as bullying or unhelpful criticism, when they occur. In the online course setting, instructors must be diligent in monitoring communication boards and following up with students.

6. **Assess what is working (and what is not).**

Instructors should assess whether the selected communication and collaboration tools are effectively supporting interaction among students and between students and instructors. Answers to the following questions give insight on the quantity and quality of interactions:

- Who participates in the conversations, and are there any distinguishing characteristics between those who do and do not participate?
- Is the instructor able to respond to students in a timely fashion?
- Are students engaging in meaningful conversation on the communication boards?
- Is teamwork improving—for example, as gauged by the quality of group work and projects?

Instructors should continuously revisit the learning outcomes of their courses and ensure any collaborative activities and communications they use align with—and support—these outcomes. Instructors should tap into resources at their institutions for help staying abreast of new technologies that might be able to further facilitate communication and collaboration in their courses.

Potential Obstacles and the Panel's Advice

OBSTACLE: *Instructors might not be familiar with the technologies that can effectively foster communication and collaboration.*

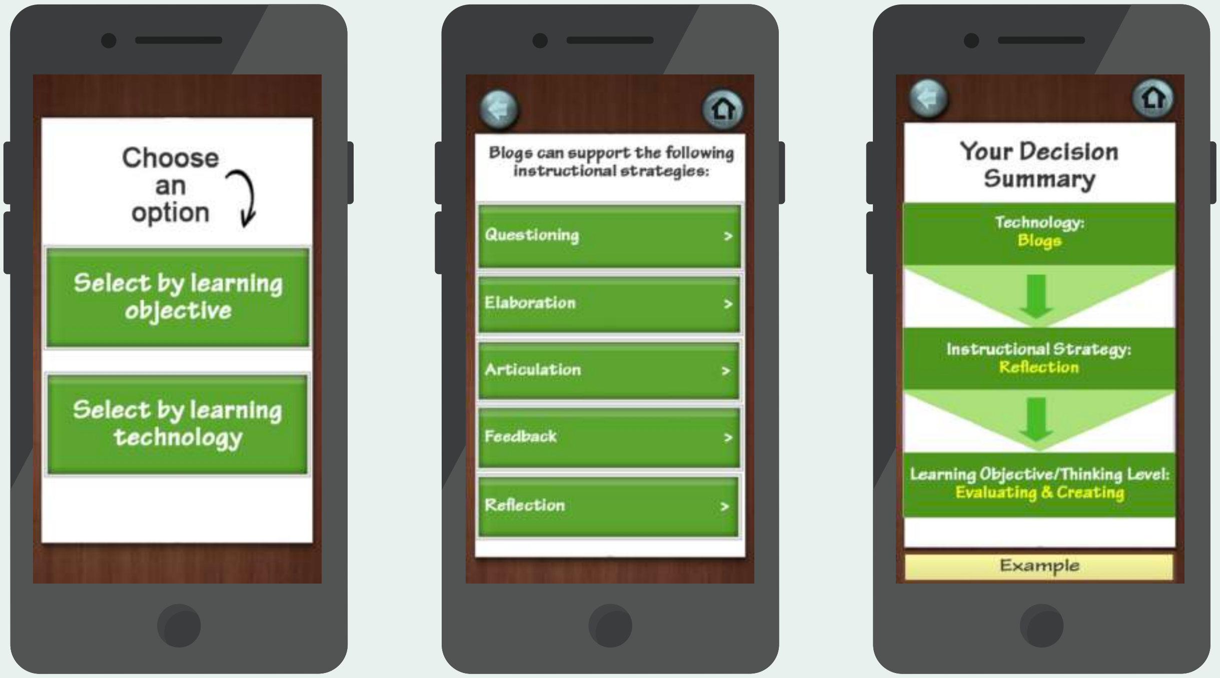
PANEL'S ADVICE: Professional development programs at both the campus and department level should feature workshops and trainings on technologies, including those that enhance communication and collaboration. Instructors can consult with teaching and learning staff and/or instructional design centers at their institution to get one-on-one guidance for selecting and implementing these tools in their courses.

Instructors can also consult publically available resources, such as the examples featured in Figures 1.3 and 1.4. The Tech Select Decision Aide, featured in **Figure 1.3**, can be used to guide the selection of instructional technologies, including communication and collaboration tools.

EDUCAUSE, a nonprofit association whose mission is to advance higher education through the use of information technology, offers several types of research and publications. Its "7 Things You Should Know About" series (see **Figure 1.4**) includes briefs on communication and collaboration tools.

FIGURE 1.3. EXAMPLE OF A TOOL THAT SUPPORTS SELECTION OF INSTRUCTIONAL TECHNOLOGY: TECH SELECT DECISION AIDE

Tech Select Decision Aide – Each technology, like any tool, has its advantages and disadvantages. Choosing the wrong technology can lead to frustration, unnecessary time expenditures, and can negatively impact the user experience. The Tech Select Decision Aide seeks to optimize the selection process so that instructional designers, trainers, faculty, and other educational professionals will be more prepared to meet the training needs of their end users. Tech Select is available as a mobile app or through the web-based Learning Asset Technology Integration Support Tool (LATIST).



SOURCE: http://cehdclass.gmu.edu/ndabbagh/resources/TechSelectApp6.2/TechSelectApp6.2/index.html

FIGURE 1.4. EDUCAUSE'S "7 THINGS YOU SHOULD KNOW ABOUT" SERIES

EDUCAUSE has a collection of concise briefs that summarize emerging technologies and practices and answer the seven following questions:

1. What is it?
2. How does it work?
3. Who's doing it?
4. Why is it significant?
5. What are the downsides?
6. Where is it going?
7. What are the implications for higher education?

The briefs on Collaborative Learning Spaces, Video Communication, and Assessing Online Team-Based Learning might interest instructors exploring communication and collaboration tools to adopt in their courses.

SOURCE: https://www.educause.edu/research-and-publications/7-things-you-should-know-about

OBSTACLE: *Instructors might feel overwhelmed by managing the added workload of responding to communications with students, especially if they are using multiple technologies to support asynchronous and synchronous social interactions.*

PANEL'S ADVICE: Instructors should not feel that they need to respond to every student post in online discussions. However, it is worth taking a few minutes to highlight key contributions—both constructive and problematic—and to model the difference between productive and less productive contributions. When possible, they can use self-assessment, peer assessment, and peer evaluation to alleviate their workload. They also can limit the number of posts and amount of text per post. In large courses, instructors can also ask teaching assistants to help with monitoring and responding to student communications.

Assigning students as discussion facilitators is another strategy. The strategy is most effective if the instructor creates multiple discussion forums with fewer numbers of students each. Doing so makes the instructor a more efficient facilitator of student-to-student exchanges; it also encourages students to own and engage in the learning process.[18]

OBSTACLE: *Student participation and engagement with communication and collaboration tools is limited.*

PANEL'S ADVICE: Students may be resistant to the use of communication and collaboration platforms that instructors put in place for course activities and assignments. This resistance can stem from a reluctance to use new and unfamiliar tools and/or a dissatisfaction with the interface of the tools. The latter can be addressed by structuring asynchronous communication and requiring participation through the use of evaluation rubrics and instructor guidelines; guidelines can also be developed for active participation when using synchronous communication and collaboration tools.

If students are reluctant to take up new technologies, instructors can leverage the tools that students are already using or are familiar with. This can increase the likelihood that they may be more comfortable and willing to use those tools to communicate with other students and instructors.

OBSTACLE: *Privacy concerns can discourage instructors and students from using communication and collaboration tools.*

PANEL'S ADVICE: Sharing information online via communication and collaboration tools can pose some risk to the privacy of both students and instructors. That risk understandably might make some students and/or instructors uncomfortable, and instructors should carefully consider these concerns before adopting such tools for their courses. Both instructors and students should be aware of and use strategies to protect themselves online. Sample privacy protection guidelines are featured in **Figure 1.2** (above). Instructors should be as transparent as possible about their instructional use of communication and collaboration tools, particularly social media, and allow concerned students to opt out of using them.

Recommendation 2: Use varied, personalized, and readily available digital resources to design and deliver instructional content.

With instructor support and appropriate pedagogy, technology can help create productive educational experiences for larger numbers of students and a more diverse student population.[19] Traditional course formats and materials, on the other hand, can limit access to educational opportunities. Approaches to teaching and learning that require students to be in a specific place, at a specific time, and for a fixed duration necessarily bound opportunities for interaction. Those boundaries can limit the ways in which students work with both faculty and peers to solve problems, seek help, or engage deeply with content in and out of the classroom. Similarly, familiar educational resources, such as textbooks and readings, limit how content can be presented to students and how they can process that content.

The panel recommends that institutions of higher education leverage technology to help students learn more productively by:

- **(Recommendation 2a)** varying, blending, or accelerating course formats; and
- **(Recommendation 2b)** packaging course content to minimize cost, maximize accessibility, and accommodate different learning preferences.

Recommendation 2a focuses on the format of an entire course. Specifically, administrators can encourage instructors and instructional designers to use technology to create blended or flipped courses, in which some lecture material and other course content are delivered online. These formats may preserve more class time for hands-on and other experiential activities, group assignments, and individualized instruction, rather than for lecture. Such formats can also be used to accelerate instruction; for example, by allowing students to accelerate their completion of a course of study or to transition more quickly from developmental to credit-bearing courses.

Recommendation 2b focuses on interventions that can be applied at either the course or the module level. Technology can be used to package content in multiple ways that help students access and study course materials. This is especially true when the interface is interactive, flexible, and offers multiple ways and times for students to access the content. Students' understanding of course content can be deepened by providing them with digital representations of that content that help them visualize complex processes. Course interfaces can also include digital review and study tools, such as podcasts, that provide multiple ways for students to access and study course material.

WWC staff and the panel assigned a moderate level of evidence based on 16 studies. Eleven studies meet WWC group design standards without reservations.[20,21] Five studies meet WWC group design standards with reservations.[22] See **Appendix C** for a detailed rationale for the Level of Evidence for Recommendation 2.

SPOTLIGHT ON IMPLEMENTATION: ACCELERATED BLENDED LEARNING

The Open Learning Initiative (OLI) project at Carnegie Mellon University provides free, online course content to students in a variety of subjects. OLI is an open education resource that can be used to structure courses in an accelerated, blended format rather than a traditional, face-to-face format. The OLI-Statistics course at Carnegie Mellon University covers introductory statistics topics, allows students to practice applications of those topics, and provides immediate and targeted feedback on understanding of topics. The 8-week OLI-Statistics allows students to accelerate course completion, while the traditional face-to-face version of the course takes 15 weeks to complete. Students in the OLI course also meet with an instructor twice a week in 50-minute sessions to ask questions and review challenging material.

The **OLI-Statistics** course provides most of its instructional content online. Course topics are presented in a hierarchy, visible from a navigation bar on the left side of the webpage. Instructional content includes short visual animations of statistical concepts with narration. At key transitions between topics, the system reminds students of how statistical concepts connect with one another. The system provides multiple opportunities for practice throughout each lesson, including:

- Comprehension questions;
- Real-life situations to test understanding;
- Short-answer reflection questions; and
- A tool to experiment with statistical properties such as the mean and median.

"Mini-tutors" give students real-time hints and feedback as they practice their skills.

Study Findings: Lovett and colleagues (2008) report the impact of the flipped classroom format on the comprehensive assessment in statistics course measure was positive and statistically significant.

SPOTLIGHT ON IMPLEMENTATION: DIGITAL VISUALIZATION THROUGH TIME COMPRESSED ANIMATED DELIVERY

Time Compressed Animated Delivery (TCAD) is a method of presenting information using two- and three-dimensional animations. This method is particularly well suited for teaching students about complex processes covered in science courses. TCAD was used by Trevisan, Oki, and Senger (2010) to deliver an animated digital representation of follicular dynamics, a key process in reproductive physiology that often confuses students because it is a cyclic change in anatomy that is integrated with other complex physiological processes. Trevisan and colleagues used a 17-minute TCAD video on follicular dynamics in an undergraduate reproductive physiology lecture. They followed these steps to develop the TCAD video:

1. Storyboarding to visualize the instructional design;
2. Producing step-animations by starting with static images that can then be animated according to storyboard specifications and synchronized with voice-over descriptions of the topic; and
3. Developing 3-D anatomical models with the appropriate texture, transparency, and lighting, which are then animated.

Study Findings: The impact of the animated presentation on students' academic achievement was positive and statistically significant.

How to Carry Out the Recommendation

The guidance below is informed by the studies that support the recommendation, as well as the expert panel's expertise and knowledge of resources and strategies available to help implement the recommendation.

Applies to Recommendation 2a

1. Leverage technology to vary the format for delivering courses.

A variety of options exist to structure a course in ways that differ from traditional classroom instruction. Blended learning formats, which provide a combination of online and classroom instruction, can leverage the advantages of each instructional delivery approach. This provides students with opportunities both to learn at their own pace and on their own time and also to interact with an instructor and peers online and in person during face-to-face classes.

Flipped classroom models used in blended settings provide lecture material outside of class time, often through videos and podcasts, allowing students to learn and process lesson content at their own pace. This frees up class time for hands-on activities, group assignments, and learning experiences tailored to the preferences and interests of different students.

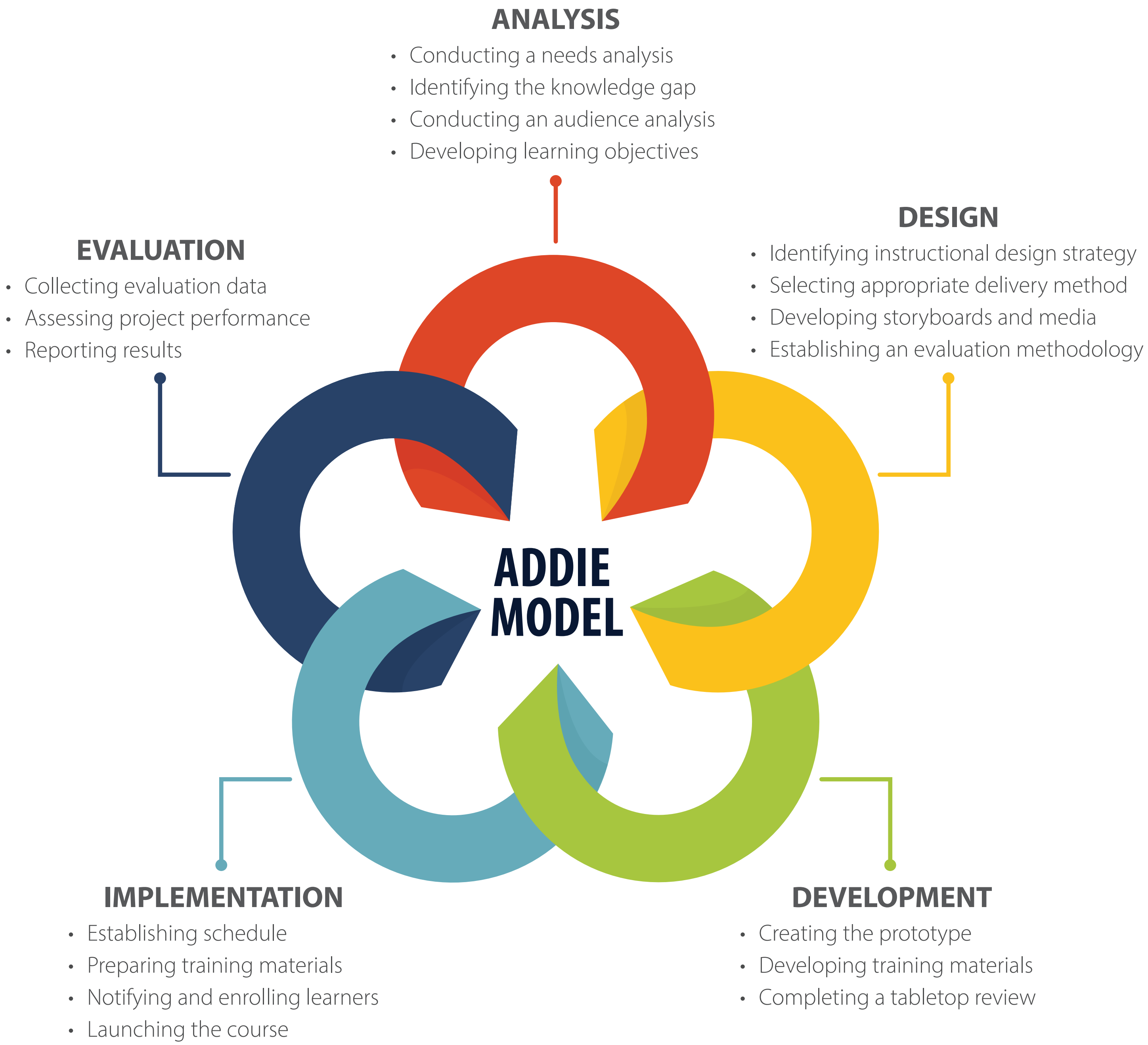
Interactive online course modules provide asynchronous online instruction that can be structured to provide students the benefit of immediate feedback through adaptive learning features. As appropriate, instructors can also use technology to encourage self-paced learning or to accelerate instruction, allowing students to speed the completion of a course of study or to catch up with the rest of their cohort.[23]

Instructional designers may be more aware of information about the effectiveness of available technologies than are instructors. Designers can collaborate with instructors to help them select course delivery structures that are appropriate for the content of the course and the students taking the course. They also can help instructors plan and implement blended and flipped course formats. Further, they can guide instructors in their selection of online course activities, including interactive modules that provide students feedback as they navigate the lesson content.

The ADDIE (Analyze, Design, Develop, Implement, Evaluate) model offers a framework for designing and developing education and training programs. Instructors and instructional designers can use ADDIE to develop flexible course delivery formats—and appropriate content and materials—that align with course goals and objectives. The ADDIE model, a five-phase course-development process created in the 1970s by Florida State University for the U.S. military, is featured in **Figure 2.1**.

There are several considerations in planning for online education, including those related to institutional context, available finances, and hardware and software. Key considerations for planning online instruction (adapted from Picciano, 2015) are summarized in **Figure 2.2**.

FIGURE 2.1. THE ADDIE MODEL: A SAMPLE FRAMEWORK FOR DEVELOPING COURSES



SOURCE: http://www.elearning.niu.edu/services/onlinecoursedev.shtml

FIGURE 2.2. SAMPLE CHECKLIST FOR PLANNING ONLINE EDUCATION

PLANNING FOR ONLINE EDUCATION

- ✓ **Environmental Scanning –** An external review of the educational environment is needed to ensure that technology is appropriate, does not become obsolete quickly, and addresses key considerations in higher education, including (a) enrollment patterns such as expanding enrollment and expansion of life-long learning, (b) student retention, (c) rising tuition and student loan debt, (d) government oversight and accountability, and (e) commoditization of higher education.

- ✓ **Developing Goals –** Institutional, educational, and social goals of an institution should be considered. For example, goals for online education may include an expansion of social life, attainment of more research grants, or increasing an institution's research profile. No two campuses have the same goals.

- ✓ **Online Education Applications –** In addition to fully online, massive open online course (MOOC), and blended learning applications, online education applications can include (a) adding learning analytics software to monitor student progress, (b) making greater use of social media software in existing courses, (c) integrating mobile technologies in instruction, (d) creating genres of courses with blended or flipped classrooms, (e) adding adaptive learning software to learning environments, and (f) undertaking blended learning initiatives in areas such as STEM that have more specific or complex learning needs.

- ✓ **Hardware –** Hardware needs are generally straightforward, and must support a network size appropriate for the application. Additional considerations include (a) use of mobile devices instead of laptops in classrooms and (b) supporting faculty acquisition of laptops.

- ✓ **Software –** Most colleges and universities use a learning management system (LMS). Regardless of which LMS a college chooses, substantial in-house programming and systems support is needed. An LMS should be integrated with a college's database to allow for the efficient transfer of course and student data. Third-party vendors may also be contracted to develop online courses and MOOCs.

- ✓ **Staff/Faculty Development –** Faculty "buy in" is critical to the success of any technology application. By involving staff and faculty in the planning and decision-making process, colleges can roll out technology-enabled courses and course enhancements more effectively. Staff training and support (e.g., one-on-one coaching, incentives) can facilitate the take-up of new technologies.

- ✓ **Facilities and Infrastructure –** Central technology supports such as campus-wide wi-fi and help desk support are needed to successfully implement online courses, as is instructional design support to help instructors transition to new course delivery modalities.

PLANNING FOR ONLINE EDUCATION CONTINUED

- ✓ **Finances –** Online education initiatives require funding, which can be substantial with bold new initiatives or relatively modest with incremental enhancements. While online education may expand course enrollment, results are mixed as to whether these technologies can improve a college's financial position. Finances must also be carefully monitored and a contingency plan made when working with third-party vendors, who may overpromise and under-deliver on their products.

- ✓ **Policies –** Existing policies should be reviewed to ensure that those related to curriculum approval, workload, intellectual property, accreditation compliance, faculty observations, and evaluations are not infringed upon. Colleges should also be aware of external compliance issues, such as Section 504 of the Rehabilitation Act of 1973 and the Americans with Disabilities Act (ADA) of 1990. Although most major learning management systems are accessible to students with disabilities, this should be monitored. Moreover, copyright infringement laws should be reviewed before developing or expanding online education.

- ✓ **Evaluation –** Evaluation criteria should be developed that relate to the goals and objectives of the online education application. The data capture capabilities of online and blended learning have opened up new areas of evaluation. For example, instructional transactions on blogs, discussion boards, and wikis can be measured and monitored. Faculty experiences with new technologies should also be monitored, and continued long after initial implementation.

SOURCE: Adapted from Picciano, A.G. (2015). Planning for Online Education: A Systems Model. Online Learning Journal, 19(5), 142-158. https://onlinelearningconsortium.org/jaln_full_issue/online-learning-journal-volume-19-issue-5-december-2015/

Applies to Recommendation 2b

2. Plan instruction so that course content is carefully packaged and sequenced, and use technology to scaffold students' acquisition and application of the content.

Instructors who wish to adopt blended or flipped course formats should ensure the course content is suitably matched to the selected course structure and delivery modalities. In doing so, instructors decide which content will be covered in online modules, in class, or in both learning environments. Instructors who are accelerating a course using a restructured format should ensure that the material of that course is conducive to a condensed schedule. All instructors should also consider how to extend learning by using communication and collaboration tools to prompt or continue discussions outside of class sessions (see **Recommendation 1**).

Instructors must also consider their method(s) for delivering content. Very complex material being introduced for the first time might be effectively delivered via an audio podcast with accompanying visuals, as opposed to an audio-only podcast, for example. Instructors can accommodate students' varied learning preferences by offering multiple pathways to learning the same material. One way to do this is to package content in more than one format. Instructors can provide content in both video and print formats, giving learners some control over the media they use to consume the information. When students are learning through online modules, instructor-led sequencing of the information presented can serve as a scaffold to support student learning.[24]

With support from their colleagues or instructional designers, instructors should aim to incorporate multiple media formats throughout the duration of a course. By presenting material in multiple ways, instructors may help students develop mental representations, reduce their cognitive load, and test their understanding of content. Students' understanding of course material may be deepened through engaging in interactive online modules or by viewing simulations or visualizing content in new ways. Technology such as podcasts, instructional videos, and other online media may be used to maximize efficiencies in students' review of course material and homework. Students can also use technologies to demonstrate their understanding and apply their knowledge.

Tutorials to help instructors learn about instructional design principles for packaging, sequencing, and delivering course material via technology can supplement on-campus professional development on course delivery technologies. Course content can often be embedded in learning management system platforms. Instructors also can guide students to access content from Open Educational Resources, including resources available from both internet and intranet sites.

Applies to Recommendations 2a and 2b

3. When varying course formats or course packaging, instructors should clearly communicate expectations for what students should do during the course.

In addition to describing a course's goals and objectives, instructors must explain its format and modes for delivering its content. They also should describe their expectations for what students need to be prepared to do before, during, and after class sessions. For example, if the instructor is adopting a flipped classroom model, students need to understand the amount of study and preparation that will be required of them before and during those face-to-face sessions.

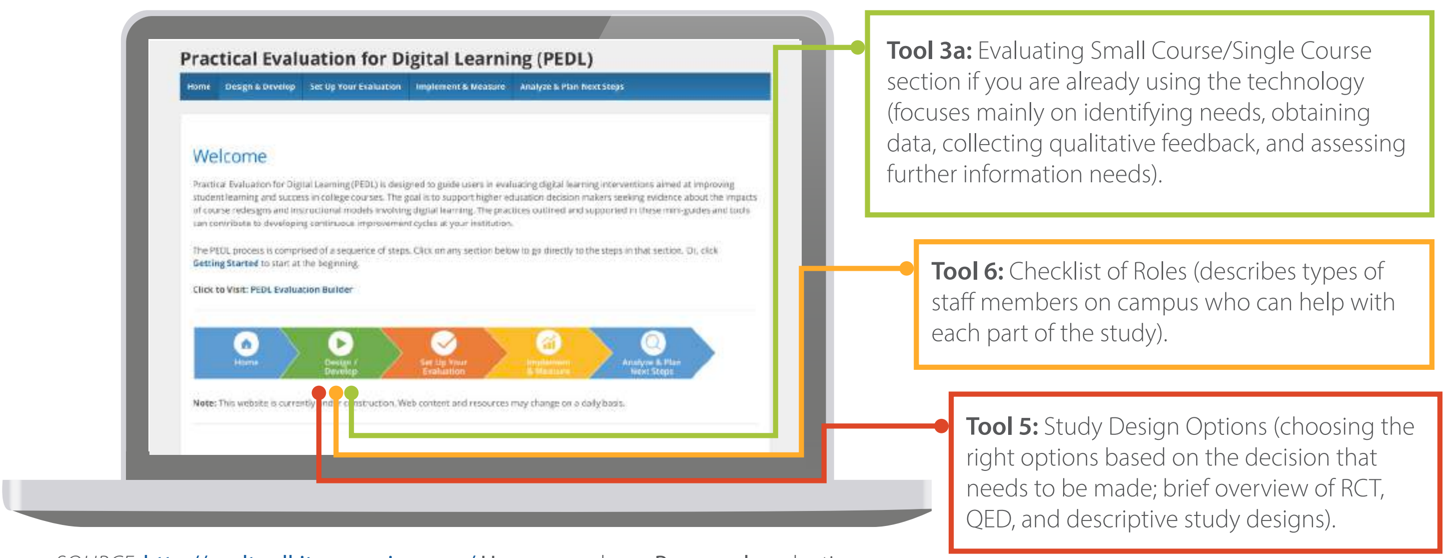
Instructors might plan to primarily follow a traditional face-to-face format but also incorporate various technologies to deliver or review course content. They should demonstrate to students how they are expected to use those technologies to support their learning or complete assignments. For example, instructors who incorporate content from an adaptive learning course should explain not only how students access its learning modules, but also how students' completion of—and feedback from—those modules connects to other course activities and assignments.

Instructors should develop and share grading rubrics with students so they know what they must do to demonstrate successful class preparation, participation, and reflection in both online and face-to-face learning environments.

4. Monitor and evaluate the effectiveness of course formats and use of multimedia to deliver content.

Instructors, department heads, and administrators share responsibility in monitoring and evaluating the effectiveness of the course formats and delivery modes used to engage and teach learners. Together, they can determine which instructional approaches should be continued—or discontinued—with future student cohorts. The Practical Evaluation for Digital Learning (PEDL) toolkit offers guides on how each of these stakeholders can evaluate digital learning interventions.[25] The PEDL process and examples of tools included in the PEDL toolkit are shown in **Figure 2.3**.

FIGURE 2.3. SAMPLE TOOLKIT FOR EVALUATING DIGITAL LEARNING INTERVENTIONS: PRACTICAL EVALUATION FOR DIGITAL LEARNING (PEDL)



SOURCE: http://evaltoolkit.wpengine.com/ **Username:** demo **Password:** evaluation

Potential Obstacles and the Panel's Advice

OBSTACLE: *Instructors might find it difficult to design or adapt course materials that apply new technologies, especially if administrators are unable to provide resources to support such efforts.*

PANEL'S ADVICE: It is essential that good design principles be applied prior to restructuring a course to use technology. Administrators can lead collaborative design efforts. Such efforts might include working with an instructional designer to develop or adapt a range of tools for instructors to use, and then training instructors on how to use those tools effectively. As available, instructors can be supported by a campus's center for teaching and learning staff, who can provide guidance on how to apply good design principles to technology-supported course formats. Instructional designers can also share their knowledge of which content creation and delivery technologies are popular amongst other instructors. Designers also can share any insight they have about which multimedia formats align with students' varying learning preferences.

When developing courses that include online lessons or activities, instructors can borrow or adapt existing materials if they lack the time and resources to develop new materials. With the help of instructional designers, instructors can integrate into their courses openly available content, such as examples from YouTube, Creative Commons, MERLOT, or SkillsCommons. An overview of the resources available in MERLOT is provided in **Figure 2.4**.

The MERLOT collection consists of tens of thousands of discipline-specific learning materials, learning exercises, and Content Builder webpages. All of these items have been contributed by the MERLOT member community. Some contributors have authored the materials themselves. Other contributors have discovered the materials, found them useful, and wished to share their enthusiasm for the materials with others in the teaching and learning community. MERLOT also offers a customized search engine for educators that searches more than 60 other free and open online libraries of teaching materials as well as the web.

Instructors who want the ability to personalize course material can focus on resources and tools that allow them to customize content delivery. Some Open Educational Resources materials can be used to customize content, instead of instructors building content from scratch.

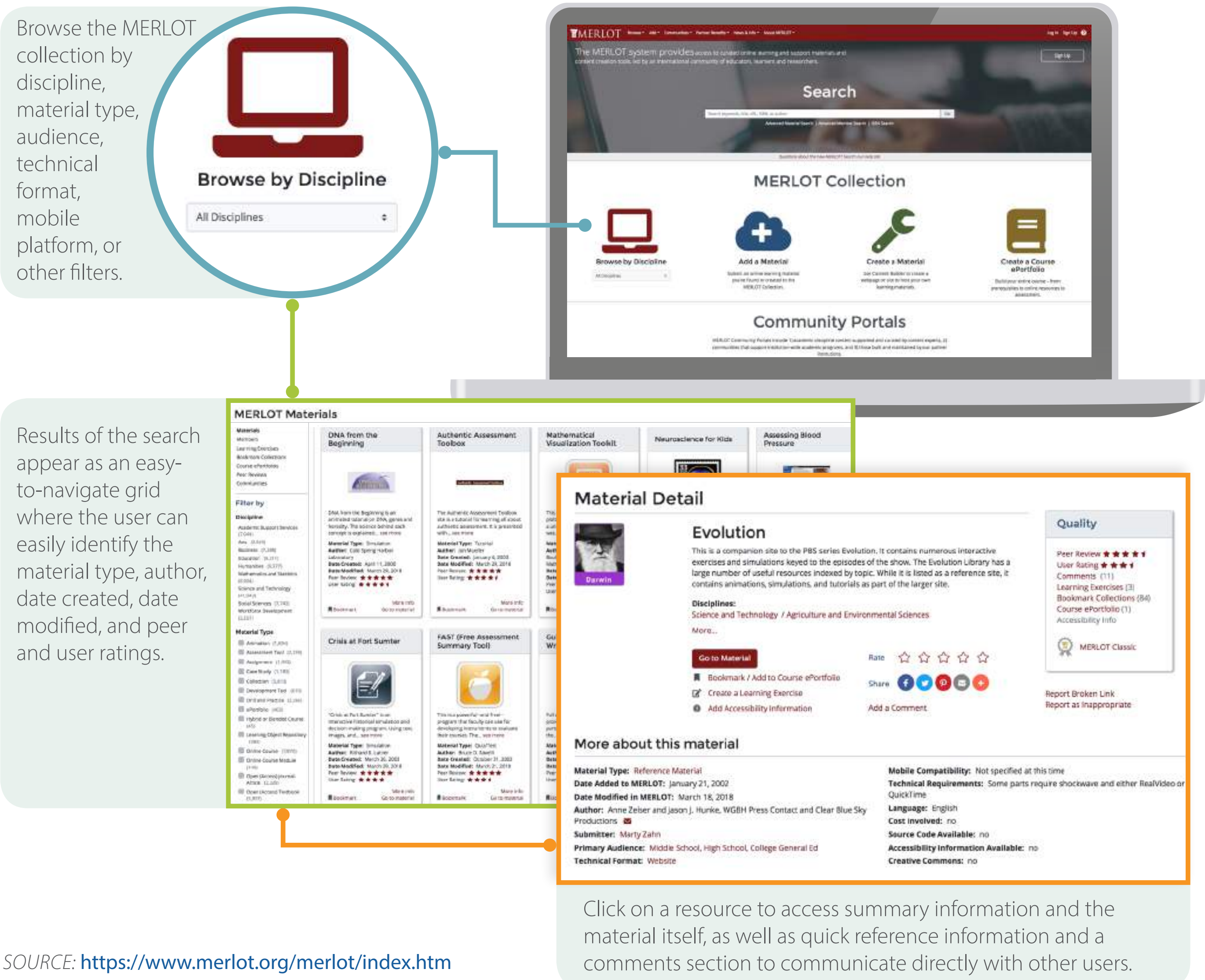
OBSTACLE: *Students' focus on the content of a lesson could be compromised if they are preoccupied learning how to use new technologies.*

PANEL'S ADVICE: Students may be unfamiliar with the latest technologies. Instructors should consider leveraging technology that students have already used or that students will find intuitive. Instructors also should consider using technologies that are widely used on campus, as these might come with more help desk support either from campus instructional design or technology staff or from the developers of the platform or software.

At the beginning of the semester and as needed throughout it, instructors should provide students with an orientation to each of the technologies they use, as well as information about where to get help if they encounter difficulties using it. When learning a new technology is a course objective, such as when students in a communications course are expected to know how to use social networking effectively, instructors should provide students with practice opportunities to develop fluency with the technology.

FIGURE 2.4. SAMPLE REPOSITORY OF OPEN EDUCATIONAL RESOURCES: MERLOT (MULTIMEDIA EDUCATIONAL RESOURCE FOR LEARNING AND ONLINE TEACHING)

The MERLOT collection consists of tens of thousands of discipline-specific learning materials, learning exercises, and Content Builder webpages, together with associated comments, and bookmark collections, all intended to enhance the teaching experience of using a learning material. All of these items have been contributed by the MERLOT member community, who have either authored the materials themselves, or who have discovered the materials, found them useful, and wished to share their enthusiasm for the materials with others in the teaching and learning community. MERLOT also searches over 60 other free and open online libraries of teaching materials as well as the web with a customized search engine for educators.



SOURCE: https://www.merlot.org/merlot/index.htm

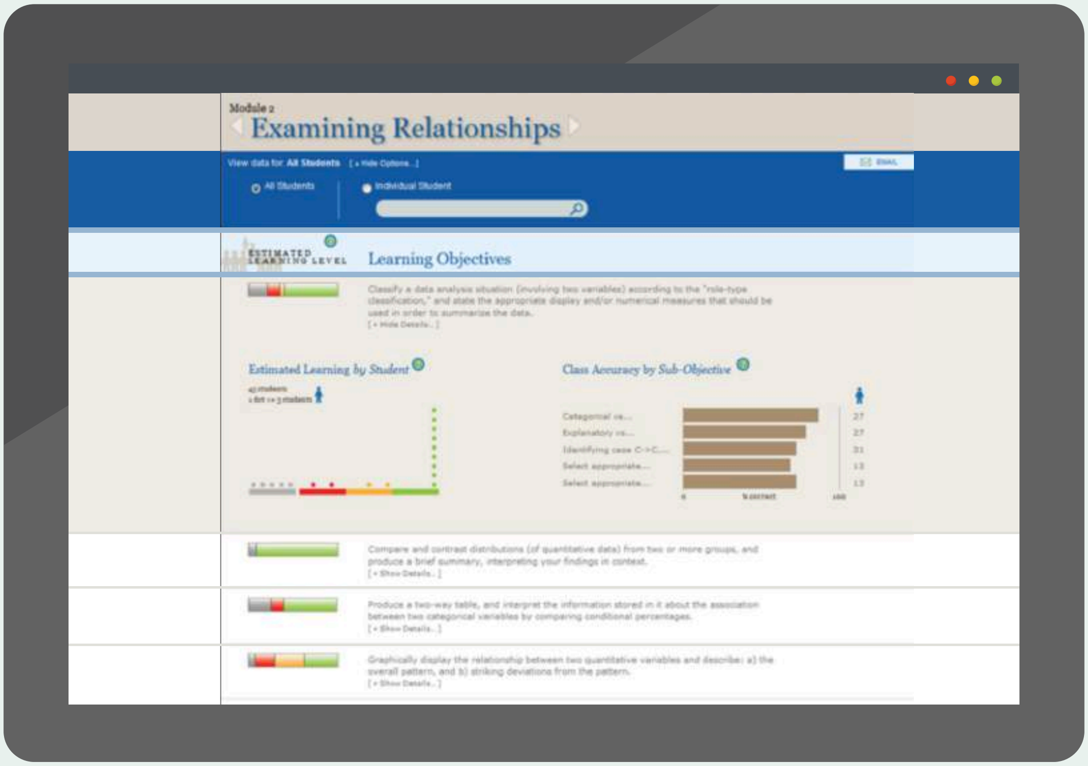
OBSTACLE: *Because technology affords students the opportunity to learn more on their own time, it might be difficult to quickly identify students who are not learning effectively with new technologies.*

PANEL'S ADVICE: Progress monitoring is important regardless of whether a course is delivered online or in a traditional format. There are some technologies that can make it much easier for instructors to identify students who are at risk of poor performance. For example, instructors of students completing modules through the Open Learning Initiative have access to real-time feedback and data provided to students.[26] Instructors then can use these data to identify students in need of targeted interventions or extra support.

A sample Open Learning Initiative "learning dashboard" available to instructors is featured in **Figure 2.5**. Instructors can also work with instructional designers to learn how to use learning management system data to track student engagement with course materials. Further, instructors should work with students to help them learn how to read and interpret their own activity data, including giving them benchmarks of how much time on task is associated with above average and excellent performance.

FIGURE 2.5. SAMPLE OPEN LEARNING INITIATIVE (OLI) LEARNING DASHBOARD

Data from student activities and assessments are displayed in OLI's Learning Dashboards, which are specific to each course. Each Learning Dashboard includes information about student participation and performance at both the class and individual-student level. OLI recommends reviewing its Learning Dashboard before each class session and allocating in-class time to either address difficult topics with which students are struggling or push forward with more challenging material if data suggest students are excelling with the previous concepts.



SOURCE: http://oli.cmu.edu/get-to-know-oli/course-features/

OBSTACLE: *Some students might not be able to afford the devices such as smartphones or laptops needed to access education materials, a shortcoming often referred to as the "digital divide."*

PANEL'S ADVICE: In designing and providing instructional material that students will use online, designers and instructors must understand who their students are and their access to technology. Many colleges and universities survey new students to determine the nature and extent of their access to internet technology for the purpose of informing campus investments. As a result, many colleges and universities provide expanded access to technology facilities on campus. Though a step in the right direction, campus access is not comparable to access at home where students can conveniently engage in course activities anytime day or night and as frequently as they wish.

At the beginning of the semester, instructors should invite students to fill out a survey to report whether they currently use or have access to the technologies that will be used in the course. This helps instructors understand and plan for the needs of the overall class around access and fluency with the selected technologies.

When feasible, instructors should select technology that students can access at low or no cost, or be prepared to help seek institutional support for students who need financial help to access it. Faculty should have conversations and explore options with administrators, the campuses Information Technology department, and relevant student support offices such as Financial Aid in advance of adopting technology whose costs may be passed on to students. Pedagogy First, featured in **Figure 2.6**, is an example of a free tool that supports technology selection. Users can use the tool's screening function to quickly identify technologies that are free for instructors and students.

FIGURE 2.6. SAMPLE TOOL TO GUIDE SELECTION OF TECHNOLOGY: PEDAGOGY FIRST

The Pedagogy First tool created by the Grand Canyon University - Center for Innovation in Research and Teaching provides a decision tree to help instructors select a specific technology that meets their pedagogical needs. Users can search for specific technologies they are already familiar with, or they can answer a series of questions to narrow down the list of available technologies.

As users select what they hope to accomplish with the integration of technology, levels of student and instructor expertise with technology, and how much time the instructor can dedicate to initial setup, the number of resources matching the user's selections is updated and technology recommendations are provided.

SOURCE: Mandernach, B. J., Love, H., Williams, B. & Brooks, J. (2016). Pedagogy First. Center for Innovation in Research and Teaching, Grand Canyon University. Available at: https://cirt.gcu.edu/pedagogyfirst

Recommendation 3: Incorporate technology that models and fosters self-regulated learning strategies.

The panel recommends using technologies that facilitate the incorporation of self-regulated learning into all learning environments, including face-to-face, blended, and online course delivery formats, as a way to help students successfully self-direct their engagement with course content and learn more effectively.[27] Self-regulated learning is a process in which students understand and control their own learning. It is driven by meta-cognition, which involves thinking about one's thinking, strategic actions such as planning and self-monitoring, and self-efficacy and motivation to learn.

Effective learning depends on knowing how to learn and to manage one's own learning processes. Some students gain these skills prior to enrolling in college, but many do not. Those who do not often struggle once in college, where instructor supervision can be minimal and students have considerable autonomy in their educational activities. They may lack awareness and understanding of their own learning processes and struggle to self-direct their learning activities. Online and blended learning environments can magnify these challenges because they can require extra levels of self-direction, organization, and planning from the student.[28,29]

To address these challenges, technology can be used to activate or scaffold the following self-regulation skills:[30]

- **Goal setting:** Prompts can be embedded in online courses, or in text messages outside of a face-to-face class, to encourage students to set learning goals. For example, rubrics may accompany activities to help students understand how to successfully meet the expectations of the task at hand.
- **Strategies to organize, code, and rehearse information:** Note-taking features can be incorporated into learning modules, or note-taking applications can be provided on a course learning management system. Concept mapping tools can be used to help students organize and comprehend large amounts of information. Reminders delivered via email, text message, or smartphone can prompt students to study or rehearse. Examples of these features can be found in the ***"Spotlight on Implementation"*** below.
- **Self-monitoring:** Online interactive modules can be programmed to model ways to self-monitor by asking students to record reflections on their thought processes or justifications for their answers. Modules can also be programmed to help students keep track of their study time.
- **Self-evaluating and self-correcting:** Web-based courses or modules can provide flexible ways for students to self-evaluate through embedded knowledge checks, or they can be programmed to provide clues for self-correcting. Embedded knowledge checks appear within the learning material. They can aid learning without increasing students' cognitive load, while also providing students with immediate feedback on which content they have mastered or need to continue reviewing.
- **Help-seeking:** Web-based modules or courses, course and learning management systems, communication and collaboration tools, content creation and delivery tools, social media, and the like, can all be used to foster help-seeking by providing easy access to both online resources and tutoring supports.

- **Time planning and management:** Myriad applications are available for use in web-based modules, course and learning management systems, and smartphones, such as task reminders embedded in calendars or visualizations of timelines.

WWC staff and the panel assigned a moderate level of evidence based on four studies that examined the effectiveness of various strategies to foster or activate student self-regulation. All four studies meet WWC group design standards without reservations.[31] See **Appendix C** for a detailed rationale for the Level of Evidence for Recommendation 3.

SPOTLIGHT ON IMPLEMENTATION: NOTE TAKING AND SELF-MONITORING PROMPTS TO SUPPORT SELF-REGULATED LEARNING

Note taking is a critical skill for postsecondary students. Taking good notes enables students to effectively encode information and refer back to it later. Kauffman and colleagues (2011) investigated how note-taking methods and self-monitoring prompts interact and influence students' collection, organization, and integration of online information, as well as achievement. Students took notes on a web-based article on educational measurement. Students were assigned to use one of three note-taking methods—conventional, outline, or matrix. As they proceeded through the educational measurement article, some of the students received electronic self-monitoring prompts, and corresponding questions, like:

> "There was a lot of information covered on that webpage. Now would be a good time to ask yourself if you have collected all the important information. If you believe you can answer the question below, even with your notes, then you are probably ready to move on to the next section. Otherwise you may want to return to the Central Tendency and Dispersion page."

Study Findings: The impact of online note taking using the matrix method on student achievement was positive and statistically significant, while the outline method had indeterminate effects.

How to Carry Out the Recommendation

The guidance below is informed by the studies that support the recommendation, as well as the expert panel's expertise and knowledge of resources and strategies available to help implement the recommendation.

1. Select tools and technologies that serve as scaffolds to help students apply self-regulated learning strategies.

Some tools might help students learn specific content, such as a lesson within a unit, whereas others might support the way students engage with the course and its related content more generally. Instructors should consider what they want students to accomplish with regard to self-regulated learning—either throughout a course or during a specific lesson or unit—and select tools to help students acquire and apply self-regulated learning strategies.

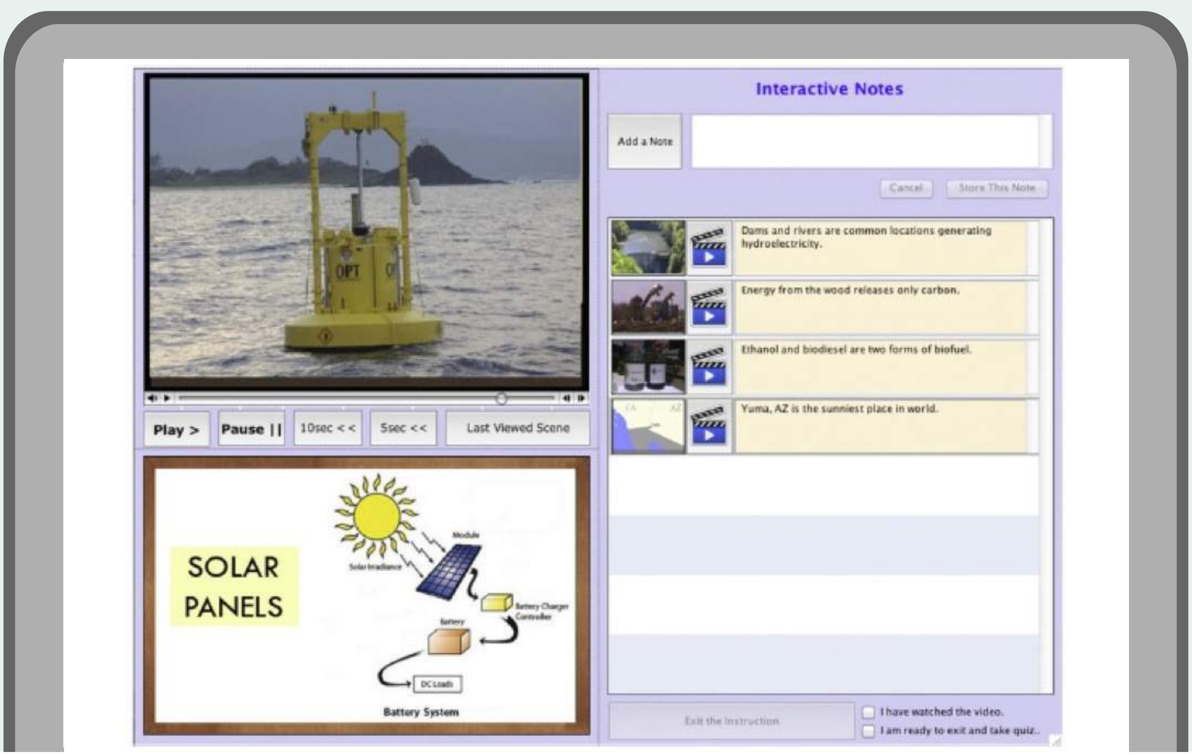
Instructors should select tools and technologies with interactive interfaces that can be used to encourage and support students' use of self-regulated learning strategies while completing activities in online learning environments. For example, video-based learning modules with interactive components, including note-taking features, practice questions, and supplemental resources related to the topic, are one way to boost student engagement and scaffold students' use of self-regulated learning strategies while learning in video-based settings (see **Figure 3.1**).[32]

FIGURE 3.1. EXAMPLE OF INTERACTIVE INTERFACE TO SUPPORT STUDENTS' USE OF SELF-REGULATED LEARNING STRATEGIES

Interactive video-based interfaces allow students to view video, take notes, and complete quizzes to demonstrate knowledge and understanding.

Students can play and review video content.

Students can use the interactive notes feature to type notes. Notes are displayed next to the corresponding video frame.



SOURCE: Delen, E. (2013). Scaffolding and enhancing learners' self-regulated learning: Testing the effects of online video-based interactive learning environment on learning outcomes. (Doctoral dissertation). https://doi.org/1969.1/151123

Self-monitoring prompts embedded in online activities boost students' comprehension by activating prior knowledge and encouraging them to organize their thinking while learning. These prompts also support students when applying their knowledge in different activities or learning environments. Structured note taking can facilitate information collection and academic achievement in online learning environments, and prompting students to self-monitor themselves *during* note taking helps them filter information and deepen understanding as they move along in a lesson.[33]

Content creation and delivery tools can support self-regulated learning. Such tools include those for instructors to upload a course syllabus, course content, and assignments, and for students to access course resources and readings. They do so by giving students what they need to engage in the processes of goal setting, help seeking, self-evaluation, and selecting strategies for completing tasks. Communication and collaboration tools can help foster interaction and help seeking by establishing an open and friendly community of learners. Administrative tools such as calendars and web-based to-do lists can support students' time planning and management skills.[34]

There are several strategies for sending students reminders and prompts—sometimes called "nudge" messages—that provide tips and coach students to use self-regulated learning strategies. Email and text-based reminders are one way to encourage students to stay on track while completing course assignments and studying for exams. Examples of text-based reminders and prompts are provided in **Figure 3.2**.

Nudge messages are being built into adaptive learning environments; smartphone apps and student support software are being designed to provide students coaching and reminders to use self-regulated learning strategies throughout the semester. For example, some apps and software provide students with access to information about assignments, campus resources and supports, and availability of course materials. These tools can also be used to track students' progress toward goals, such as on-time attendance.

Assessment tools, such as those to post grades and track student progress, can support students' task strategies, self-monitoring, and self-evaluation.[35] Some technologies can facilitate automated monitoring of student progress and can generate alerts or messages to instructors and/or students.

Messages to students can be personalized to offer encouragement and support during the semester to both students who are thriving and those who might be at risk for failure. For example, messages generated by E^2Coach (**Figure 3.3**), a software-based student-support system, advise students by sending personalized messages and information about how their performance compares to their classmates'. The personalized messages include information about goals and values the individual students identified at the beginning of the semester.

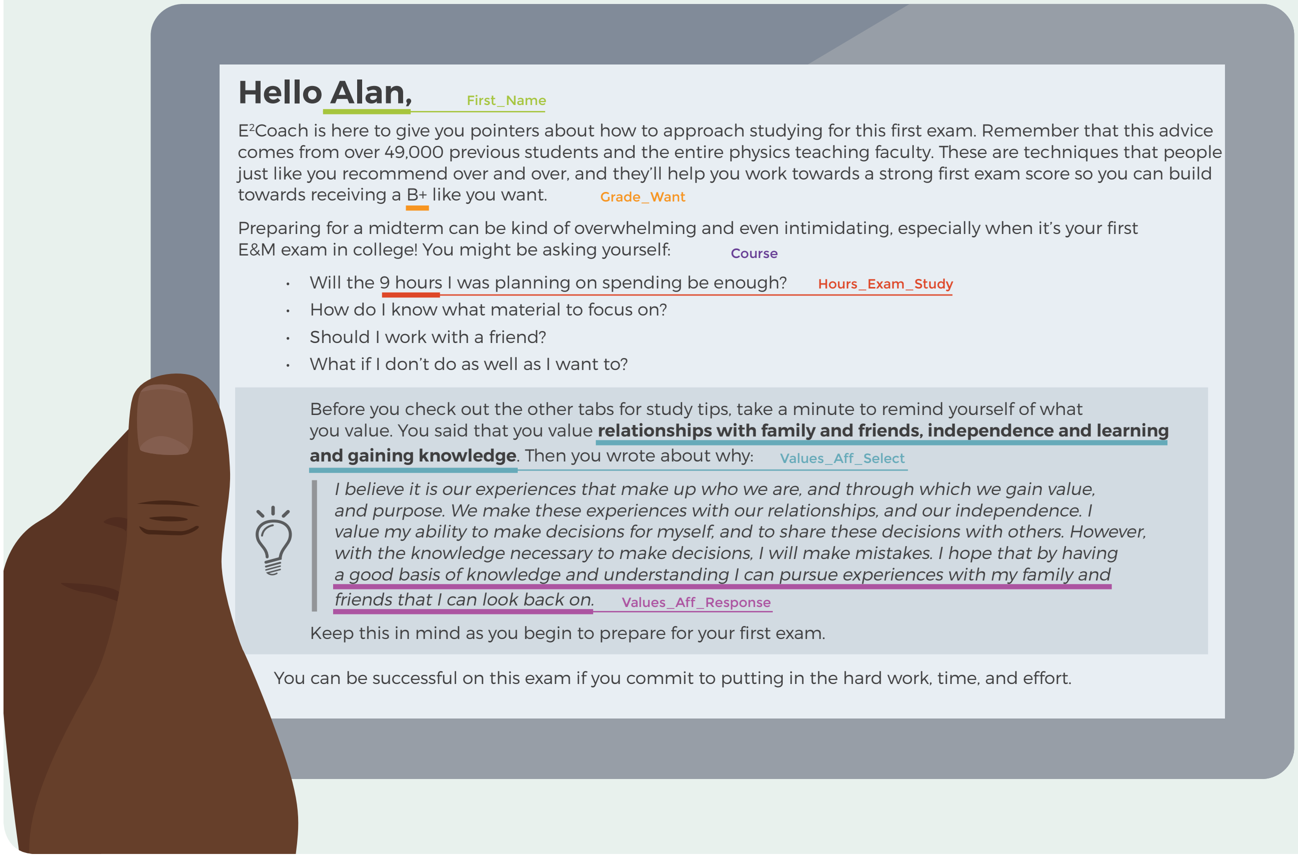
FIGURE 3.2. SAMPLE TEXT-BASED REMINDERS AND PROMPTS TO SUPPORT SELF-REGULATED LEARNING

Text-based reminders and metacognitive prompts are designed to provide tips and to coach students to use self-regulated learning strategies as they complete course assignments and study for exams.

SOURCE: Adapted from Sullivan, S. M. (2016). *The effects of prompting metacognition using email or text reminders on student participation, persistence, and performance in a blended course* (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses. (Accession No. 10102309)

FIGURE 3.3. SAMPLE INDIVIDUALIZED EMAIL BASED ON STUDENT GOALS AND PERFORMANCE

E²Coach can send individualized messages to students based on their course goals and performance. This message is tailored to a student whose first course exam is approaching.



SOURCE: https://er.educause.edu/articles/2013/12/e2coach-tailoring-support-for-students-in-introductory-stem-courses

2. Model how to use self-regulated learning strategies, and provide students with opportunities to practice self-regulated learning strategies using technology.

Students may need instruction on self-regulated learning strategies, including what they are, why they are important, and how to use them. Campus resource centers should offer students training, videos, and other resources on self-regulated learning strategies. Strategies might include time management tips, study skills, concept mapping tools, and note-taking and comprehension aids, such as those in **Figure 3.4**.

Instructors and advisors should also become well versed in these resources so they can encourage students to access, learn, and apply self-regulated learning strategies. Instructors should model the use of self-regulated learning strategies. They should provide explicit guidance and examples of strategies and behaviors used by students who successfully navigated the course in previous semesters, thus providing "best practices" to adopt. Recommendation 5 ("Teach students how to become self-regulated learners") in the Practice Guide *Strategies for Postsecondary Students in Developmental Education*[36] offers tips for teaching students in developmental education courses how to enact self-regulated learning strategies.

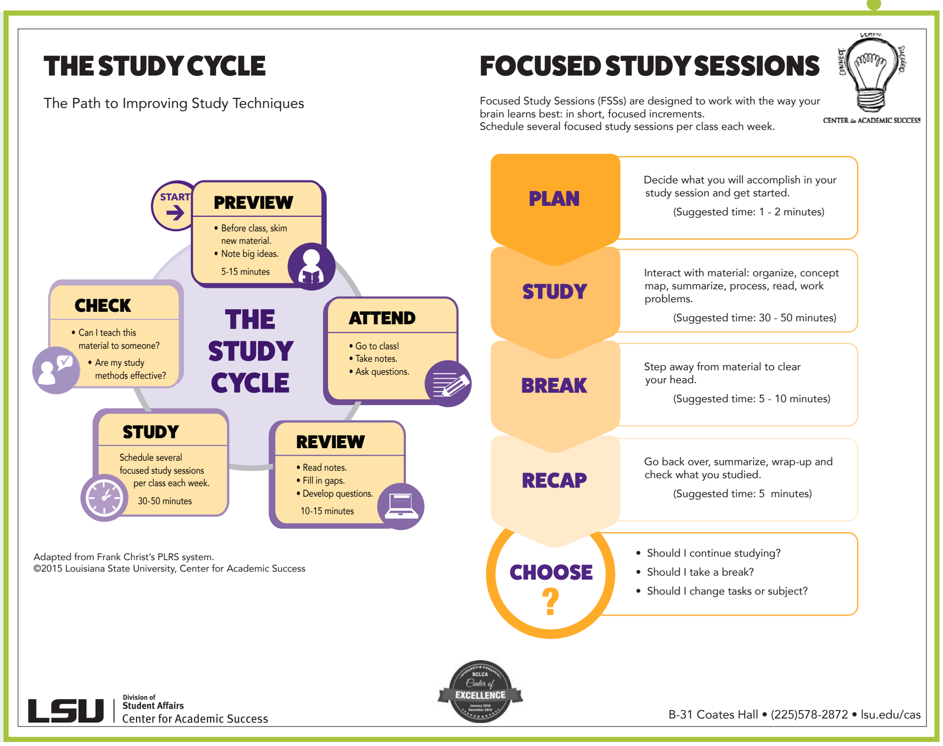
Students need opportunities to practice self-regulated learning strategies before they can get into the habit of applying them. Allowing students to build on prior knowledge through practice supports the transfer and application of knowledge and skills across settings or learning

FIGURE 3.4. EXAMPLE OF CAMPUS RESOURCES TO SUPPORT SELF-REGULATED LEARNING

LSU's Virtual Learning Center offers interactive resources to help students achieve their academic goals. Workshops feature success strategies and interactive quizzes.

Campuses can offer students resources for time management, planning, preparing for class, and identifying strengths.

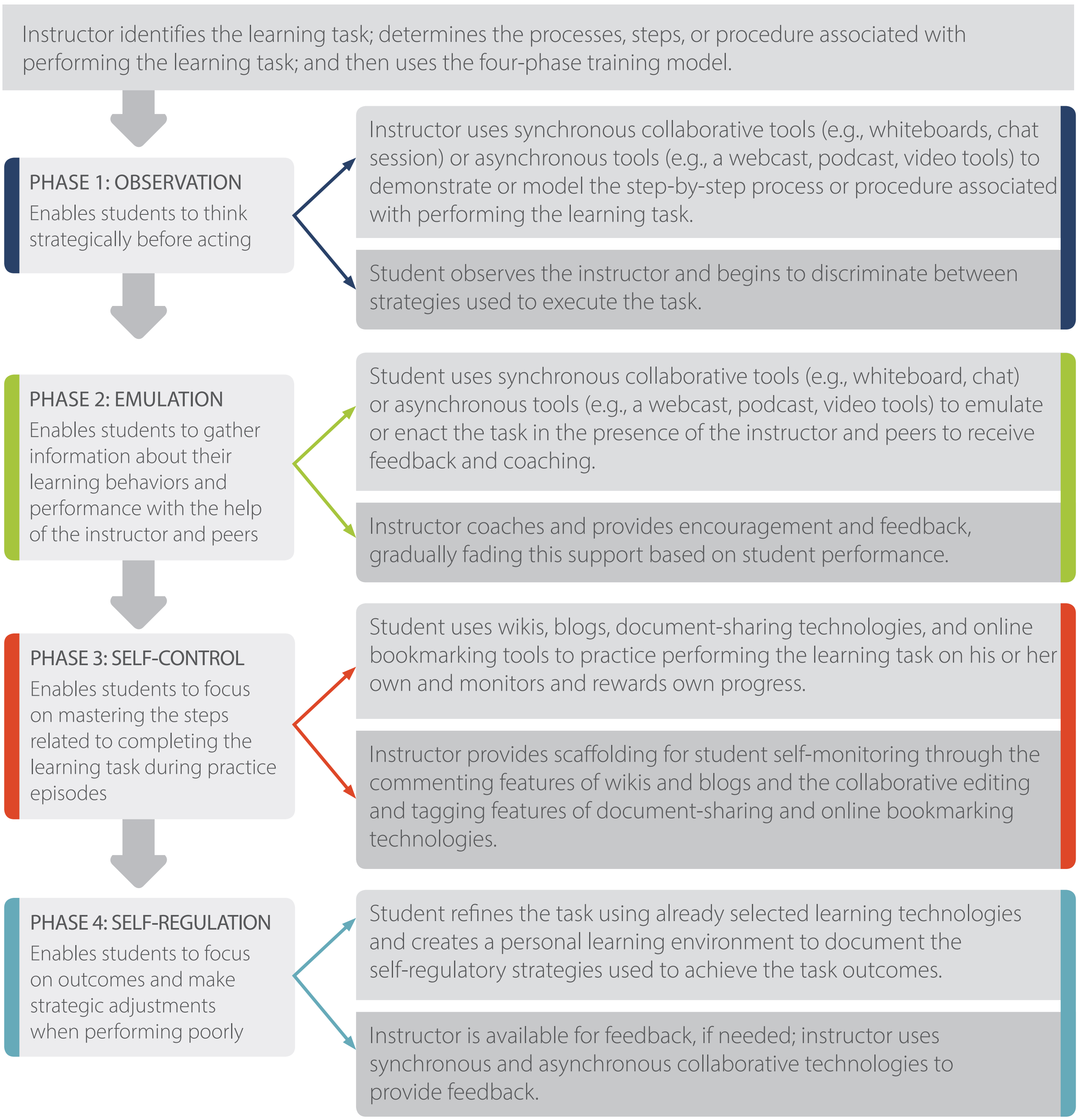
Learning support sites (like LSU's) enable students to find specific resources related to studying.



SOURCE: http://lsu.edu/students/cas/makebettergrades/successresources/virtuallearningcenter.php contexts. Instructors should encourage students to draw on prior knowledge as they are learning new information or solving unfamiliar problems.

Kitsantas and colleagues (2015) offer a four-level model of self-regulation development (see **Figure 3.5**) that can be used as a training tool to support college students' self-regulation through a range of learning technologies. The instructor can use this training model to guide students through four phases of a learning task—from observation to self-regulation.

FIGURE 3.5. SAMPLE TRAINING MODEL TO SUPPORT SELF-REGULATION THROUGH LEARNING TECHNOLOGIES



SOURCE: Adapted from Kitsantas et al. (2015), p. 286

3. Select technologies that feature tutoring or mentoring components to support students in using self-regulated learning strategies.

Traditional face-to-face tutoring can be especially helpful for students who are in online or blended learning settings.[37] Tutors can serve as a scaffold by providing supports and helping students enact various aspects of self-regulated learning. Aspects might include planning their learning, monitoring their understanding, and applying different strategies to learn content. Emerging technologies, such as intelligent tutoring systems, cognitive tutors, and adaptive learning environments, can offer promising alternatives to face-to-face adaptive tutoring, which can be resource intensive.

Pedagogical agents can be embedded in computer-based learning environments to complement and extend other scaffolds such as searchable text, simulations, and concept maps. MetaTutor, for example, is an adaptive learning environment that includes pedagogical agents to scaffold students' use of self-regulated learning processes while learning challenging science topics. The interface elements in MetaTutor (see **Figure 3.6**) support the following:

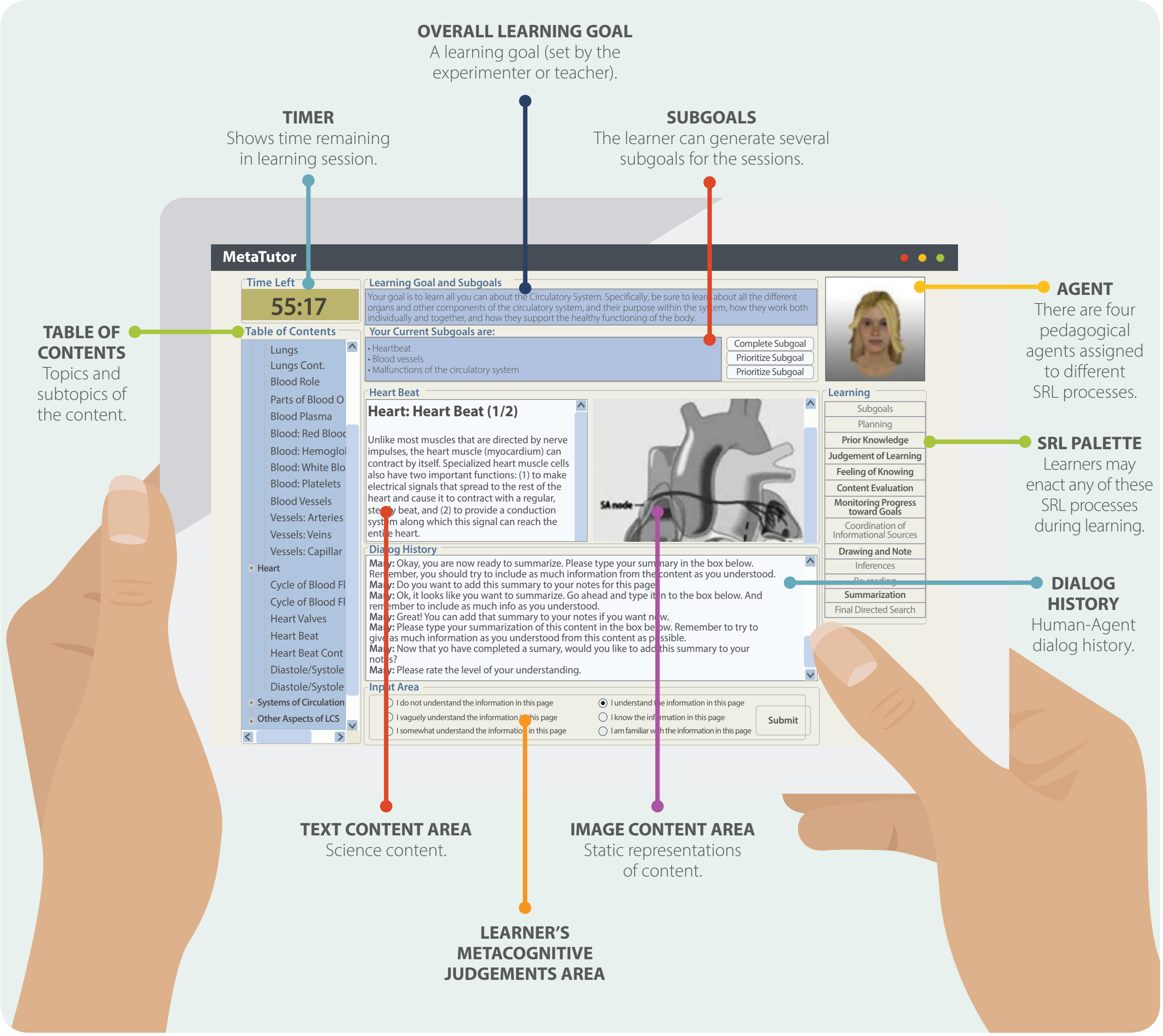
- Identification of an overall learning goal for the learning session, which is set by the instructor;
- Selection of subgoals, which are set by the student;
- An organized table of contents to help students navigate the content;
- Selection of self-regulated learning processes to use during the learning session; and
- Pedagogical agents to support the student with selected self-regulated learning strategies during the learning session:
  - » As the students make their way through the content, which is displayed through text and static images, the pedagogical agent prompts them to use the selected self-regulated learning processes.
  - » Prompts, including suggestions and questions, are recorded in the Dialog History box. Students may review the Human-Agent dialog history during the session and save it for future reference.
  - » The Input Area is where students can take notes and submit answers to questions.
  - » Periodically, the pedagogical agent uses the Input Area to prompt students to reflect on the content they are learning and submit a metacognitive judgment of their level of understanding of that content.

4. Assess whether the selected technologies are effectively supporting students in their use of self-regulated learning strategies.

Most online environments, including course and learning management systems, track students' time spent in various activities or functions. To the extent possible, instructors should monitor which functions and features students are using most frequently. Instructors should poll students to determine whether the technologies, such as note-taking features, self-monitoring prompts, and feedback features, are helping them apply specific self-regulated learning strategies. Instructors can also examine usage data and student performance to see if there is any association between the two.

Instructors can also use online usage data to help students understand how classmates interacting with similar features to the same degree/frequency are performing in the course. For example, the Check My Activity tool at University of Maryland, Baltimore County was designed to be a "self-service feedback tool" for students. Students can compare their online course activity against a class average and can also check their activity and frequency of use against an anonymous summary of peers who earned the same, higher, or lower grade for any assignment (see **Figure 3.7**).

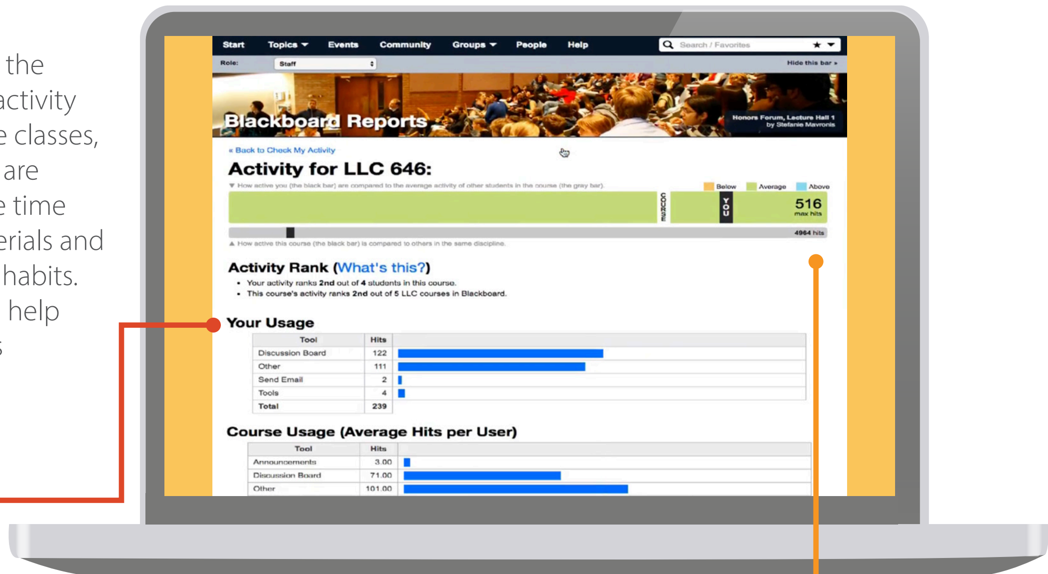
FIGURE 3.6. EXAMPLE OF ADAPTIVE LEARNING ENVIRONMENT WITH PEDAGOGICAL AGENTS TO SUPPORT SELF-REGULATED LEARNING

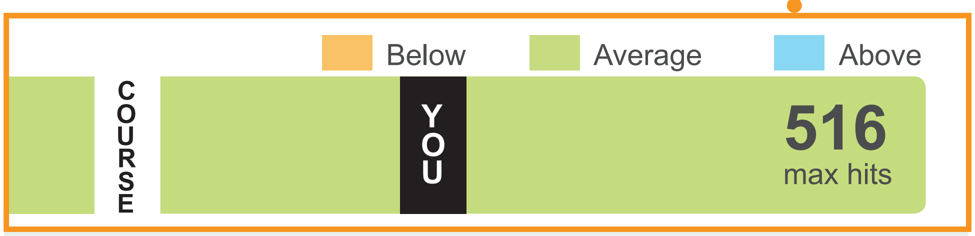


SOURCE: Azevedo, R., Moos, D.C., Johnson, A.M., & Chauncey, A.D. (2010). Measuring Cognitive and Metacognitive Regulatory Processes During Hypermedia Learning: Issues and Challenges. *Educational Psychologist*, *45 (4)*, 210 — 223. http://dx.doi.org/10.1080/00461520.2010.515934

FIGURE 3.7. SAMPLE TOOL FOR STUDENTS TO MONITOR PROGRESS: CHECK MY ACTIVITY

- The University of Maryland, Baltimore County (UMBC) uses a Blackboard learning management system (LMS) to support faculty and students. To supplement the LMS, the university created a custom *Check My Activity* (CMA) tool that allows learners to compare their own level of activity in Blackboard Learn (number of sessions, number of clicks by tool type, amount of time in class) against an anonymous summary of course peers. If instructors use the LMS grade book, students can also compare their own activity with peers earning the same, higher, or lower grade on any assignment.
- By providing students with the ability to benchmark their activity against others in their same classes, underperforming students are encouraged to spend more time engaging with course materials and developing effective study habits. Using *Check My Activity* can help raise awareness that fosters self-regulated learning.





- Students can see how active they are on Blackboard compared to others, as this feature highlights their number of visits to the site compared to the class's total visits.
- The color green represents falling within the average, while yellow represents 20% below and blue represents 20% above.
- This feature also shows what the course average is and how the individual student compares.

Information on site use is also made easily acccessible in bar charts. "Other" may include messaging, calendars, announcements, and other interactive features.

Your Usage

Tool	Hits	
Discussion Board	122	
Other	111	
Send Email	2	
Tools	4	
Total	**239**	

SOURCE: http://blog.blackboard.com/student-facing-learning-analytics-self-regulated-learning

Potential Obstacles and the Panel's Advice

OBSTACLE: *Instructors do not believe self-regulated learning is something they should have to teach college students.*

PANEL'S ADVICE: Many instructors believe students should already know how to monitor their learning, and many students do not believe they need to be taught how to self-regulate their learning. Administrators should incorporate self-regulated learning into their institution-wide learning objectives. They should share evidence that self-regulated learning is associated with positive student outcomes and that technology is an effective way to support self-regulated learning. To further underscore the institution's commitment to encouraging self-regulated learning, administrators can also encourage instructors to integrate discipline-specific versions of the objective into their courses.

Professional development programs for instructors should include training on the importance of self-regulated learning skills. They are especially important in computer-based learning environments and activities, which often involve less guidance and support from the instructor. Training can provide instructors with examples of how to incorporate and model the use of self-regulated learning strategies in their courses.

Students can vary in their degree of comfort and readiness for working in a self-regulated learning environment. They should be offered university- and department-level training. The training should provide students explicit instruction in self-regulated learning strategies and help them understand how to effectively apply the strategies in their learning. Once instructors and students understand the importance of self-regulated learning skills and how students can apply them, they might be more receptive to exploring and engaging with the scaffolding features embedded within many of the technologies they already use.

OBSTACLE: *Instructors might be uncertain about the best way to incorporate self-regulated learning strategies into their specific courses.*

PANEL'S ADVICE: Incorporating self-regulated learning strategies into classroom activities does not need to be burdensome or time-consuming. McGuire (2015) offers several approaches for instructors and suggests students can be introduced to self-regulated learning strategies in an hour-long workshop. Instructional designers and professional development staff can assist instructors in articulating the goals and objectives for their course or for the activities within their course.

Instructional designers can also help instructors identify strategies and actions students can take to meet these goals and objectives.

Next designers can help instructors think about how to provide opportunities for students to learn—and practice—self-regulated learning strategies throughout the semester. As a follow-up to workshops, instructional designers should consider one-on-one meetings with instructors to familiarize them with technologies available to scaffold students' self-regulated learning and to teach them how to integrate these technologies into their courses.

OBSTACLE: *Web-based technologies designed to support self-regulated learning can lack interfaces that are intuitive and efficient for learners to navigate.*

PANEL'S ADVICE: When designing or selecting web-based activities or modules, instructors and instructional designers should ensure each interface is designed to allow students to effectively apply self-regulated learning strategies. To ensure students are maximizing their time and attention focusing on the relevant content, it is essential to make sure learners are not over-burdened by learning how to use new tools and interfaces. Students and instructors should have access to instructions, an orientation, and a help feature to ensure they are aware of and able to efficiently use all functions within the technology.

Recommendation 4: Use technology to provide timely and targeted feedback on student performance.

The panel recommends using technology to facilitate the provision of timely and targeted feedback to students about their performance. Specifically, technology is recommended as a tool to assess students' skills and understanding and to deliver the results as feedback to students and instructors. Students learn more effectively when they are actively engaged in learning activities and have direct access to information about what they are doing right or wrong.[38] However, some college classes provide limited opportunities during class for students to actively engage with content and demonstrate their skills or understanding of key concepts. This is especially common in large or lecture-based classes. Deep understanding and retention of material can be difficult when opportunities to apply new knowledge are not provided concurrent with its delivery. Outside of class, students can more effectively prepare for exams and for the next class if they have access to information about how well they have mastered the content and its application.[39]

Technology permits rapid assessment and tabulation of student responses and can be used both in and outside of class. Thus, technology provides opportunities for students to engage with content and demonstrate their understanding, or lack of understanding, to themselves and to their instructor at the time that learning activities occur. Technology that facilitates assessment and the provision of timely feedback, whether in or outside of class, with individual students or with groups, also provides data that can be used to tailor and modify instruction to better address students' learning needs and challenges.

Among the most widely used technologies in traditional face-to-face courses for providing immediate feedback are automated student response systems. These can be hand-held devices or polling applications for smartphones or tablets/laptops that allow students to respond to questions; software then rapidly tabulates responses and shows the results to the class so students can check their answers and see how they compare to those of their peers. Outside of class time, or in blended and online courses, timely feedback can be provided via online assessments, assignments, or polling applications. Feedback systems can also be incorporated into online courses and modules by using embedded assessments; many learning management systems have these options built in. Developments in artificial intelligence enable feedback to be individually tailored via adaptive systems, such as intelligent tutoring systems.

With all of these technologies, the rapid tabulation of data permits students to check their performance quickly and allows instruction to be adapted and differentiated in light of student responses. This differentiation can be performed by human instructors or can be programmed into online courses and modules.

WWC staff and the expert panel assigned a moderate level of evidence based on eight studies. Five studies meet WWC group design standards without reservations.[40] Two studies meet WWC group design standards with reservations.[41] One study that tested multiple interventions reported on comparisons that meet group design standards without reservations and comparisons that meet group design standards with reservations.[42] See **Appendix C** for a detailed rationale for the Level of Evidence for Recommendation 4.

SPOTLIGHT ON IMPLEMENTATION: USING ONLINE HOMEWORK AND STUDENT RESPONSE SYSTEMS TO PROVIDE TIMELY AND TARGETED FEEDBACK TO STUDENTS

An instructor teaching a developmental pre-algebra course at a community college used online assignments and student response systems to provide timely and targeted feedback to students about their performance. The class met twice a week.

Online homework assignments provided the instructor with student information to plan the next class session. Prior to each class, students were assigned online homework and were expected to complete it in advance. Although students did not receive scores on the homework assignments prior to class, the online homework assignment platform allowed students to practice concepts and get help with the homework problems. Each class section started with a review, where the instructor was able to address students' questions on their previous homework assignment.

The instructor followed a three-segment format during class to assess student understanding of previously taught and new content in real time:

- First, the instructor used a *student response system* to review the material covered in the previous session, using *rapid-fire* questions from the homework. The instructor typically showed 12-15 problems on the screen. Students worked in pairs to solve the problems and recorded their answers with their individual devices. After a reasonable amount of time, the instructor posted the distribution of responses on the screen and then demonstrated the solution. Particularly difficult concepts were often highlighted by using more than one question.
- The second segment of class focused on introducing new concepts. After each new concept was introduced, students were given additional problems to solve using their devices. These questions were designed using an *easy-hard* or *easy-hard-hard* format. The first question was designed so that most students would get the answer correct and was intended to build their confidence. The second and third questions were more difficult; the second question was often similarly constructed to the instructor's examples, while the third question required students to apply the concept in a novel or unfamiliar way. As with the homework review, students could work together and answers were posted on the screen. The instructor then illustrated the solution step-by-step.
- Finally, students could begin work on the new assignment while the instructor was available for help. The student response system platform used in the course was a radio frequency system called Turning Point® that was purchased by the college. This platform is compatible with Microsoft PowerPoint®. The online homework was provided by the textbook publisher through a system called Course Compass®.

Study Findings: Moreau (2009) reports the use of the student response system had indeterminate effects on student achievement.

How to Carry Out the Recommendation

The guidance below is informed by the studies that support the recommendation, as well as the expert panel's expertise and knowledge of resources and strategies available to help implement the recommendation.

1. Determine the course segments or content for which students would benefit most from timely and targeted feedback.

In planning a course syllabus, instructors should identify in advance common mistakes and "bottleneck concepts," the foundational concepts that, when students find them difficult to understand, prevent them from grasping more complex, related concepts. Students and instructors benefit from timely feedback about performance related to concepts that are commonly misunderstood by students.[43] Exams and homework from previous terms can be mined to identify such concepts. Class discussions and student questions can also help identify the nature of common student misunderstandings.

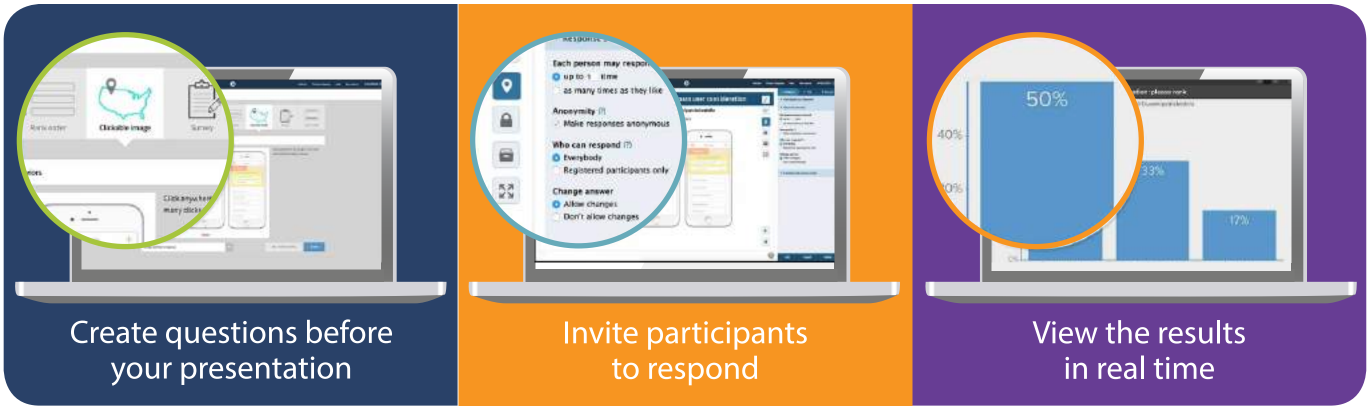
Armed with this information, instructors can then select the concepts to cover and plan the timing of assessment, such as polling in class or giving quizzes prior to class meetings. They also can plan the type and format of feedback (group or individual) best suited to helping students understand their mistakes or get past the bottleneck concepts. For example, in-class polling can be more appropriate for remediating common misconceptions that can be addressed quickly by the instructor in real time—for example, the difference between *correlation* and *causality* in a statistics course. On more complex bottleneck concepts, instructors might be able to better tailor class meetings, and students might benefit more from those classes, if assessment and feedback on those concepts occur prior to the class meeting. After determining the course segments and content for which students would benefit from timely and targeted feedback, instructors can decide whether technology could be useful to facilitate the collection of student responses and provision of feedback.

2. Decide which technologies to use for providing feedback.

After deciding to use technology to check students' understanding and provide timely, targeted feedback, instructors must select the tools that best align with their course format, the content about which feedback will be provided, and the institutional context in which they operate. When selecting technologies to provide feedback to students, instructors should determine the availability of technology, as well as which technologies other instructors and students currently use.

Face-to-face learning environments can incorporate technology-based questioning and real-time tabulation of data from the entire class. For polling or quizzing students, older-style student response systems, often called "clickers," might be available for classroom use. There are, however, newer web- and smartphone-based applications that can perform the same tasks, and students might feel more comfortable using their laptops or smartphones to respond to questions. Poll Everywhere (see **Figure 4.1**) allows instructors to create questions before class, which they then administer and can immediately see the results of during class.

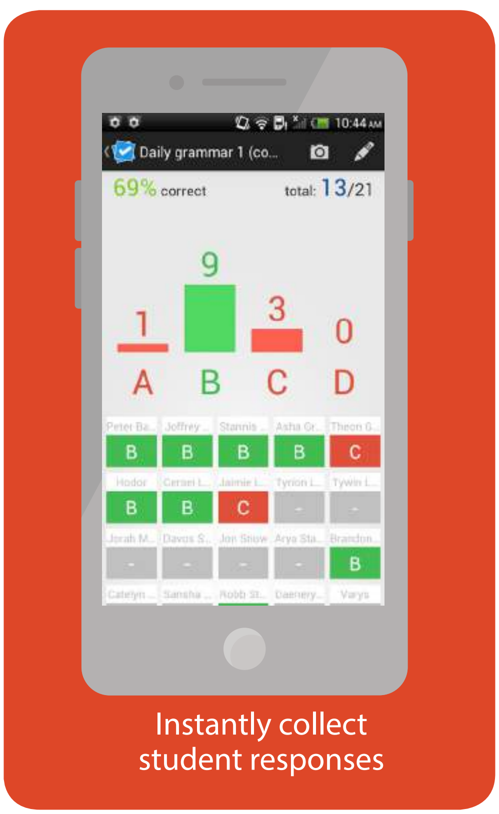
FIGURE 4.1. SAMPLE CLASSROOM POLLING TOOL: POLL EVERYWHERE



SOURCE: https://www.polleverywhere.com/how-it-works

Not all technologies designed to provide students with in-class feedback require individual student devices. Instructors are the only ones who need a smartphone or tablet to use Plickers (paper clickers), which allow them to conduct real-time checks for understanding and to administer "exit tickets" (impromptu polls).

FIGURE 4.2. SAMPLE CLASSROOM RESPONSE SYSTEM: PLICKERS



SOURCE: https://itunes.apple.com/us/app/plickers/id701184049?mt=8

Students receive a paper card, which they can hold up to be scanned by the instructor using an app on a smartphone or tablet. Data are automatically saved for individual students.

In online courses, especially those that are delivered asynchronously, it might be more feasible to provide immediate feedback to students through automated scoring of online homework or quizzes. Online learning environments can be designed to provide students immediate feedback on navigational choices and on answers they provide to questions posed throughout a lesson, in online homework, or in quizzes.

Many of the adaptive learning environments have built-in assessments and can provide timely feedback. The Open Learning Initiative, introduced in Recommendation 2, offers free, open access to course materials that provide immediate feedback. The feedback helps students assess their own learning and study effectively while also providing instructors with immediate grading and feedback on students' progress.

3. **Strategically incorporate feedback technologies into the course.**

Instructors must make decisions about how to incorporate feedback into their lectures and course units. The physical organization, features, and amenities of the classroom, such as seating arrangements and availability of wireless internet, for example, might influence choices about which technologies can be used for in-class assessment and feedback. At the same time, class size and class duration should be considered when planning how to incorporate technology-based feedback into a face-to-face course, as these factors can influence how much time the instructor dedicates to discussion of student responses.

Students can respond to questions individually or in small groups, and instructors can choose to provide opportunities for students to receive both individual and group feedback. When used effectively, technology-based questioning techniques not only provide opportunities for giving timely feedback, but also support active learning and engagement during class.

Instructors teaching online or blended courses should work with instructional designers to build in knowledge checks that call on students to apply and demonstrate their understanding of course material. Online homework or quizzes with automated grading features offer students and instructors immediate feedback on student performance that takes place outside of class.

In all types of course formats, technologies should be selected to provide feedback that aligns with course objectives and goals. Students should understand whether and how feedback plays into their assignment and course grades. Instructors using student response systems for in-class activities must decide whether or not to assign credit to feedback generated from technology-driven checks for student understanding. In deciding, they should weigh the benefits of allowing students to anonymously demonstrate their understanding versus a desire to use the results for attendance and/or grading. Ungraded feedback allows students to practice demonstrating their knowledge without fear of consequence if they answer incorrectly, but making participation count toward the student's grade can promote engagement with the assessment. Instructors of online courses should work with instructional designers to decide how frequently feedback should be provided in content modules.

4. Design questions that align with the desired learning objectives.

Instructors must make decisions about what content and technology are best suited for assessing students and providing them with feedback. They also must construct the questions they will ask in class with student response systems, include on online homework assignments, or use in online assessments. Before drafting questions, instructors should identify learning objectives for the activity or unit that will include feedback. Instructors can draw on their understanding of common misconceptions about the material—informed by students' past work, questions, and performance—to create questions and answer choices that are plausible enough to challenge students to work through those misconceptions.[44]

The optimal difficulty level of questions can vary for different groups of students, and instructors should pilot and refine questions. Rather than posing single questions to students, instructors should use easy-hard-hard question sequences,[45] where the easy question builds confidence, the first hard question introduces cognitive conflict, and the second hard question introduces a different context.

Instructional designers and teaching and learning center staff can help instructors write questions at the higher levels of Bloom's Taxonomy in order to extend their assessment beyond knowledge-level multiple-choice questions. Instructors should especially consider interpretive and analytic (*why, how,* and *in your opinion*) questions rather than recall (*who, what,* or *when*) questions. **Figure 4.3** provides an overview of different questions instructors can ask using student response systems.

When designing multiple-choice questions, instructors should include incorrect response options that elicit common misunderstandings, which create ready-made opportunities to correct them. Tactics for meeting a variety of question design goals that instructors may have when using student response systems are presented in **Figure 4.4**.

FIGURE 4.3. TYPES OF QUESTIONS THAT CAN BE USED WITH CLASSROOM RESPONSE SYSTEMS

1 RECALL QUESTIONS
ask students to recall facts, concepts, or techniques and don't require higher-order thinking skills.

2 CONCEPTUAL UNDERSTANDING QUESTIONS
go beyond recall and assess students' understanding of important concepts. They are often based on common student misconceptions.

3 APPLICATION QUESTIONS
require students to apply their knowledge and understanding to particular situations and contexts. These questions often ask students to make a decision or choice in a given scenario and can connect course content to "real-world" situations.

4 CRITICAL THINKING QUESTIONS
operate at the higher levels of Bloom's Taxonomy, requiring students to analyze relationships among multiple concepts or make evaluations based on particular criteria. These questions can be very effective in preparing students to engage in class discussions about their reasons.

5 STUDENT PERSPECTIVE QUESTIONS
ask students to share their opinions, experiences, or demographic information. These questions do not have correct answers and can often generate rich discussion, particularly questions about ethical, legal, or moral issues. The anonymity that clickers provide is often an essential ingredient in asking these kinds of questions.

6 CONFIDENCE LEVEL QUESTIONS
are asking following content questions. Asking students to rate their confidence in their answers (high, medium, or low) can aid in metacognition—learning about one's own learning.

7 MONITORING QUESTIONS
are designed to provide instructors with information about how their students are approaching the learning process in their courses. For example, asking students how long they took to complete an assignment they have just turned in can provide instructors with useful information about the difficulty of the assignment.

8 CLASSROOM EXPERIMENTS
conducted by faculty or other researchers can be facilitated by collecting data from students using classroom response systems.

SOURCE: https://cft.vanderbilt.edu/cft/guides-sub-pages/clickers/

FIGURE 4.4. EXAMPLE DESIGN TACTICS FOR CREATING CLICKER QUESTIONS

QUESTION DESIGN GOALS	TACTICS
DIRECT ATTENTION AND RAISE AWARENESS	• Remove potentially distracting features and steps (i.e., nonessentials) • Use scenarios and features that lead students to compare and contrast • Extend the context; ask familiar questions of unfamiliar scenarios • Reuse familiar question situations; new ideas should be introduced in familiar question scenarios • Use questions to draw students into making an error then follow up with a question that leads them to realize their mistake, and allow them to go back ("Oops-go-back")
STIMULATE COGNITIVE PROCESSES	• Interpret representations; provide necessary information or answer options in alternative representations • Identify a set or subset of situations, objects, or processes • Rank variants of situations, objects, or processes according to some measurable quality • Constrain the solution by instructing students to use, or avoid, certain problem solving approaches • Reveal better problem solving approaches • Present a problem and ask students to identify the strategy that would most effectively reach a solution • Push students to identify what information is necessary to solve a problem by including extraneous information and omitting necessary information
FORMATIVE USE OF RESPONSE DATA	• Use answer choices that reveal likely difficulties including common errors, misunderstandings, and alternative assumptions and interpretations • Use "none of the above" answer choices, and make it the correct answer often enough that it is useful
PROMOTING ARTICULATION/ DISCUSSION	• Use qualitative questions that promote discussion of concepts and ideas • Use analysis and reasoning questions that require substantial decision making • Use questions with multiple defensible answers that require unstated assumptions, trap unjustified assumptions, and/or are deliberately ambiguous to generate discussion • Design questions that deliberately catch students in common misconceptions

SOURCE: Beatty et al. (2006)

Yourstone and colleagues (2008) suggest that instructors should allow students in face-to-face courses to discuss individual answers to questions after they have submitted them but before the correct answer is revealed. Doing so promotes peer learning and deeper understanding. Students also benefit from time to discuss and reflect on both correct and incorrect responses. Instructors can take advantage of "teachable moments" by reviewing all answer choices, especially those that suggest students are not grasping the content.

Depending on the platform used by individual online learning modules, feedback can be corrective or explanatory or both. Corrective feedback provides the correct answer when a student selects an incorrect answer; explanatory feedback goes a step further by providing an explanation of the correct and incorrect answers. Both corrective and explanatory feedback can be effective for supporting student learning, depending on the material.[46]

5. Use data to inform instruction, and to help students guide their learning.

Instructors collecting real-time data about students' understanding during a face-to-face class or in a synchronous online session can implement audience-paced instruction. Such instruction means the instructor can decide whether to continue a lecture/discussion or pause to elaborate on concepts students are not yet mastering.

Data collected from student response systems can be tabulated quickly for the instructor, and the instructor can decide whether or not to graphically display a summary of the data. Instructors can use webpages or chat functions that allow students to anonymously post questions and comments during a class. Then the instructor can periodically pause to check for questions and comments and address any without individual students feeling on the spot for raising the question or comment.

Data gathered through online assessments conducted during lessons, especially if tabulated quickly for the instructor, can highlight concepts the instructor should review with students before moving to the next lesson or unit in the course. If shared with students, these data can also help students understand how their performance compares to their peers'.

When providing timely and targeted feedback to students, instructors also can provide guidance on how students can use data to improve their future performance. For example, instructors might suggest students revisit course materials or they might recommend new content to study. Instructors can leverage data and analytic capabilities built into many technologies to improve their use of the technology over time. Data collected during class can be saved and analyzed to assess question efficacy, as well as to modify questions for future semesters.

6. Work collaboratively to adopt and integrate newer technologies.

Many technologies are available to provide students timely, targeted feedback during in-class sessions. Even more sophisticated technologies are being developed to provide students with feedback that supports metacognitive thinking and reflection when they are online, such as adaptive learning environments, interactive online modules and courses, and intelligent tutoring systems. Instructors, instructional designers, and software developers can collaborate to develop and adopt these technologies. Open Learning Initiative is one such collaborative opportunity. It invites instructors to help develop or evaluate courses that the Initiative is currently building.

Education technology startup companies also can be good partners for instructional designers and instructors who are interested in integrating new technologies into their classrooms.[47] The federally supported Small Business Innovation Research program also provides opportunities to receive grants for conducting research and development on innovative technologies.

Potential Obstacles and the Panel's Advice[48]

OBSTACLE: *Creating questions that support timely and targeted feedback can be time-consuming.*

PANEL'S ADVICE: Many resources are available to instructors interested in incorporating timely and targeted feedback into their courses. Textbooks often come with supplementary materials, including assessment questions; some websites offer freely available question banks or libraries. Many course and learning management systems provide software that allows instructors to develop and maintain question banks or question pools. Instructors can team up with other instructors teaching similar courses to co-develop or exchange questions. Students should be invited to submit questions for in-class discussion and review. Questions submitted in advance of the class can be reviewed by the instructor, and they can also be saved for use with future groups of students.

OBSTACLE: *Lecture time is limited, and adding real-time checks for understanding and follow-up discussion can be time-consuming.*

PANEL'S ADVICE: Instructors should be judicious in their use of real-time polling and feedback. Instead of feeling obligated to dedicate large amounts of time to this type of assessment, instructors can leverage feedback technologies selectively. For example, they can use these technologies when covering particularly complex topics, to break up a lengthy lecture, or as a way to check for understanding at the beginning or end of a class.

OBSTACLE: *Adapting instruction during a lesson based on student responses can be difficult, especially for instructors with less teaching experience or familiarity with the content they are teaching.*

PANEL'S ADVICE: For even the most experienced instructors, preparation is key. Instructors should be fully prepared to discuss both the correct and incorrect answer choices for all questions posed to students. They should also be prepared to explain or reteach content when students demonstrate misunderstandings through in-class polling or on quick assessments. Peer-led discussion may also be an effective strategy for helping students work through misunderstandings.[49]

When instructors do not feel sufficiently prepared to immediately adjust instruction based on student responses, they can review data and make adjustments before the next class session. Administrators can play a key role here by connecting instructors with the necessary resources, such as professional development and teaching and learning centers, to support this preparation.

Recommendation 5: Use simulation technologies that help students engage in complex problem-solving.

The panel recommends the use of technologies such as computer simulations, game-based learning, and virtual reality environments that simulate and allow students to grapple with complex problems. Incorporating complex problem-solving activities into postsecondary instruction allows students to interact more deeply with learning material, to practice higher-order thinking skills, and to make connections among concepts. These activities can promote engagement, which enhances student understanding and improves retention of material.[50] Problem-solving activities such as case studies or field projects are common in higher education. Often, however, the amount of time students have to solve a problem within a typical semester is limited, or they might not be able to test and explore the results of multiple solutions.[51] As technology has evolved, new options that provide realistic and immersive problem situations, support testing and analysis of multiple scenarios, and involve social interactions among students have emerged. These are promising strategies for engaging students in complex problem-solving.

Technologies that simulate complex problems can mitigate the time and place constraints of traditional case studies or field projects. They also provide students with the opportunity to work through challenging situations where they are safe to be wrong without consequences. These technologies can allow students to take multiple approaches to solving a problem and help them understand the implications of the approach they decide to take by simulating consequences.

This recommendation emphasizes the use of technology that is designed to feature realistic, complex problems that help students deepen their understanding and develop higher-order thinking skills. Technologies that simulate complex problems might include one or more of the following features: allow learners to make decisions and observe the outcomes of their decisions, provide an opportunity for students to practice newly acquired skills, facilitate problem-based learning, and allow for immersive role playing.

WWC staff and the panel assigned a minimal level of evidence based on two studies that examined the effects of a web-based simulated problem-based learning experience. One study meets WWC group design standards without reservations[52] and one study meets WWC group design standards with reservations.[53] See **Appendix C** for a detailed rationale for the Level of Evidence for Recommendation 5.

SPOTLIGHT ON IMPLEMENTATION: COMMUNITY PUBLIC HEALTH SIMULATION

Two instructors of an undergraduate Health Behavior course implemented and tested a semester-long internet-based simulation of a community public health problem with a group of undergraduate public health majors (Spinello & Fischbach, 2004). The simulation was designed to give students the opportunity to use problem-solving and critical thinking to develop their own solution to a poorly defined, authentic problem.

For their lesson, the professors used a web-based platform to simulate the effects of a mock disease outbreak in a virtual community. The simulation had students act as public health officials and explore the problem through newspaper clippings and television media, through the use of simulated epidemiological data, and with surveys or interviews with characters in the simulation, such as medical professionals, reporters, patients. The online, media-rich environment gave the simulation a realistic look and feel and allowed the students to explore the problem from multiple perspectives and test intervention strategies. The simulation mimicked real-world problems by unfolding over time, so that students were required to work on solutions without having the full picture. The instructor could also change the environment by inserting features into the simulation, such as a request for an interview from a local reporter or phone messages from local physicians or family members. In addition, there was a simulated conference room that permitted the students to communicate asynchronously and allowed the instructor to pose as a simulation character in such meetings.

Students worked in small groups to address the virtual outbreak, and each action or intervention taken by the student groups resulted in instructor-implemented changes in the environment. In this way, students could see the results of their interventions and propose modifications or adjustments to their plans. During the course, for example, one student group elected not to respond to a request from a journalist for an interview. In response, the local news station announced plans to run an expose on the health department's bungled attempts to address the problem.

Study Findings: The impact of the web-based community health simulation on academic achievement was positive and statistically significant.

How to Carry Out the Recommendation

The guidance below is informed by the studies that support the recommendation, as well as the expert panel's expertise and knowledge of resources and strategies available to help implement the recommendation.

1. **Assess and decide whether a course offers the appropriate context for using technologies that simulate complex problems to promote higher-order thinking and problem-solving skills.**

   Not all courses are suited for including complex simulations or problem-based learning activities. Instructors and instructional designers should consider whether the curriculum and content of the course can give students the time to engage with authentic, complex problems or the focus instead is on mastery of introductory core concepts. In planning and implementing successful simulated learning experiences, instructor and student preparation are important, as is including time for post-experience discussion and reflection.

2. **Establish the learning objectives first, and then select an activity with the right level of complexity.**

   Instructors and instructional designers should first determine the goals they hope to achieve through technologies that simulate complex problems, and then select an activity or case that can help to accomplish those goals. Simulated problems should be aligned to both the learning content and the desired learning outcomes of the course.

Instructors should consider whether they want students to work independently or in small groups, and then identify technologies that have been successfully used by other instructors in that setting. They should select a technology that has the appropriate amount of complexity to achieve the learning objective or one that increases in complexity as learners achieve deeper understanding of the material. See **Figure 5.1** for an example of an online simulation tool available to instructors and instructional designers.

FIGURE 5.1. SAMPLE ONLINE SIMULATION TOOL: CALIFORNIA BUDGET CHALLENGE

SOURCE: https://www.budgetchallenge.org/challenges/12/pages/instructions

3. Introduce students to expectations for the simulated learning activity, and provide supports to ensure they feel comfortable in the learning environment.

Instructors should be clear and transparent about the outcomes students are expected to achieve through the simulated learning activity. Instructors also should explain the features of the exercise that will help students achieve these outcomes. When introducing the objectives and expectations for the task, instructors should clearly explain how students will be assessed and graded. If students will be working in groups or teams, expectations about the contributions of individuals within the group should be clear.

Instructors also should explain that team-based learning focused on solving a complex problem is an opportunity for students to develop collaborative decision-making skills. If possible, each team member should be provided with a specific role or set of responsibilities for engaging with the activity. Strategies used to structure learning activities that require teams of students to engage with complex problems are featured in **Figure 5.2**.

FIGURE 5.2. SAMPLE TIPS FOR GROUP PROBLEM-BASED LEARNING ASSIGNMENTS USING IMMERSIVE TECHNOLOGY

1. Convey the expectation that students work collaboratively to solve or manage the problem.
2. If students are collaborating online, encourage the use of synchronous collaboration tools such as group chat, shared whiteboards, video conferencing, and group browsing.
3. Make the learning objectives of the assignment readily accessible to the students.
4. Give students the ability to negotiate their own learning needs in the context of the assignment.
5. If possible, assign tutors to work directly with the teams to provide support and facilitate discussion (but not to direct discussion). This tutor can also plan real-time collaboration sessions using the synchronous tools mentioned previously.

SOURCE: Savin-Baden, M., Tombs, C., Poulton, T., Conradi, E., Kavia, S., Burden, D., & Beaumont, C. (2011). An evaluation of implementing problem-based learning scenarios in an immersive virtual world. *International Journal of Medical Education, 2*, 116.

Before allowing students to begin such learning activities, instructors should make sure the technology is working and there are no other barriers to navigating it. This includes explaining how to use the technology and where students can get help should technology-related questions arise.

4. Lead students in reflective discussion to help them evaluate their own learning.

Instructors should help students to understand there might not be a "right" answer to simulated problems presented in activities, especially because students bring diverse perspectives to situations. Students should be encouraged to be comfortable with ambiguity and failure and should be guided to reflect on and learn from their mistakes. Instructors should encourage collaboration so that students take advantage of the opportunity to learn from the experiences of peers engaging with the same complex problem.

Students participating in simulated learning activities are not directly provided solutions to the problems at hand. Learning occurs as they construct and apply their own solutions. Instructors can facilitate that learning by guiding students to complete short reflections or assessments throughout the process. For example:

- Rubrics and questionnaires can guide students to reflect on learning-related activities, challenges, and accomplishments.

- Think-aloud protocols can help instructors understand what learners are thinking as they engage with both the content and the technology.

Other feedback mechanisms, such as questions about students' confidence level or level of interest, can be embedded throughout simulated learning activities. Data about students' experiences with an activity can be used to inform instructors' decisions about whether and how to use the simulated activity again with a different group of students.

5. **Keep an eye out for new or evolving technologies that support effective, engaging, complex problem-solving.**

Emerging immersive, virtual world, augmented- and mixed-reality, and artificial intelligence technologies all offer exciting learning opportunities for students to work together on complex problems that simulate real-world scenarios. Evidence on the impacts of these emerging technologies on learning is scant thus far. Educators should keep an eye out for information on how these cutting-edge technologies can be applied to foster learning in face-to-face, online, or blended courses. Teaching and learning centers on campus can be excellent resources for identifying new technologies.

Potential Obstacles and the Panel's Advice

OBSTACLE: *Many instructors follow lesson plans they have previously developed, and some might be reluctant to give up time they normally spend lecturing to make room for simulated problem-solving activities.*

PANEL'S ADVICE: Instructors can blend complex problem-solving simulations with course content in a way that does not require a wholesale redesign of their course. They can incorporate these activities into their courses gradually without taking up too much lecture time, by assigning students to prepare for the activity before class and then allowing time for students to debrief about the simulated problem in the context of a lesson being taught during class.

Depending on the instructor's goals and the complexity of the simulated activity, instructional designers can estimate how much time it would take to develop a new simulation or customize an existing one. After implementing the simulated learning activity the first time, the instructor can weigh the outcomes, benefits, and tradeoffs of using technology to simulate complex problems in the course, and then consider whether or not to use the same or different technology in the future.

OBSTACLE: *It can be challenging and time-consuming to design and implement effective lessons using technology that simulates complex problems.*

PANEL'S ADVICE: There are many off-the-shelf simulations that instructors can use. Instructional designers can provide professional development to instructors and help them think through objectives, resources, and time constraints to select the most appropriate learning technology to simulate complex problems. Teaching centers and instructional designers can also provide instructors with strategies to integrate simulated activities into other course activities and assignments. There are also emerging tools and authoring environments that can help instructors more easily co-develop and implement simulated problems with instructional designers.

OBSTACLE: *The open-ended nature of simulated learning environments can make it particularly challenging for students to engage with and solve problems.*

PANEL'S ADVICE: Instructors and instructional designers should select simulated activities that offer clear guidance, instructions, and readily accessible help features for both students and instructors. When possible, instructors should use their understanding of student needs and learning preferences to inform their selection of simulated learning activities.

Instructors can ask their students about their past experiences with technology-based simulated activities and use that information to tailor instructions and guidance to fit the experience level of the class. If students are expected to work in groups, instructors can pair more experienced students with less experienced students. Practice sessions can also be helpful for students who are struggling with the technology.

A

ADAPTIVE LEARNING is an educational method that uses computer algorithms to coordinate the interaction with the learner and deliver customized resources and learning activities to address the unique needs of each learner. Computers adapt the presentation of educational material according to students' learning needs, as indicated by their responses to questions, tasks, and experiences.

ADMINISTRATOR refers to staff at postsecondary institutions in leadership positions, such as deans, provosts, and department heads. These individuals might assist with the implementation of recommendations in this guide by providing resources and supports to instructors, instructional designers, advisors, and other staff who use technology to support postsecondary student learning.

ARTIFICIAL INTELLIGENCE (AI) refers to computer systems that undertake tasks usually thought to require human cognitive processes and decision-making capabilities. To exhibit intelligence, computers apply algorithms to find patterns in large amounts of data—a process called machine learning, which plays a key role in a number of AI applications. AI learning agents have the potential to function like adaptive learning but at a much more sophisticated and nuanced level.

AUGMENTED REALITY is an enhanced version of reality created by the use of technology to overlay digital information on an image of something being viewed through a device (such as a smartphone camera). This can also refer to the technology used to create augmented reality.

B

BLENDED LEARNING courses combine face-to-face classroom instruction with online learning, reducing classroom contact hours. Blended learning is sometimes referred to as **hybrid learning**.

BLOOM'S TAXONOMY is a classification system used to define and distinguish different levels of human *cognition*—that is, thinking, learning, and understanding. Educators have typically used Bloom's taxonomy to inform or guide the development of assessments (tests and other evaluations of student learning), curriculum (units, lessons, projects, and other learning activities), and instructional methods such as questioning strategies. The original taxonomy (developed in the 1950s) was updated in 2001 (Anderson & Krathwohl, 2001), when three categories were renamed and all the categories were expressed as verbs rather than nouns. The revised categories are: Remembering, Understanding, Applying, Analyzing, Evaluating, and Creating.

C

COGNITIVE LOAD refers to the amount of information that the human brain's working memory can hold at one time. Because working memory has a limited capacity, instructional methods should avoid overloading it with additional activities that don't directly contribute to learning.

COMPUTER SIMULATIONS involve the usage of a computer for the imitation of a real-world process or system.

CONCEPT MAPS are diagrams or graphical tools that visually represent relationships among concepts and ideas. Most concept maps depict ideas as boxes or circles (also called *nodes*), which are structured hierarchically and connected with lines or arrows (also called *arcs*). These lines are labeled with linking words and phrases to help explain the nature of the connections. A **concept mapping tool** is used to create concept maps.

COURSE OR LEARNING MANAGEMENT SYSTEM refers to a web-based system for the administration, documentation, tracking, reporting, and delivery of educational courses or training programs. Such systems are used by instructors to manage and deliver course materials to students, administer tests and other assignments, track student progress, and manage record keeping. Instructors can also use these systems to communicate with students, to share course materials, and to encourage discussion among students. Popular examples of these systems include Blackboard, Canvas, and Moodle.

E

ENGAGEMENT refers to the degree of attention, curiosity, interest, optimism, and passion that students show when they are learning or being taught, which extends to the level of motivation they have to learn and progress in their education.

G

GAME-BASED LEARNING is a type of game play that has defined learning outcomes. Generally, game-based learning is designed to balance subject matter with game play and the ability of the player to retain and apply said subject matter to the real world. Three main elements of game-based learning are competition, engagement, and immediate rewards.

I

IMMERSIVE TECHNOLOGY refers to technology that blurs the line between the physical world and digital or simulated world, thereby creating a sense of immersion. Immersive technology enables **mixed reality**.

IMMERSIVE VIRTUAL WORLD refers to a simulated environment, facilitated by networked computers, that provides multiple users with avatars and communication tools with which to act and interact in real-time.

INSTRUCTIONAL DESIGNERS assist with designing and redesigning courses and academic programs. Their major task is to work with faculty and other instructional designers to create pedagogically appropriate material such as content, media, and manuals that are used in teaching and learning. They are cognizant of and rely on learning theory to develop material that will appeal to and engage students in their studies.

INSTRUCTOR refers to any individual who teaches full- or part-time at the postsecondary level. This includes faculty and adjunct professors; it can also include graduate students and other staff responsible for teaching courses.

INTELLIGENT TUTORING SYSTEM refers to a computer system that aims to provide immediate and customized instruction or feedback to learners, usually without requiring intervention from a human teacher. Such systems have the common goal of enabling learning in a meaningful and effective manner by using a variety of computing technologies. An intelligent tutoring system typically aims to replicate the demonstrated benefits of one-to-one, personalized tutoring in contexts where students would otherwise have access to one-to-many instruction from a single teacher (e.g., classroom lectures) or no teacher at all (e.g., online homework).

M

META-ANALYSIS is the statistical procedure for systematically combining data from two or more similar studies to develop a conclusion that has greater statistical power than either study alone.

MIXED REALITY is the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects coexist and interact in real time. Mixed reality uses **immersive technology**.

MODULES organize course content by weeks, units, or some other organizational structure. Each module can contain files, discussions, assignments, quizzes, and other learning materials. A course is made up of one or more modules packaged together.

O

OPEN EDUCATIONAL RESOURCES (OER) are freely accessible, openly licensed text, media, and other digital assets that are useful for teaching, learning, and assessing, as well as for research purposes. OER describes publicly accessible materials and resources for any user to use, re-mix, improve, and redistribute under some licenses.

P

PEDAGOGICAL AGENT is a concept borrowed from computer science and **artificial intelligence** and applied to education, usually as part of an **intelligent tutoring system**. It is a simulated human-like interface between the learner and the content, in an educational environment. A pedagogical agent is designed to model the interactions between a student and another person. A pedagogical agent can be assigned various roles in the learning environment, such as tutor or co-learner, depending on the desired purpose of the agent.

S

SCAFFOLDING is an instructional process through which supports for students are added in order to enhance their learning and aid in their mastery of tasks. This is done by systematically building on students' experiences and knowledge as they are learning new skills. As students master the assigned tasks, the supports are gradually removed so they gain greater independence in the learning process.

SELF-REGULATED LEARNING is a cyclical process, wherein the student plans for a task, monitors his/her performance, and then reflects on the outcome. The cycle then repeats as the student uses the reflection to adjust and prepare for the next task. The process is not one-size-fits-all; it should be tailored for individual students and for specific learning tasks.

SOCIAL LEARNING THEORY is the belief that people learn from one another, via observation, imitation, and modeling.

V

VIRTUAL REALITY is an artificial environment experienced through sensory stimuli (such as sights and sounds) provided by a computer and in which one's actions partially determine what happens in the environment. This can also refer to the technology used to create or access a virtual reality.

VIRTUAL WORLD refers to a computer-based online community environment designed and shared by individuals so they can interact in a custom-built, simulated world. Users interact with one another in this simulated world using text-based, two-dimensional, or three-dimensional graphical models called *avatars*. Avatars are graphically rendered using computer graphics imaging or any other rendering technology. Individuals control their avatar using their keyboard, mouse, and other specially designed command and simulation gadgets. Today's virtual worlds are purpose-built for entertainment, social, educational, and training purposes.

Appendix A: Postscript From the Institute of Education Sciences

What Is a Practice Guide?

The Institute of Education Sciences (IES) publishes practice guides to share evidence and expert guidance on addressing education-related challenges not readily solved with a single program, policy, or practice. Each practice guide's panel of experts develops recommendations for a coherent approach to a multifaceted problem. Each recommendation is explicitly connected to supporting evidence. Using What Works Clearinghouse™ (WWC) group design standards and WWC pilot regression discontinuity standards, the supporting evidence is rated to reflect how well the research demonstrates the effectiveness of the recommended practices.

Strong evidence means positive findings are demonstrated in multiple well-designed, well-executed studies, leaving little or no doubt that the positive effects are caused by the recommended practice. *Moderate evidence* means well-designed studies show positive impacts, but there are questions about whether the findings can be generalized beyond the study samples or whether the studies definitively show evidence that the practice is effective. *Minimal evidence* means that there is not definitive evidence that the recommended practice is effective in improving the outcome of interest, although there might be data to suggest a correlation between the practice and the outcome of interest. (See **Table A.1** for more details on levels of evidence.)

How Are Practice Guides Developed?

To produce a practice guide, IES first selects a topic. Topic selection is informed by inquiries and requests to the WWC Help Desk, a limited literature search, and evaluation of the topic's evidence base. Next, IES recruits a panel chair who has a national reputation and expertise in the topic. The chair, working with IES and WWC staff, then selects panelists to co-author the guide. Panelists are selected based on their expertise in the topic area and the belief that they can work together to develop relevant, evidence-based recommendations. Panels include two practitioners with expertise in the topic.

Relevant studies are identified through panel recommendations and a systematic literature search. These studies are then reviewed against the WWC group design standards by certified reviewers who rate each effectiveness study. The panel synthesizes the evidence into recommendations. WWC staff summarize the research and help draft the practice guide.

IES practice guides are then subjected to external peer review. This review is done independently of the IES staff that supported the development of the guide. A critical task of the peer reviewers of a practice guide is to determine whether the evidence cited in support of particular recommendations is up-to-date and that studies of similar or better quality that point in a different direction have not been overlooked. Peer reviewers also evaluate whether the level of evidence category assigned to each recommendation is appropriate. After the review, a practice guide is revised to meet any concerns of the reviewers and to gain the approval of the standards and review staff at IES.

Institute of Education Sciences Levels of Evidence for What Works Clearinghouse Practice Guides

This section provides information about the role of evidence in IES's WWC practice guides. It describes how practice guide panels determine the level of evidence for each recommendation and explains the criteria for each of the three levels of evidence (strong evidence, moderate evidence, and minimal evidence).

The level of evidence assigned to each recommendation in this practice guide represents the panel's judgment of the quality of the existing research to support a claim that, when these practices were implemented in past research, positive effects were observed on student outcomes. After careful review of the studies supporting each recommendation, panelists determine the level of evidence for each recommendation using the criteria in **Table A.1**. The panel first considers the relevance of individual studies to the recommendation and then discusses the entire evidence base, taking the following into consideration:

- The number of studies
- The study designs
- The internal validity of the studies
- Whether the studies represent the range of participants and settings on which the recommendation is focused
- Whether findings from the studies can be attributed to the recommended practice
- Whether findings in the studies are consistently positive

A rating of *strong evidence* refers to consistent evidence that the recommended strategies, programs, or practices improve student outcomes for a diverse population of students.* In other words, there is strong causal and generalizable evidence.

A rating of *moderate evidence* refers either to evidence from studies that allow strong causal conclusions but cannot be generalized with assurance to the population on which a recommendation is focused (perhaps because the findings have not been widely replicated) or to evidence from studies that are generalizable but have some causal ambiguity. It also might be that the studies that exist do not specifically examine the outcomes of interest in the practice guide, although the studies might be related to the recommendation.

A rating of *minimal evidence* suggests that the panel cannot point to a body of evidence that demonstrates the practice's positive effect on student achievement. In some cases, this simply means that the recommended practices would be difficult to study in a rigorous, experimental fashion[†]; in other cases, it means that researchers have not yet studied this practice, or that there is weak or conflicting evidence of effectiveness. A minimal evidence rating does not indicate that the recommendation is any less important than other recommendations with a strong or moderate evidence rating.

In developing the levels of evidence, the panel considers each of the criteria in **Table A.1**. The level of evidence rating is determined by the lowest rating achieved for any individual criterion. Thus, for a recommendation to get a strong rating, the research must be rated as strong on each criterion. If at least one criterion receives a rating of moderate and none receives a rating of minimal, then the level of evidence is determined to be moderate. If one or more criteria receive a rating of minimal, then the level of evidence is determined to be minimal.

The panel relied on WWC group design standards and WWC pilot regression discontinuity standards to assess the quality of evidence supporting education programs and practices. The WWC evaluates evidence for the causal validity of instructional programs and practices according to WWC group design standards. Information about these design standards is available at **https://whatworks.ed.gov**. Eligible studies that meet WWC group design standards without reservations or meet WWC group design standards with reservations are indicated by **bold text** in the endnotes and references pages.

* Following WWC guidelines, improved outcomes are indicated by either a positive, statistically significant effect or a positive, substantively important effect size. The WWC defines substantively important, or large, effects on outcomes to be those with effect sizes greater than or equal to 0.25 standard deviations. See the WWC guidelines at **https://whatworks.ed.gov**.

[†] For more information, see the WWC Frequently Asked Questions page for practice guides at **https://whatworks.ed.gov**.

A Final Note About IES Practice Guides

In policy and other arenas, expert panels typically try to build a consensus, forging statements that all its members endorse. Practice guides do more than find common ground; they create a list of actionable recommendations. Where research clearly shows which practices are effective, the panelists use this evidence to guide their recommendations. However, in some cases, research does not provide a clear indication of what works. In these cases, the panelists' interpretation of the existing (but incomplete) evidence plays an important role in guiding the recommendations. As a result, it is possible that two teams of recognized experts working independently to produce a practice guide on the same topic would come to different conclusions.

Institute of Education Sciences

Table A.1. IES levels of evidence for What Works Clearinghouse practice guides

	EVIDENCE BASE		
CRITERIA	STRONG	MODERATE	MINIMAL
Validity	High internal validity (high-quality causal designs). Studies must meet WWC design standards with or without reservations.[a] AND High external validity (requires multiple studies with high-quality causal designs that represent the population on which the recommendation is focused). Studies must meet WWC design standards with or without reservations.	High internal validity but moderate external validity (i.e., studies that support strong causal conclusions, but generalization is uncertain). OR High external validity but moderate internal validity (i.e., studies that support the generality of a relation, but the causality is uncertain).[b]	The research may include evidence from studies that do not meet the criteria for moderate or strong evidence (for example, case studies, qualitative research).
Effects on relevant outcomes	Consistent positive effects without contradictory evidence (i.e., no statistically significant negative effects) in studies with high internal validity.	A preponderance of evidence of positive effects. Contradictory evidence (i.e., statistically significant negative effects) must be discussed by the panel and considered with regard to relevance to the scope of the guide and intensity of the recommendation as a component of the intervention evaluated.	There may be weak or contradictory evidence of effects.
Relevance to scope	Direct relevance to scope (i.e., ecological validity)—relevant context (for example, classroom vs. laboratory), sample (for example, age and characteristics), and outcomes evaluated.	Relevance to scope (ecological validity) may vary, including relevant context (for example, classroom vs. laboratory), sample (for example, age and characteristics), and outcomes evaluated. At least some research is directly relevant to scope (but the research that is relevant to scope does not qualify as strong with respect to validity).	The research may be out of the scope of the practice guide.

	EVIDENCE BASE		
CRITERIA	STRONG	MODERATE	MINIMAL
Relationship between research and the recommendations	Direct test of the recommendation in the studies or the recommendation is a major component of the intervention tested in the studies.	Intensity of the recommendation as a component of the interventions evaluated in the studies may vary.	Studies for which the intensity of the recommendation as a component of the interventions evaluated in the studies is low; and/or the recommendation reflects expert opinion based on reasonable extrapolations from research.
Panel confidence	The panel has a high degree of confidence that this practice is effective.	The panel determines that the research does not rise to the level of strong but is more compelling than a minimal level of evidence. The panel may not be confident about whether the research has effectively controlled for other explanations or whether the practice would be effective in most or all contexts.	In the panel's opinion, the recommendation must be addressed as part of the practice guide; however, the panel cannot point to a body of research that rises to the level of moderate or strong.
Role of expert opinion	Not applicable.	Not applicable.	Expert opinion based on defensible interpretations of theory (theories). (In some cases, this simply means that the recommended practices would be difficult to study in a rigorous, experimental fashion; in other cases, it means that researchers have not yet studied this practice.)
When assessment is the focus of the recommendation	For assessments, meets the standards of *The Standards for Educational and Psychological Testing*.[c]	For assessments, evidence of reliability that meets *The Standards for Educational and Psychological Testing* but with evidence of validity from samples not adequately representative of the population on which the recommendation is focused.	Not applicable.

[a] This includes randomized controlled trials (RCTs) and quasi-experimental design studies (QEDs). Studies not contributing to levels of evidence include single-case designs (SCDs) evaluated with WWC pilot SCD standards and regression discontinuity designs (RDDs) evaluated with pilot RDD standards.

[b] The research may include studies generally meeting WWC group design standards and supporting the effectiveness of a program, practice, or approach with small sample sizes and/or other conditions of implementation or analysis that limit generalizability. The research may include studies that support the generality of a relation but do not meet WWC group design standards due only to lack of demonstrated equivalence at pretest for QEDs. QEDs without equivalence must include a pretest covariate as a statistical control for selection bias. These studies must be accompanied by at least one relevant study meeting WWC design standards. For this practice guide, the latter studies did not need to be considered because a sufficient number of studies meet WWC design standards for each recommendation.

[c] American Educational Research Association, American Psychological Association, & National Council on Measurement in Education (1999).

Appendix B: Methods and Processes for Developing This Practice Guide

Phase 1: Selecting the Topic and the Panel; Establishing a Review Protocol

The initial step in the development of a practice guide, as described in Appendix A, is the selection of the topic. WWC staff[54] nominated practice guide topics based on their relevance to postsecondary education practitioners and the amount of rigorous research available. To inform the level of rigorous research, WWC staff conducted a preliminary literature search and screened abstracts to identify topics where a critical mass of rigorous evidence might exist. The relevance to postsecondary educators was informed by consultations with postsecondary education advisors. After the topic of "using technology to support postsecondary student learning" was nominated for this guide and selected by IES, a team of nationally recognized experts was selected to form the panel.

EXPERT PANEL. This practice guide was developed by WWC staff in conjunction with the expert panel. The panel comprised Dr. Nada Dabbagh, George Mason University; Dr. Randall Bass, Georgetown University; Dr. MJ Bishop, University System of Maryland; Dr. Anthony G. Picciano, City University of New York; and Dr. Jennifer Sparrow, Penn State University. The recommendations in the practice guide drew on the panel's nationally recognized expertise and its balance of researcher and practitioner experience in the field of instructional technology.

SCOPE AND PURPOSE. The panel and WWC staff initially defined the scope and purpose of the practice guide by focusing on the following question: *What are the most promising technologies associated with improving postsecondary student learning outcomes?* Using this guiding question, WWC staff worked with the panel to identify the types of technologies that would be covered by the practice guide; describe how those technologies support learning and instruction; and identify the parameters to be placed on the research included in the practice guide. WWC staff then codified these decisions into a practice guide review protocol.

PRACTICE GUIDE REVIEW PROTOCOL. The review protocol defines the following: the purpose of the practice guide; interventions, populations, and outcomes covered by eligible research; the evidence criteria to be defined in reviews; and procedures for conducting the literature search. The protocol specifies that studies used as evidence will examine interventions that use technology to support student learning in various ways. In addition, to be eligible for the review, a research study had to:

- use a comparison group design (e.g., a randomized control trial or a quasi-experimental design);
- involve college students in the United States;
- be published in 1997 or later; and
- report on one or more outcomes in the following domains: (1) academic achievement, (2) college attendance, (3) credit accumulation and persistence, (4) attainment of a degree, certificate, or credential, (5) post-college employment and income, or (6) student engagement and motivation.

Phase 2: Literature Search and Review

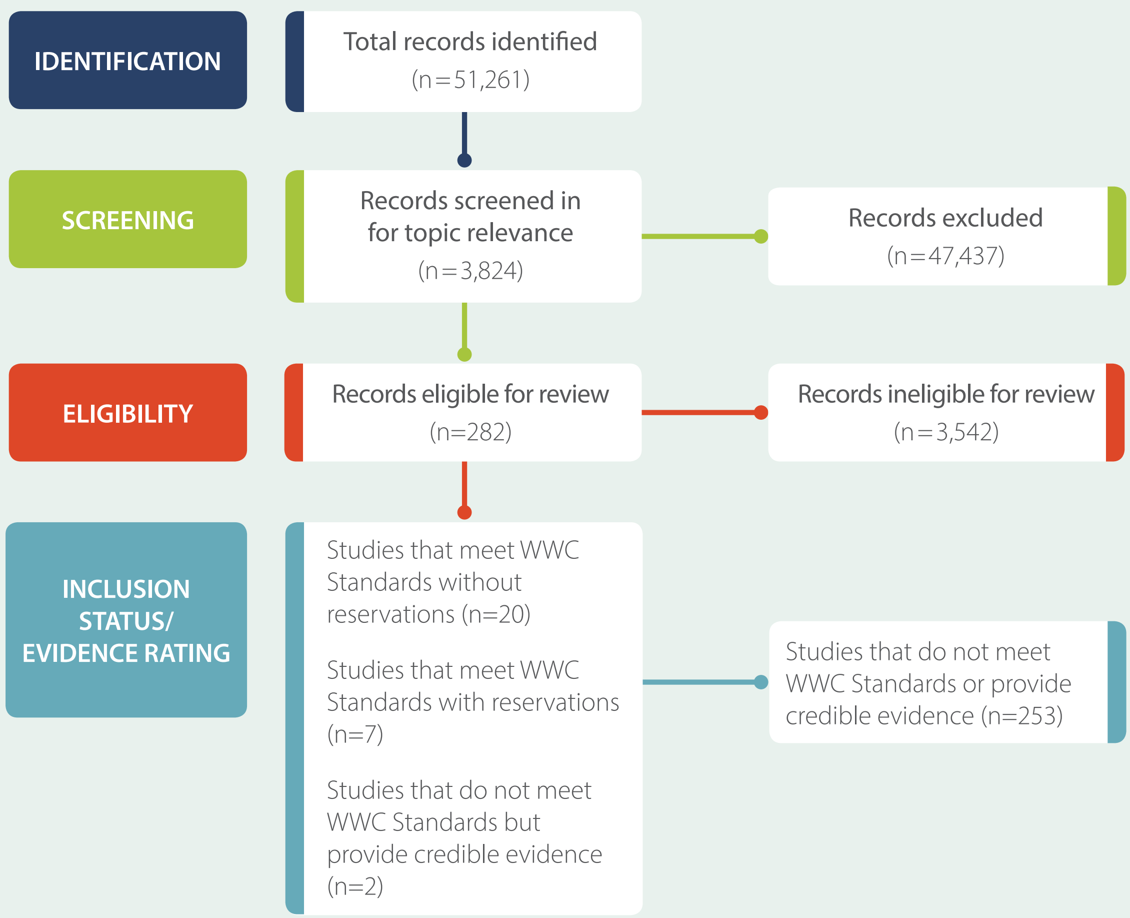
A comprehensive literature search was conducted to identify all studies potentially relevant to the practice guide. The search focused on studies published between 1997 and 2017 that examined practices for using technology to support learning in postsecondary settings. The studies were primarily identified through keyword searches of several databases, and supplemented with additional studies recommended by the expert panel.

The literature search generated more than 50,000 studies. All studies were screened for eligibility for the practice guide, using the criteria defined in the review protocol. Eligible studies were then reviewed by WWC-certified staff against the standards defined in the *What Works Clearinghouse Procedures and Standards Handbook, Version 3.0*.[55] Once the review was complete, studies were assigned one of the following evidence ratings:

- Meets WWC Group Design Standards Without Reservations;
- Meets WWC Group Design Standards With Reservations; or
- Does Not Meet WWC Group Design Standards.

Studies that met WWC standards, either with or without reservations, were classified as having a positive or negative effect on student outcomes if the findings were statistically significant. The number of studies that the WWC identified, screened, deemed eligible, and ultimately included as supporting evidence in the practice guide can be found in **Figure B.1**.

FIGURE B.1. STUDIES IDENTIFIED, SCREENED, AND REVIEWED FOR PRACTICE GUIDE



Phase 3: Generating the Recommendations

After the literature review, WWC staff convened a meeting with the panel to discuss the results. The panel considered details of 29 studies, including each one's WWC evidence ratings, setting, sample, and findings. Adding their expert guidance, the panel produced five recommendations on how to use technology to support postsecondary student learning. The panel also assigned a level of evidence rating to each recommendation. The ratings capture both the confidence of the panel in the effectiveness of the recommendation and the strength of the evidence for the effect of the practice on postsecondary student outcomes (see **Appendix A** for the IES ratings scheme).

The five recommendations in this practice guide are supported by 27 studies that meet WWC group design standards with or without reservations and by two additional studies that did not meet WWC group design standards. Findings from those two studies were included in Recommendation 1 because the panel determined that in supporting that recommendation, they added value beyond the studies that did meet standards. Specifically, each of the two studies offers a "direct test of the recommendation" (on this point, see "Relationship Between Research and the Recommendations" in **Table A.1 of Appendix A**).

Phase 4: Drafting the Practice Guide

WWC staff worked in conjunction with the panel to draft the Practice Guide. This included drafting the following for each of the five recommendations: evidence summary, implementation guidance, panel advice on overcoming potential obstacles, and tools and resources. The Practice Guide underwent several rounds of internal review, which included review from postsecondary education advisors, as well as IES external peer review (as described in **Appendix A**).

Appendix C: Rationale for Evidence Ratings

The level of evidence assigned to each recommendation is based on expert guidance from the panel members and the findings from studies that examined the effectiveness of recommended practices. As noted in the introduction to this practice guide, rigorous research on the effects of technological interventions on student outcomes is rather limited. More rigorous research on new technologies and how best to support instructors' and administrators' uses of technology is needed.

For this practice guide, study findings in an outcome domain are classified as having one of the following effects:[3]

- ***Statistically significant positive effect.*** These findings indicate a positive impact of the intervention on the outcome, statistically significant at $p \le .05$.
- ***Indeterminate effect.*** These findings do not indicate a directional impact of the intervention. They are not statistically significant.
- ***Statistically significant negative effect.*** These findings indicate a negative impact of the intervention on the outcome, statistically significant at $p \le .05$.

Findings reported in studies that meet WWC group design standards could have been adjusted by the WWC in two scenarios: (1) the author reported multiple comparisons within a given outcome domain and did not adjust the critical p-value when determining significance; or (2) the unit of assignment in an randomized controlled trial (RCT) was different from the unit of analysis, such as when course sections are randomly assigned to conditions, individual student test scores are analyzed, and the clustering of students within course sections is not accounted for in the analysis model. In scenario (1), the WWC applied a Benjamini-Hochberg correction. In scenario (2), the WWC applied a clustering correction. For more information about the corrections applied by the WWC, see the *What Works Clearinghouse Procedures and Standards Handbook, Version 3.0*.

ELIGIBLE POPULATIONS. The recommendations in this guide are primarily intended for instructors, administrators, and other staff who work with postsecondary students at 2-year and 4-year institutions. This can include undergraduate, graduate, and professional students, as well as students in technical or vocational education. Across the 29 studies that support the recommendations in this practice guide, all have samples that include undergraduate students and two have samples that include graduate students.

ELIGIBLE OUTCOMES. The study outcomes eligible for inclusion in this practice guide fall into one of the following six domains:

1. **Academic achievement** refers to the extent to which a student masters academic content. Eligible measures of academic achievement arise naturally from student educational experiences; those measures include final grades, grade point average, the ratio of college-level courses passed vs. failed, and unit exam scores.
2. **College attendance** refers to outcomes that measure attendance rates or absenteeism.
3. **Credit accumulation and persistence** refers to progress toward the completion of a degree, certificate, or program. Outcomes can include the number of college-level credits earned or enrolled (accumulation) and whether the student did or did not enroll the next semester (persistence).
4. **Attainment of a degree, certificate, or credential** refers to graduation from or the otherwise successful completion of a degree, certificate, or credential.

[3] *Statistically significant* findings are those unlikely to have occurred by chance.

5. **Post-college employment and income** refers to outcomes related to employment after the postsecondary experience, including employment and income.

6. **Student engagement and motivation** refers to outcomes related to motivation, intrinsic and extrinsic; engagement; and related constructs such as goal orientation and self-regulation.

Findings in three of the domains above are captured in the 29 studies that support the recommendations in this practice guide: academic achievement outcomes are addressed in 27 studies, credit accumulation and persistence outcomes are addressed in four studies, and student engagement and motivation outcomes are addressed in one study. None of the 29 studies that meet WWC standards captured findings in any of the other three domains (attendance, attainment, or employment).

CLASSIFYING THE INTERVENTION AND COMPARISON CONDITIONS. Some studies that support the recommendations in this practice guide evaluated multiple treatment conditions, or compared a treatment condition to a comparison condition where technology supports were also offered. In the tables included in this appendix, the two columns "Intervention Condition" and "Comparison Condition" describe what supports were available to students in each condition. This information is intended to help readers understand what comparisons were made in the studies that led the panel to determine that the findings support the recommendations. For example, intervention conditions that are described as technologies that provide low-cost access to course content could have academic achievement domain outcomes equal to outcomes of students in a traditional face-to-face comparison condition. In such a case, the finding can be interpreted as positive, as the technology is expanding access to education without sacrificing academic performance.

STUDY DETAILS. Details about the participants, setting, intervention and comparison conditions,[4] outcomes, and effect sizes for the 29 included studies are presented in the tables that follow. Each table is preceded by a justification for why the findings, when considered collectively across studies supporting that recommendation, lead to its assigned evidence rating. Inside each table, studies that meet WWC group design standards are listed alphabetically by first author; studies that do not meet WWC group design standards are presented at the end. For studies that included multiple outcomes in a domain, reported effect sizes and statistical significance are for the domain and calculated as described in the *WWC Procedures and Standards Handbook, Version 3.0* (pp. 27–29). A domain average across all studies that contribute to a recommendation is presented at the end of each table. These averages were generated by a fixed-effect meta-analysis model using inverse-variance weights. One feature of this approach is that effects generated from larger sample sizes have more weight than those generated from smaller samples (see Hedges & Vevea, 1998).

[4] The description of the intervention condition includes information about the duration of the intervention. The WWC does not take into account length of exposure to an intervention when summarizing findings.

Recommendation 1. Use communication and collaboration tools to increase interaction among students and between students and instructors.

Rationale for Level of Evidence: *Minimal*

WWC staff and the expert panel assigned a minimal level of evidence based on three studies of the effectiveness of communication tools designed to foster collaboration and build community. One of the studies[56] meets WWC group design standards without reservations, and the two other studies[57] do not meet WWC group design standards.

Evidence from all three studies provided a direct test of the recommendation. Junco and colleagues (2011) examined the effects of a Twitter-based intervention encouraging interaction around educationally relevant topics on the achievement of undergraduate pre-health majors. The study conducted by Fagioli and colleagues (2015) did not meet WWC standards because baseline equivalence was not established. Still, it had a very large sample across seven community colleges and used a rigorous matching approach to form intervention and comparison groups.[58] It examined the impact of Facebook-based Schools App on student achievement. Nalbone and colleagues (2016) used a sample of approximately 1,000 students at one university, but the WWC could not assess whether the intervention and comparison groups were equivalent at baseline. Those authors examined the effects of a Facebook-based social network on student retention.

This evidence suggests positive effects of communication and collaboration tools on academic success outcomes, although some indeterminate effects were observed. Academic achievement was assessed in two of the three studies.[59] Junco and colleagues (2011) reported that the end-of-semester GPA for the intervention students was 2.79 versus 2.28 for the comparison group students, a statistically significant difference. Fagioli and colleagues (2015) also reported a statistically significant impact on end-of-term GPA. Persistence was assessed in two of the three studies;[60] both studies reported statistically significant positive impacts on persistence in favor of the intervention groups. Student engagement was reported in one study,[61] which found that students in the Twitter collaboration and community-building intervention exhibited significantly higher engagement than students in the comparison group.

The panel determined all three studies involved direct tests of the recommendation, were conducted in college course settings, and involved a large number of students across nine postsecondary institutions. However, only one of the three studies meets WWC standards. Therefore, the panel has assigned a minimal level of evidence for this recommendation. This rating is supported by strength of the evidence according to the following criteria:

- **Consistency of Effects on Relevant Outcomes.** Two studies related to this recommendation found positive and statistically significant effects on measures of academic achievement.[62] Two studies found positive and statistically significant effects on credit accumulation and persistence.[63] One study found positive and statistically significant effects on student engagement and motivation.[64] No studies found negative effects on any outcome.

- **Internal Validity of Supporting Evidence.** One study is a randomized controlled trial (RCT) with low attrition that meets WWC group design standards without reservations.[65] Two other studies that contribute evidence are quasi-experimental designs (QEDs) that do not meet WWC group design standards.[66] One study that does not meet WWC group design standards uses propensity score matching to form intervention and comparison groups.[67]

- **Relationship Between the Evidence and Recommendation 1.** The study interventions consist of communication and collaboration tools, particularly social networking tools, designed to facilitate interaction and build a sense of community among students and faculty. Evidence from all three studies used to support Recommendation 1 is considered to be a direct test of the recommendation.
- **External Validity of Supporting Evidence.** The student samples across all studies include 144,458 students in nine postsecondary institutions. Both 2- and 4-year colleges are represented in the study samples. The interventions occurred during the academic year and were tested in natural classroom and campus settings.

Table C.1. Studies providing evidence for Recommendation 1: Use communication and collaboration tools to increase interaction among students and between students and instructors

Study	Participants	Setting	Intervention Condition	Comparison Condition	Outcome Domain and WWC Calculated Effect Size
Fagioli, Rios-Aguilar, & Deil-Amen (2015) *QED* *Does not meet WWC group design standards*	143,307 undergraduates	7 community colleges in 7 states (AR, AZ, CA, OH, NY, TX, and WY)	Schools App Users: Students in the intervention condition joined the Schools App, a Facebook-based application for use only by invited students, faculty, and staff at a specific college. The app is designed to facilitate and manage social engagement for college students, allowing them to get to know other students at the college, organize social activities offline, access campus information, ask questions, and seek advice. The intervention condition is subdivided into active users (those who posted or commented on the app, liked other users' comments, or joined offered meet-ups); passive users (those who spent more than a minute on the app but did not complete any of the active activities); and inactive members (those who did not spend any time on the app). (*Intervention Duration:* 2 semesters)	Nonmembers of Schools App: The comparison condition is the students at the study colleges during the same terms who chose not to join the Schools App.	Academic achievement:[a] *Active users:* GPA was 0.04 points higher than nonmembers* *Passive users:* GPA was 0.02 points higher than nonmembers* Credit accumulation and persistence: *Active users:* 1.28 times more likely to persist than nonmembers* *Passive users:* 1.35 times more likely to persist than nonmembers*

Study	Participants	Setting	Intervention Condition	Comparison Condition	Outcome Domain and WWC Calculated Effect Size
Junco, Heiberger, & Loken (2011) *RCT* *Meets WWC group design standards without reservations*	118 undergraduate pre-health professional majors	1 US college	Twitter: Twitter was used to continue class discussions, allow students to ask questions, remind students of assignments and campus events, provide information on academic and personal support services, and organize service learning projects and study groups. (*Intervention Duration:* 14 weeks)	Business as Usual Instruction with Ning: The comparison sections were taught using business-as-usual instructional methods with the Ning social networking site for the usual learning management system. Instructors in the comparison sections used Ning to provide students the same information that was provided to students in the intervention sections via Twitter. Faculty-student interaction on Ning was minimal compared to the intervention condition.	Academic achievement: $g = +0.52$* Student engagement: $g = +0.64$*
Nalbone et al. (2016) *QED* *Does not meet WWC group design standards*	1,033 undergraduates	1 university in the Midwest	Facebook Group Participants: The intervention group consisted of first-year students who were part of the university's Center for Student Achievement (CSA), were enrolled in a first-year experience course for CSA students only, and opted to participate in both (1) a Facebook group for only members of their first-year experience course and (2) a Facebook group for all first-year students in the intervention group. Two cohorts of students participated in the study. (*Intervention Duration:* 2 years)	Nonparticipants in the Facebook Group: The comparison group consisted of first-year students who were not a part of the CSA and were enrolled in a non-CSA first-year experience course with a professor who volunteered to be part of the study. These students did not receive the offer to join the Facebook groups.	Credit accumulation and persistence: $g = +1.05$*
Domain Averages for Recommendation 1 (studies that meet WWC group design standards only)					**Academic achievement: $g = +0.52$*** **Student engagement: $g = +0.64$***

[a] There was insufficient information reported in Fagioli et al. (2015) to generate effect sizes for the academic achievement and credit accumulation and persistence domains. In the table, coefficients from the analysis models are presented.

* = statistically significant at the .05 level.

Recommendation 2. Use varied, personalized, and readily available digital resources to design and deliver instructional content.

Rationale for Level of Evidence: *Moderate*

WWC staff and the panel assigned a moderate level of evidence based on 16 studies (see **Table C.2**). Eleven studies meet WWC group design standards without reservations.[68,69] Five studies meet WWC group design standards with reservations.[70]

Of the 16 studies, seven are relevant to **Recommendation 2a**, exploring redesigning instruction using technology.[71] All seven studies are a direct test of the recommendation; the studies compared blended, flipped, or online course sections to sections of the same course taught in a traditional face-to-face format. In one of the studies,[72] the blended section was accelerated, whereas the traditional section took a full semester. Results of a meta-analysis of these seven studies indicate that students in the blended, flipped, or online sections performed, on average, as well on academic achievement measures as their counterparts in traditional sections ($g = -0.01$, $p = .80$), indicating that the delivery of portions of course content online is not detrimental to academic performance. The panel interprets this as a positive finding. If students in blended learning courses can achieve similar academic progress as students in traditional lecture courses, then blended approaches can be delivered to a broader audience, with less classroom time, and at a lower cost.

In one study[73] related to **Recommendation 2a**, the impact of blended, accelerated instruction on credit accumulation and persistence was positive and statistically significant. Eighty-seven (87) percent of students in the blended sections completed the course, compared to 82 percent of students in the face-to-face sections. Furthermore, 80 percent of students in the blended sections passed the course, compared to 76 percent of students in the face-to-face sections. In another study,[74] the impact of a flipped classroom format on the comprehensive assessment in statistics course measure was positive and statistically significant.

Of the 16 studies, nine provide support for **Recommendation 2b**, exploring the effects of various types of enhancements to online resources or digital resources for delivering instructional content such as online review tools, podcasts, and visualization aids.[75] All studies are a direct test of the recommendation, and all examined outcomes in the achievement domain. The outcome measures in most of these studies were narrow knowledge tests related to the content delivered through the digital resource; one study[76] examined the impact of a redesigned course on final course grades. Results of a meta-analysis of these nine studies indicate a positive and statistically significant effect of the digital resources ($g = 0.35$, $p < .01$). This effect size means that we would expect a comparison group student who earned the median score (50th percentile) on a knowledge test to have scored in the 62nd percentile if she had been in the intervention group.

Each study supporting this recommendation has high internal validity. The collection of studies demonstrate high external validity and relevance to a range of postsecondary settings. Nearly all of the studies find positive or neutral effects on academic achievement. Nine of the studies supporting this recommendation provide a direct test of digital resources for delivering instructional content, whereas the other seven compared blended, flipped, or online courses to traditional face-to-face courses. The strong internal and external validity of the supporting studies, and the preponderance of positive effects among studies that provide a direct test of the recommendation, has led the panel to assign a moderate level of evidence to this recommendation. This rating is supported by strength of the evidence according to the following criteria:

- **Consistency of Effects on Relevant Outcomes.** The studies supporting the recommendation found positive, indeterminate, and negative effects in the academic achievement domain. Six studies found positive effects on outcomes in the academic achievement domain.[77] Nine studies found indeterminate effects in this domain.[78] One study found negative effects on academic achievement.[79] One of the studies that found indeterminate effects on academic achievement also found positive effects on credit accumulation and persistence.[80]

- **Internal Validity of Supporting Evidence.** The studies supporting this recommendation have strong internal validity. All 11 studies that meet WWC group design standards without reservations were RCTs with low sample attrition.[81] The five studies that meet WWC group design standards with reservations used QEDs.

- **Relationship Between the Evidence and Recommendation 2.** The studies supporting this recommendation examine interventions that are closely aligned with at least one element of Recommendation 2. Six of the studies compare blended courses to traditional face-to-face courses.[82] One of the studies compares online course delivery to traditional face-to-face.[83] The other nine studies test a variety of digital resources for delivering instructional content.[84]

- **External Validity of Supporting Evidence.** The 16 studies supporting this recommendation compared the recommended practices to traditional classroom instructional techniques. Across all studies, the samples consisted of 3,380 undergraduate students at postsecondary institutions across the United States. The length of the interventions varied, ranging from a 12-minute podcast to a full-semester course.

Table C.2. Studies providing evidence for Recommendation 2: Use varied, personalized, and readily available digital resources to design and deliver instructional content

Study	Participants	Setting	Intervention Condition	Comparison Condition	Outcome Domain and WWC Calculated Effect Size
RECOMMENDATION 2A					
Banks (2004) *QED* *Meets WWC group design standards with reservations*	157 undergraduate and graduate students	1 regionally accredited institution serving students in 4 states (AZ, CA, CO, and UT)	Hybrid Instruction (Accelerated Format): The intervention condition incorporated asynchronous delivery of weekly course module content (assigned readings) using Microsoft Outlook Express. Students in the intervention condition responded to discussion questions posted to newsgroups by the instructor and other students. Communication among students and between students and the instructor was primarily asynchronous, through email. Two-thirds of the course content was covered online and one-third was covered in a traditional classroom. (*Intervention Duration:* 1 semester)	Traditional Classroom Instruction (Accelerated Format): The comparison group received instruction in an accelerated format during weekly 4-hour in-person workshops in the evening.	Academic achievement: $g = -0.05$

Study	Participants	Setting	Intervention Condition	Comparison Condition	Outcome Domain and WWC Calculated Effect Size
Bowen, Chingos, Lack, & Nygren (2014) Additional source: Bowen, Chingos, Lack, & Nygren (2012) *RCT* *Meets WWC group design standards without reservations*	605 undergraduate students	6 public universities (NY and MD)	Interactive Learning Online (ILO): Students assigned to the hybrid statistics courses participated in ILO, which included machine-guided instruction and face-to-face instruction each week. These sections were delivered in a hybrid mode, in which most of the instruction was delivered through interactive online materials, but the online instruction was supplemented by a weekly 1-hour face-to-face session, so that students could ask questions or be given targeted assistance by the instructor. The ILO intervention included textual explanations of concepts, worked examples, and practice problems. Students were also required to manipulate data using statistical software. (*Intervention Duration:* 1 semester)	Face-to-Face Instruction: Students assigned to the traditional statistics courses were taught introductory statistics as it is usually offered at their institutions, with face-to-face instruction.	Academic achievement: g = +0.09 Credit accumulation and persistence: g = +0.19*
Coates, Humphreys, Kane, & Vachris (2004) *QED* *Meets WWC group design standards with reservations*	126 students	3 public universities (NY, MD, and VA)	Online Instruction: Students in the intervention condition took a principles of economics course, either microeconomics or macroeconomics, entirely online Each participating university used a different textbook and mode of online delivery. Either asynchronous or synchronous communication discussion forums were used. All three universities use electronic tests and exams and allow for extra credit in the online courses. (*Intervention Duration:* 1 semester)	Business As Usual Lecture: Comparison students in the one principles of economics course at each institution involved face-to-face business as usual lectures using the same content as the online course.	Academic achievement: g = -0.39*

Study	Participants	Setting	Intervention Condition	Comparison Condition	Outcome Domain and WWC Calculated Effect Size
Lovett, Meyer, & Thille (2008) **Additional Source: Lovett, Meyer, & Thille (2010)** *RCT* *Meets WWC group design standards without reservations*	61 undergraduate students	1 university (PA)	Open Learning Initiative (OLI), Accelerated Course: Students enrolled in an interactive online statistics course. Students in the OLI course acquired most of the course content online, meeting with an instructor approximately two times a week for 50-minute sessions to ask questions and review more challenging material. The course was completed in an accelerated format (8 weeks instead of 15). (*Intervention Duration:* 8 weeks)	Traditional Course: Students received traditional instruction in a 15-week introductory statistics course. The content was the same as that delivered in the intervention condition.	Academic achievement: $g = +0.55$*
Overmyer (2014) *QED* *Meets WWC group design standards with reservations*	301 undergraduate students	1 US university	Flipped Classroom: Students enrolled in the flipped classroom sections of a college algebra course watched recorded video lessons outside of class time. Instructors created 30 video lessons that had an average runtime of 20 minutes. Instructors also made solution videos for exams and posted them online after tests were returned to students rather than going over exams in class. Students completed basic homework questions (multiple-choice questions focused on concepts and vocabulary) outside of class after watching the lecture videos. During class time, students worked on additional homework questions involving formulas and applications. Some sections of the flipped classroom included collaborative group work, inquiry-based learning, and active whole-class discussions during class time. (*Intervention Duration:* 14 weeks)	Traditional Classroom: Students enrolled in the traditional sections of a college algebra course watched live lectures during class time. All homework problems were assigned to be completed outside of class time. The homework problems were exactly the same for the flipped classroom model and for the traditional classroom model.	Academic achievement: $g = +0.11$

Study	Participants	Setting	Intervention Condition	Comparison Condition	Outcome Domain and WWC Calculated Effect Size
Schunn & Patchan (2009) *QED* *Meets WWC group design standards with reservations*	188 undergraduate students	Large, public research institution in the US	<u>Open Learning Initiative (OLI), Logic and Proofs Course</u>: Students enrolled in an interactive online logic and proofs course. This course combined online instruction with a small amount of targeted face-to-face instruction. (*Intervention Duration:* 13 weeks)	<u>Traditional Course</u>: Students received traditional instruction in a 13-week logic and proofs course. The content was the same as that delivered in the intervention condition.	Academic achievement: $g = -0.07$
Yong, Levy, & Lape (2015) **Additional source: Lape (2016)** *RCT* *Meets WWC group design standards without reservations*	172 undergraduate students	1 college (CA)	<u>Flipped Classroom</u>: Students in the flipped sections of an introductory differential equations course were assigned to watch one to two 15-minute lecture videos that presented PowerPoint slides with "live virtual ink annotations" and audio narration by the professor. An online survey was given at the end of each video to determine whether students watched the assigned videos. At the beginning of the class, the professor answered questions about the videos. During the rest of the course time, students worked independently or cooperatively on selected homework problems, and the professors interacted with students by asking and answering questions. A portion of class time was often reserved for working on mathematical modeling tasks in small groups. (*Intervention Duration:* 7 weeks)	<u>Traditional Classroom</u>: Most of class time was spent on lectures relying on the same PowerPoint slides and materials used in the flipped sections. Classes usually included at least one practice problem that students could work on independently or in small groups, during which time the professors would walk around the room to assess students' understanding of the material and answer questions. All homework questions were completed outside of class time. The duration of the course and amount of total class time mirrored the flipped sections.	Academic achievement: $g = -0.25$
Domain Averages for Recommendation 2a					**Academic Achievement: g = -0.01** **Credit accumulation and persistence: g = +0.19***

Study	Participants	Setting	Intervention Condition	Comparison Condition	Outcome Domain and WWC Calculated Effect Size
RECOMMENDATION 2B					
Bannan-Ritland & Grabowski (2002) *RCT* *Meets WWC group design standards without reservations*	137 undergraduate students in three statistics courses	1 university in eastern US	Visual Summary with Manipulation: Instruction on heart content is provided via webpages using hypertext and images that can be manipulated. Students can click and drag images in the web-pages and are presented with text information that supports the visuals. (*Intervention Duration:* one lesson, length of lesson unknown)	Text and Graphics Only: In the comparison condition, students received an online instruction module on heart content via text and graphics only.	Academic achievement: $g = -0.29$
			Learner Manipulation: Instruction on heart content is provided via webpages using hypertext and images that can be manipulated. Students can click and drag images in the web-pages, but no text information that supports the visuals is presented. (*Intervention Duration:* one lesson, length of lesson unknown)		Academic achievement: $g = -0.39$

Study	Participants	Setting	Intervention Condition	Comparison Condition	Outcome Domain and WWC Calculated Effect Size
Chou (2009) **Additional source: Chou (2013)** *RCT* *Meets WWC group design standards without reservations*	62 undergraduate students	1 university (PA)	Visualized Concept Maps: Instruction on heart content is provided via three to five webpages using hypertext and visualized concept maps. In this condition, hypertext is presented along with 19 concept maps that relate to the instructional content. The concept maps comprise oval text boxes that represent concepts and arrows that represent relationships between concepts. When students move their mouse pointer over the ovals in the concept map, related images are presented (using Flash animation) on the screen that reinforce the concept. (*Intervention Duration:* 25 minutes)	Hypertext Only: In the comparison condition, students received an online instruction module on heart content via hypertext only.	Academic achievement: $g = +1.35$*
Couzin (2016) *RCT* *Meets WWC group design standards without reservations*	420 undergraduate students	1 statewide community college system	Online Course Modified to Incorporate Universal Design for Learning Principles: The intervention students took an online writing course that was modified to implement Universal Design for Learning (UDL) principles focusing on multiple means of representation, engagement, and expression. These principles were applied to numerous elements of the course including session checklists, web-based games, practice quizzes, rubrics, additional videos, and infographics, among others. (*Intervention Duration:* 16 weeks)	Unmodified Online Course: In the comparison condition, students took the original unmodified version of the online writing course.	Academic achievement: $g = +0.05$
Evans, Yaron, & Leinhardt (2008) **Additional source: Evans (2007)** *RCT* *Meets WWC group design standards without reservations*	45 undergraduate students	1 university (PA)	OLI Stoichiometry Review Course: This course includes an overarching real-world story, an exploratory virtual laboratory, a variety of practice contexts, and immediate feedback on actions and submitted responses. (*Intervention Duration:* 20-25 hours)	Text-Only Study Guide: Students assigned to the comparison group were given a text-only study guide. The study guide covers the same content as the online review course but does not include the overarching story, dynamic interface, or feedback. The review guide takes an estimated 12 to 15 hours to complete.	Academic achievement: $g = +0.63$*

Study	Participants	Setting	Intervention Condition	Comparison Condition	Outcome Domain and WWC Calculated Effect Size
Fratangeli (2009) *RCT* *Meets WWC group design standards without reservations*	84 undergraduate students	1 university in the Mid-Atlantic	Podcast-Based Lesson: Students in an introductory communications class were given a podcast-based lesson. (*Intervention Duration:* 1 lesson)	Regular Lecture-Based Lesson: Students in the comparison group were given a regular lecture-based lesson.	Academic achievement: $g = -0.35$
Galbraith (2014) *RCT* *Meets WWC group design standards without reservations*	97 undergraduate students	1 university (ID)	Instructor-Directed Multimedia Format and Sequencing: Students completed an online family finances learning unit (total viewing time of 152 minutes). The unit consisted of 12 Learning Objects (LOs). The instructor sequenced the LOs and picked one multimedia format for each LO for the students in this condition. The content and assignments were identical to those in the comparison condition. (*Intervention Duration:* 1 week)	Student-Directed Multimedia Format and Sequencing: Students self-directed the LO sequence and self-selected the multimedia format for each LO. The LOs were available in a variety of multimedia formats including text, PowerPoint, audio, and video.	Academic achievement: $g = +0.50$*
Kennedy et al. (2013) *RCT* *Meets WWC group design standards without reservations*	142 undergraduate students	1 university (VA)	Content Acquisition Podcast (CAP) with Lecture: Students in the intervention group watched a 12-minute Content Acquisition Podcast (CAP) on phonological awareness. The CAP contained three sections: (1) What is phonological awareness? (2) Why is phonological awareness necessary? (3) What are effective ways of teaching phonological awareness to students? When all students completed their work in the treatment and comparison conditions, students received the regularly scheduled lecture for approximately 90 minutes. (*Intervention Duration:* 12 minutes)	Reading a Practitioner-Oriented Article: Students in the comparison group read a practitioner-oriented article on the same topic. This article's content aligned to the content of the CAP, and students were instructed to take notes at their discretion. Students were allowed to take as much time as they needed to read the article.	Academic achievement: $g = +0.69$*

Study	Participants	Setting	Intervention Condition	Comparison Condition	Outcome Domain and WWC Calculated Effect Size
Rhoads (2010) *RCT* *Meets WWC group design standards with reservations*	146 undergraduate students	1 university in the Midwest	Podcasted Reviews of Course Material: The intervention condition in this study involved 5- to 7-minute podcasted reviews of course material, including audio with pictures and slide images, prior to course exams. The course was focused on health concepts for future teachers; content was delivered via lectures and in- and out-of-class projects. Professors allowed for an in-class review period the day before an exam. In the intervention condition, four podcasts on acute infections and chronic conditions including asthma, diabetes, and seizure disorders were created by the author. The author used the professors' lecture slides to create the podcasts, which were vetted by the professors for accuracy. Students came to the regularly scheduled class to view and listen to the podcasts. (*Intervention Duration:* 1 semester)	In-Class Oral Reviews: Control classrooms received traditional in-class oral reviews prior to taking the exams. Otherwise, the comparison classrooms functioned the same and had the same content and PowerPoint lectures, assignments, and activities.	Academic achievement: $g = +0.13$
Trevisan, Oki, & Senger (2010) *RCT* *Meets WWC group design standards without reservations*	Experiment 1: 364 undergraduate students	6 US universities	Time Compressed Animated Delivery (TCAD 3D): Students in the intervention condition viewed a Time Compressed Animated Delivery (TCAD 3D) teaching follicular dynamics. The digital animated presentation, which was explained by voice-over, was projected on a large screen for classroom viewing. (*Intervention Duration:* 17 minutes)	Traditional Lecture on Video: Students in the comparison condition viewed a traditional lecture on video. The lecture consisted of a PowerPoint presentation with intermittent views of the instructor, and was projected from a DVD onto a large screen for classroom viewing. The length of the video-lecture was approximately 34 minutes.	Academic achievement: $g = +1.09$*
	Experiment 2: 273 undergraduate students	6 US universities	Time Compressed Animated Delivery (TCAD 3D): The TCAD 3D content was more in-depth compared to Experiment 1 and described differential hormone regulation. (*Intervention Duration:* 17 minutes)	Traditional Lecture on Video: The length of this video was approximately 23 minutes.	Academic achievement: $g = +0.26$*
Domain Averages for Recommendation 2b					**Academic Achievement: $g = +0.35$***

* = statistically significant at the .05 level.

Recommendation 3. Incorporate technology that models and fosters self-regulated learning strategies.

Rationale for Level of Evidence: *Moderate*

WWC staff and the panel assigned a moderate level of evidence based on four studies that examined the effectiveness of various strategies to foster or activate student self-regulation (see **Table C.3**). All four studies meet WWC group design standards without reservations.[85]

All four studies provide a direct test of the recommendation. Sullivan (2016) investigated the impact of text and email course activity reminders in a blended course. Delen and colleagues (2014) studied an interactive learning environment that included supporting elements such as note taking, additional resources, and practice questions. Lin and Lehman (1999) examined the use of reason-based, rule-based, and emotion-based justification prompts in a computer simulation activity. Kauffman and colleagues (2011) explored combinations of structured matrix or outline note taking with self-monitoring prompts in a web-based learning module.

All studies related to this recommendation reported positive effects for outcomes in at least one outcome domain. Student academic achievement was assessed in all four studies.[86] Results of a meta-analysis indicated a statistically significant positive effect on their achievement in favor of the students receiving self-regulation-promoting technologies ($g = 0.66$, $p < .05$). Student persistence was reported in one study,[87] which was determined by the WWC to be an indeterminate effect ($g = 0.31$, $p = .15$).

The panel believes that the research supports a moderate level of evidence for this recommendation. The strong internal validity of the four studies, the largely consistent effects on student academic achievement, and the range of self-regulation-promoting technologies tested all point to the benefits and broad applicability of the technologies and interventions tested. This rating is supported by strength of the evidence according to the following criteria:

- **Consistency of Effects on Relevant Outcomes.** The evidence for this recommendation focuses primarily on student achievement outcomes. Three studies related to this recommendation demonstrated consistent positive effects on academic achievement outcomes, which were measured by instructor- or researcher-created assessments.[88] Two of these three studies demonstrated statistically significant effects when testing more robust scaffolds of self-regulated learning.[89] For example, matrix note-taking methods yielded more positive effects than the outline note-taking method, and reason-justification metacognitive prompts were more effective than rule-based prompts.
- **Internal Validity of Supporting Evidence.** The studies supporting this recommendation have strong internal validity. All four studies were RCTs with low sample attrition that meet WWC group design standards without reservations.
- **Relationship Between the Evidence and Recommendation 3.** The studies supporting this recommendation examined interventions that are closely aligned with the recommendation. Each provided a direct test of the effects of scaffolds designed to support students' use of self-regulated learning strategies. However, there are many self-regulation-promoting applications that might be used to support this recommendation that have not been fully tested with rigorous research.
- **External Validity of Supporting Evidence.** The studies supporting this recommendation have moderate external validity. Two interventions were delivered in courses and took place throughout an entire semester or school year,[90] whereas 10 were shorter in duration and delivered in lab settings.[91] The four studies had small student samples, ranging in size from 20 to 88 students and totaling 291.

Table C.3. Studies providing evidence for Recommendation 3: Incorporate technology that models and fosters self-regulated learning strategies

Study	Participants	Setting	Intervention Condition	Comparison Condition	Outcome Domain and WWC Calculated Effect Size
Delen, Liew, & Willson (2014) **Additional source: Delen (2013)** *RCT* *Meets WWC group design standards without reservations*	80 undergraduate and graduate students	1 college (TX)	Online Video-Based Interactive Learning Environment: The learning environment included a video viewer, interactive notes, practice questions, and additional resources that students could choose to use to learn about renewable energy. The environment included "control buttons" that allowed students to navigate the content and self-direct their learning. (*Intervention Duration:* 16 minutes)	Non-interactive Learning Environment: Students were given the same overall learning goal, content, and scaffolds as in the online video-based interactive learning environment. However, they were not able to self-direct their learning.	Academic achievement: $g = +1.11^*$
Kauffman, Zhao, & Yang (2011) *RCT* *Meets WWC group design standards without reservations*	Experiment 1: 20 undergraduate students	1 college in the Midwest	Structured Online Note Taking, Matrix Method: Students took notes on a 2,000-word passage about wildcats. The matrix method organized the information students needed to collect into a two-dimensional table, with labels on the rows and columns and text boxes in the cells. (*Intervention Duration:* 1 laboratory session)	Conventional Note Taking: Students took notes on a 2,000-word passage about wildcats. The conventional method listed the information students needed to collect above a single text box lacking any structure or labeling.	Academic achievement: $g = +0.96^*$
			Structured Online Note Taking, Outline Method: The outline method organized the information students needed to collect into three hierarchical levels with labeled text boxes. (*Intervention Duration:* 1 laboratory session)		Academic achievement: $g = -0.24$

Study	Participants	Setting	Intervention Condition	Comparison Condition	Outcome Domain and WWC Calculated Effect Size
Kauffman, Zhao, & Yang (2011) *RCT* *Meets WWC group design standards without reservations* *(continued)*	Experiment 2: 39 undergraduate students	1 college in the Midwest	Structured Online Note Taking, Matrix Method Plus Self-Monitoring Prompts: Students took notes on a 3,500-word text on educational measurement that was divided into three webpages. Students saw a self-monitoring prompt at the bottom of each webpage that encouraged them to review their notes before moving on to the next page. (*Intervention Duration:* 1 laboratory session)	Conventional Note Taking: Students took notes on a 3,500-word text on educational measurement that was divided into three webpages.	Academic achievement: $g = +2.13$*
			Structured Online Note Taking, Matrix Method Without Prompts (*Intervention Duration:* 1 laboratory session)		Academic achievement: $g = +1.36$*
			Structured Online Note Taking, Outline Method Plus Self-Monitoring Prompts (*Intervention Duration:* 1 laboratory session)		Academic achievement: $g = +0.46$
			Structured Online Note Taking, Outline Method Without Self-Monitoring Prompts (*Intervention Duration:* 1 laboratory session)		Academic achievement: $g = +0.35$

Study	Participants	Setting	Intervention Condition	Comparison Condition	Outcome Domain and WWC Calculated Effect Size
Lin & Lehman (1999) *RCT* *Meets WWC group design standards without reservations*	88 undergraduate students	1 college in the Midwest	Reason Justification Metacognition Prompts: Students were prompted to provide reasons for their actions at three points during a biology lab simulation. (*Intervention Duration:* 1 biology laboratory session)	No Metacognition Prompts	Academic achievement: *g* = +0.99*
			Rule Based Metacognition Prompts: Students were prompted to explain rules or procedures. (*Intervention Duration:* 1 biology laboratory session)	No Metacognition Prompts	Academic achievement: *g* = +0.34
			Emotion Focused Metacognition Prompts: Students were prompted to reflect on their feelings. (*Intervention Duration:* 1 biology laboratory session)	No Metacognition Prompts	Academic achievement: *g* = +0.23
Sullivan (2016) *RCT* *Meets WWC group design standards without reservations*	64 undergraduate students	1 college in the South	Text Message-Based Course Activity Reminders: These reminders directed students' attention to what they needed to do at specific time points during the course, and reminded students regularly about the due dates and deadlines for tasks and assignments. The frequency and level of detail in the reminders tapered out over the course of the semester. (*Intervention Duration:* 1 semester)	Placebo Email Messages: Placebo messages contained several practice questions before each quiz and the final exam.	Academic achievement: *g* = +0.54 Credit accumulation and persistence: *g* = +0.38
			Email-Based Course Activity Reminders (*Intervention Duration:* 1 semester)	Placebo Email Messages	Academic achievement: *g* = +0.57 Credit accumulation and persistence: *g* = +0.24
Domain Averages for Recommendation 3					**Academic achievement: *g* = +0.66*** **Credit accumulation and persistence: *g* = +0.31**

* = statistically significant at the .05 level.

Recommendation 4. Use technology to provide timely and targeted feedback on student performance.

Rationale for Level of Evidence: *Moderate*

WWC staff and the expert panel assigned a moderate level of evidence based on eight studies (see **Table C.4**). Five studies meet WWC group design standards without reservations.[92] Two studies meet WWC group design standards with reservations.[93] One study that tested multiple interventions reported on comparisons that meet group design standards without reservations and comparisons that meet group design standards with reservations.[94]

Of the 10 interventions studied for this recommendation, six focused directly on technology-supported feedback in various forms. Four of the studies involved the use of student response systems in college classrooms.[95] One intervention was a student response system application in which students answered questions before class.[96] One intervention involved targeted, correct/incorrect feedback within a simulated learning task.[97] Results of a meta-analysis of these six studies evidenced a statistically significant positive impact on academic achievement in favor of technologies that employed timely and targeted feedback ($g = 0.37$, $p < .01$).

The other four interventions studied involved online courses, a key component of which is embedded assessments with targeted and timely feedback for each instructional activity.[98] All four studies reported findings on student achievement, and one reported findings on credit accumulation and persistence. Results of a meta-analysis indicated a positive effect for the interactive courses on student achievement, but this effect is not statistically significant ($g = 0.11$, $p = .14$). The impact on credit accumulation in the one study (Bowen, Chingos, Lack, & Nygren, 2014) that measured it was positive and statistically significant ($g = 0.19$, $p < .05$). The panel could not isolate the impact of feedback from the impact of other elements of the online courses such as high-quality text and graphics or practice activities; still they believe that the incorporation of assessment and tailored feedback into every learning activity within these courses is a critical part of these interventions.

The strong internal and external validity of the supporting studies, the range of feedback technologies tested, and the largely consistent effects on student academic achievement have led the panel to assign a moderate level of evidence to this recommendation. This rating is supported by strength of the evidence according to the following criteria:

- **Consistency of Effects on Relevant Outcomes.** As expected for technologies that are used mainly within single courses, rather than across students' full schedules, the evidence focuses primarily on student achievement outcomes. One study, however, also examined the impact of feedback-facilitating technologies on another outcome of interest for this guide (i.e., effects on credit accumulation). The eight studies supporting the recommendation found both positive and indeterminate effects in the academic achievement domain. Five studies found statistically significant positive effects on outcomes in the academic achievement domain,[99] and five studies found indeterminate effects in this domain.[100] One of the studies that found indeterminate effects on academic achievement also found positive effects on credit accumulation and persistence.[101]

- **Internal Validity of Supporting Evidence.** The eight studies exhibit strong internal validity. Five studies were RCTs with low attrition that meet WWC group design standards without reservations.[102] One study was an RCT with high attrition that meets WWC group design standards with reservations.[103] One study tested three interventions in different experiments, two of which were RCTs with low attrition that meet WWC group design standards without reservations, and one of which is an RCT with high attrition that meets WWC group design standards with reservations.[104] One study was a QED that meets WWC group design standards with reservations.[105]

- **Relationship Between the Evidence and Recommendation 4.** Four studies involved the use of either student response systems or other technologies to provide targeted feedback.[106] These studies directly tested the recommendation. The Interactive Learning Online and Open Learning Initiative interventions, examined in four studies, include feedback components as part of more comprehensive intervention models that help students learn more productively by designing instruction and delivering content using varied, personalized, and accessible digital resources (see **Recommendation 2**).[107] Though the evidence includes several types of technologies, such as student response systems and online courses with embedded feedback systems, there are other technologies for which no evidence that meets WWC standards was located.
- **External Validity of Supporting Evidence.** The student samples across all studies included 1,356 students in 13 postsecondary institutions. Both 2- and 4-year colleges are represented in the study samples. The interventions occurred during the academic year and were tested in natural classroom and campus settings.

Table C.4. Studies providing evidence for Recommendation 4: Use technology to provide timely and targeted feedback on student performance

Study	Participants	Setting	Intervention Condition	Comparison Condition	Outcome Domain and WWC Calculated Effect Size
Jones, Crandall, Vogler, & Robinson (2013) *RCT* *Experiment 1: Meets WWC group design standards without reservations* *Experiments 2 and 3: Meets WWC group design standards with reservations*	Experiment 1: 49 undergraduate students	1 college in the South	iClicker Classroom Response System (CRS): Students used the iClicker CRS to answer eight multiple-choice questions for credit. (*Intervention Duration:* 2 lectures)	No CRS	Academic achievement: $g = +0.12$
	Experiment 2: 39 undergraduate students	1 college in the South	iClicker CRS for Credit (*Intervention Duration:* 2 lectures)	iClicker CRS Not for Credit	Academic achievement: $g = +0.56$*
	Experiment 3: 39 undergraduate students	1 college in the South	Mobile Ongoing Course Assessment (MOCA) Response System for Credit: Students answered 10 questions for credit outside of class time prior to the two unit lectures. (*Intervention Duration:* 2 lectures)	MOCA Response System Not for Credit	Academic achievement: $g = +0.71$*

Study	Participants	Setting	Intervention Condition	Comparison Condition	Outcome Domain and WWC Calculated Effect Size
Moreau (2009) *RCT* *Meets WWC group design standards with reservations*	113 undergraduate students	1 college (PA)	Clickers: Students answered 12-15 questions using clickers during the first 30 minutes of class, and were allowed to discuss responses with their neighbors. During the next 30 minutes, new material was presented and students answered 2-3 questions using clickers to reinforce these concepts. (*Intervention Duration:* 1 semester)	Business As Usual: Comparison sections had the same lesson, examples, practice problems, homework, quizzes, and tests as intervention sections, but they did not have embedded questions and did not use clickers.	Academic achievement: $g = +0.38$
Perez & Solomon (2005) *RCT* *Meets WWC group design standards without reservations*	27 undergraduate students	1 college (FL)	Socratic Agent (Microsoft's Genie): Students received feedback from an animated genie when they made an incorrect choice during a computer-based simulation of an electronics disassembly task. (*Intervention Duration:* 20-45 minutes)	Text Feedback: A message informed students that an incorrect choice had been made but provided no hints about the correct answer.	Academic achievement: $g = +0.03$
Yourstone, Kraye, & Albaum (2008) *RCT* *Meets WWC group design standards without reservations*	190 undergraduate students	1 college (NM)	Clicker Quizzes: Students took 21 quizzes using clickers. Each quiz included 7-12 questions. For each question, the instructor provided a set amount of time, depending on the type of question. At the end of allotted time for each question, students were shown the number of students who selected each response option and the correct option. For questions in which many students answered incorrectly, the instructor explained the correct answer to the class. (*Intervention Duration:* 1 semester)	Paper and Pencil Quizzes: Students could answer the quiz questions in any order as long as they did not spend a total of more than 15 minutes on the quiz. Quizzes were returned the following week, and at that time students could ask about questions they got wrong.	Academic achievement[a]
Domain Averages for Recommendation 4 (studies not testing ILO and OLI)					**Academic achievement** $g = +0.37$*

Study	Participants	Setting	Intervention Condition	Comparison Condition	Outcome Domain and WWC Calculated Effect Size
Bowen, Chingos, Lack, & Nygren (2014) **Additional source:** **Bowen, Chingos, Lack, & Nygren (2012)** *RCT* *Meets WWC group design standards without reservations*	605 undergraduate students	6 public universities (NY and MD)	Interactive Learning Online (ILO): Students assigned to the hybrid statistics courses participated in ILO, which included machine-guided instruction and face-to-face instruction each week. These sections were delivered in a hybrid mode, in which most of the instruction was delivered through interactive online materials, but the online instruction was supplemented by a weekly 1-hour face-to-face session, so that students could ask questions or be given targeted assistance by the instructor. The ILO intervention included textual explanations of concepts, worked examples, and practice problems. Students were also required to manipulate data using statistical software. (*Intervention Duration:* 1 semester)	Face-to-Face Instruction: Students assigned to the traditional statistics courses were taught introductory statistics as it is usually offered at their institutions with face-to-face instruction.	Academic achievement: $g = +0.09$ Credit accumulation and persistence: $g = +0.19$*
Evans, Yaron, & Leinhardt (2008) **Additional source:** **Evans (2007)** *RCT* *Meets WWC group design standards without reservations*	*45 undergraduate students*	1 university (PA)	OLI Stoichiometry Review Course: This course includes an overarching real-world story, an exploratory virtual laboratory, a variety of practice contexts, and immediate feedback on actions and submitted responses. (*Intervention Duration:* 20-25 hours)	Text-Only Study Guide: Students assigned to the comparison group were given a text-only study guide. The study guide covers the same content as the online review course but does not include the overarching story, dynamic interface, or feedback. The review guide takes an estimated 12 to 15 hours to complete.	Academic achievement: $g = +0.63$*

Study	Participants	Setting	Intervention Condition	Comparison Condition	Outcome Domain and WWC Calculated Effect Size
Lovett, Meyer, & Thille (2008) **Additional Source:** **Lovett, Meyer, & Thille (2010)** *RCT* *Meets WWC group design standards without reservations*	61 undergraduate students	1 university (PA)	Open Learning Initiative (OLI), Accelerated Course: Students enrolled in an interactive online statistics course. Students in the OLI course acquired most of the course content online, meeting with an instructor approximately two times a week for 50-minute sessions to ask questions and review more challenging material. The course was completed in an accelerated format (8 weeks instead of 15). (*Intervention Duration:* 8 weeks)	Traditional Course: Students received traditional instruction in a 15-week introductory statistics course. The content was the same as that delivered in the intervention condition.	Academic achievement: $g = +0.55$*
Schunn & Patchan (2009) *QED* *Meets WWC group design standards with reservations*	188 undergraduate students	Large, public research institution in the US	Open Learning Initiative (OLI), Logic and Proofs Course: Students enrolled in an interactive online logic and proofs course. This course combined online instruction with a small amount of targeted face-to-face instruction. (*Intervention Duration:* 13 weeks)	Traditional Course: Students received traditional instruction in a 13-week logic and proofs course. The content was the same as that delivered in the intervention condition.	Academic achievement: $g = -0.10$
Domain Averages for Recommendation 4 (studies testing ILO and OLI)					**Academic achievement $g = +0.11$** **Credit accumulation and persistence: $g = +0.19$***

[a] Author reports findings as positive and statistically significant but effect sizes cannot be estimated from information provided in the study. The statistical significance of the findings could not be confirmed by WWC.

* = statistically significant at the .05 level.

Recommendation 5. Use simulation technologies that help students engage in complex problem-solving.

Rationale for Level of Evidence: *Minimal*

WWC staff and the panel assigned a minimal level of evidence based on two studies that examined the effects of a web-based simulated problem-based learning experience (see **Table C.5**). One study meets WWC group design standards without reservations[108] and one study meets WWC group design standards with reservations.[109] The studies examined the effects of a 90-minute game-based immersive-world exercise[110] and a semester-long community health simulation[111] on student academic achievement, as measured by a short content test and scores on a final exam, respectively. Results of a meta-analysis of these two studies indicate that web-based simulated problem-based learning experiences have a statistically significant positive impact on academic achievement ($g = 0.99$, $p < .01$).

The two studies that meet standards and that are used as evidence to support this recommendation involve the use of a computer simulation and games. The successful use of simulations and immersive technologies in medical education, health care delivery, and military and job training points to the promise of using technology to simulate complex problems that can be presented to and solved by students in other areas of postsecondary education.[112] The minimal evidence rating assigned to this recommendation is due to the limited research evidence that meets WWC standards and the low level of external validity of that evidence. As technologies for simulating complex problems continue to develop and their applications for higher education expand, researchers should seek opportunities to study the impacts of these technologies on learning outcomes.

This rating is supported by strength of the evidence according to the following criteria:

- **Consistency of Effects on Relevant Outcomes.** The two studies used as evidence to support this recommendation found positive effects on measures of academic achievement.

- **Internal Validity of Supporting Evidence.** The two studies were RCTs. One study had low attrition and meets WWC group design standards without reservations.[113] The other study had high attrition and demonstrated baseline equivalence and meets WWC group design standards with reservations.[114]

- **Relationship Between the Evidence and Recommendation 5.** The two studies used as evidence to support this recommendation were direct tests of the recommendation. One study examined the impact of a web-based immersive-world game.[115] The other study examined the impact of a web-based community health simulation on academic achievement in the context of an upper-level undergraduate health behavior course.[116] The panel agreed that the academic achievement measures were testing higher-order thinking skills and understanding of complex concepts.

- **External Validity of Supporting Evidence.** The interventions occur in an upper-level undergraduate health behavior course at a public 4-year university in one study[117] and a laboratory setting in the other study.[118] Though the intervention lasted the entire semester in the health behavior course, the intervention was conducted in a short, 90-minute lab setting in the other study. The sample size across the two studies was 69 students.

Table C.5. Study providing evidence for Recommendation 5: Use simulation technologies that help students engage in complex problem-solving

Study	Participants	Setting	Intervention Condition	Comparison Condition	Outcome Domain and WWC Calculated Effect Size
Barab et al. (2008) *RCT* *Meets WWC group design standards without reservations*	51 undergraduate students	1 large, Midwestern university	Immersive World Condition: Students explored a multi-user virtual environment called the Taiga Park on a computer, which simulated an aquatic habitat. The participants interacted with other characters within functional groups in the game. In the game, participants were provided information via a first-person narrative and given options for their response. They also collected water samples and brought them to a virtual laboratory for analysis. Participants took quizzes throughout their experience and complete three quests to report their findings in the exploration. (*Intervention Duration:* 90 minutes)	Expository Text Condition: Students were presented the same information in a 38-page electronic textbook on a website. The contents were broken down into four separate instructional water quality-based activities. After each section, the participants were given the opportunity to review the contents and then took the test.	Academic achievement: $g = +1.07$*
Spinello & Fischbach (2008) **Additional source:** **Spinello (2004)** *RCT* *Meets WWC group design standards with reservations*	18 undergraduate students	1 college in the Western United States	Web-Based Community Health Simulation: Students were presented with a web-based virtual community and tools to intervene during a simulated infectious disease outbreak. Components of the simulation include information resources, an interactive mapping tool, an online survey builder that allows students to design and administer a survey and receive simulated results, a synchronous communication tool that allows students to conduct interviews with a virtual patient and physician, and a dynamic budgeting system. The web-based simulation platform allowed for an accelerated timeline for students to implement health interventions and monitor the resulting health outcomes over the course of a semester. (*Intervention Duration:* 1 semester)	Traditional Project-Based Learning Assignment: Students were assigned to work with an actual community to identify and assess community health needs and design and pilot a health behavior intervention. The semester timeline prevents students from observing health outcomes that may have resulted from the intervention.	Academic achievement: $g = +0.85$*
Domain Averages for Recommendation 5					**Academic achievement $g = +0.99$***

* = statistically significant at the .05 level.

Appendix D: About the Authors

Panel

Nada Dabbagh, PhD (Panel Chair), is Professor of Learning Technologies and Director of the Division of Learning Technologies in the College of Education and Human Development at George Mason University. Dr. Dabbagh teaches graduate courses in instructional design, e-learning pedagogy, and cognition and technology in the Instructional Design and Technology (IDT) and the Learning Technologies Design Research (LTDR) programs. Her research explores the pedagogical ecology of technology-mediated learning environments with the goal of understanding the social and cognitive consequences of learning systems design. Specific research areas include personal learning environments (PLEs), case problem generation and representation in problem-based learning (PBL), and supporting student self-regulation in online and blended learning environments. Dr. Dabbagh has an extensive publication record including three authored books and more than 100 research papers and book chapters. She has presented her research at more than 100 national and international conferences, participating frequently as keynote and invited speaker. Dr. Dabbagh has also facilitated numerous learning technology design projects, which led to award-winning technology-supported instructional materials. She holds a PhD in Instructional Systems Design from the Pennsylvania State University.

Randall Bass, PhD, is Vice Provost for Education and Professor of English at Georgetown University, where he leads the Designing the Future(s) initiative and the Red House incubator for curricular transformation and (with Heidi Elmendorf) codirects the Hub for Equity and Innovation in Higher Education. For 13 years he was the founding Executive Director of Georgetown's Center for New Designs in Learning and Scholarship (CNDLS). He has been working at the intersections of new media technologies and the scholarship of teaching and learning for nearly 30 years. On numerous national projects, he co-led efforts to enhance higher education through learning designs that educate the whole person, make sensible use of digital tools and resources, and contribute to the transformation of higher education institutions through innovation in order to better serve equity and the common good. He is the author or editor of numerous books, articles, and digital projects, including "Disrupting Ourselves: The Problem of Learning in Higher Education" (*EDUCAUSE Review,* March/April 2012); with Bret Eynon, *Open and Integrative: Designing Liberal Education for the New Digital Ecosystem* (American Association of Colleges and Universities, 2016); and with Jessie L. Moore, *Understanding Writing Transfer: Implications for Transformative Student Learning* (Stylus, 2017). He received his PhD in English and American Literature from Brown University.

MJ Bishop, EdD, is inaugural Director of the University System of Maryland's William E. Kirwan Center for Academic Innovation, established in 2013. The Center conducts research on best practices, disseminates findings, offers professional development opportunities for institutional faculty and administrators, and supports the 12 public institutions that are part of the system as they expand innovative academic practices. Previously, Dr. Bishop was Associate Professor and Director of the Lehigh University College of Education's Teaching, Learning, and Technology Program. While at Lehigh, Dr. Bishop received several awards for her research and teaching, including the 2013 Stabler Award for Excellence in Teaching for leading students to "excellence in their chosen field" as well as "excellence as human beings and as leaders of society." In addition to her teaching, she was Project Director and a co-Principal Investigator of the Clipper Project, a 5-year Andrew Mellon-funded research project evaluating the short- and long-term costs and benefits associated with offering web-based courses to high school seniors who had been "pre-admitted" to the university. Author of numerous national and international articles, Dr. Bishop's research interests include exploring how various instructional media and delivery systems might be designed and used more effectively to improve learning and teaching. Dr. Bishop holds an EdD in Instructional Design and Development from Lehigh University.

Anthony G. Picciano, PhD, is a Professor of Education Leadership at Hunter College of the City University of New York (CUNY) and in the PhD Program in Urban Education at the CUNY Graduate Center of the City University of New York. He has also held faculty appointments in the doctoral certificate program in Interactive Pedagogy and Technology at the CUNY Graduate Center, and the CUNY Online BA Program in the CUNY School of Professional Studies. He has held several senior administrative appointments at the City University and State University of New York (SUNY). Dr. Picciano's research interests are education leadership, education policy, online teaching and learning, and multimedia instructional models. He has led major research projects funded by the U.S. Department of Education, IBM, and the Alfred P. Sloan Foundation. With Jeff Seaman, he has conducted major national studies on the extent and nature of online and blended learning in American K-12 school districts. In 1998, Dr. Picciano co-founded CUNY Online, a multi-million-dollar initiative funded by the Alfred P. Sloan Foundation that provided support to faculty using the internet for course development. He was a founding member and continues to serve on the Board of Directors of the Online Learning Consortium (formerly the Alfred P. Sloan Consortium). Dr. Picciano has authored numerous articles and frequently speaks and presents at conferences on education and technology. He has edited nine journal special editions and has authored 14 books. Dr. Picciano was elected to the Inaugural Class of the Sloan Consortium's Fellows in 2010, in recognition of "outstanding publications that have advanced the field of online learning." He was also the 2010 recipient of the Sloan Consortium's *National Award for Outstanding Achievement in Online Education by an Individual*. Dr. Picciano received his PhD in Education Administration from Fordham University.

Jennifer Sparrow, EdD, is the Senior Director for Teaching and Learning with Technology at the Pennsylvania State University, where she leads a dynamic team of more than 95 learning innovators. As the Senior Director of Teaching and Learning with Technology, she champions the following strategic goals: innovation in teaching and learning with technology; strategic opportunities for faculty development; the advancement of flexible, active learning spaces; research in the scholarship of technology-enhanced teaching and learning; and inspiring excellence in teaching and learning with technology at Penn State and beyond. Dr. Sparrow's current projects include developing the next-generation computer lab, exploring the intersection of learning spaces and pedagogy, the development of a plan for increasing digital fluency, leveraging machine learning for open educational resources, and learning analytics. Dr. Sparrow serves on the Unizin Board of Directors, where she chairs the Teaching and Learning committee. She is the winner of the 2013 EDUCAUSE Rising Star Award. She received her EdD in Curriculum and Instruction from the University of Central Florida.

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The panel also would like to thank the review coordinator Hannah Engle and the team of WWC-certified reviewers for their contributions to this practice guide.

Sarah Costelloe, PhD, is a Senior Associate at Abt Associates and serves as the Practice Guide Director on the WWC Postsecondary Education, Postsecondary Preparation and Evidence Reporting (PEPPER) contract. Dr. Costelloe has nearly 15 years of experience in qualitative data collection, analysis, and interpretation and in working with stakeholders to design and implement evaluations of programs and policies funded at the district, state, and national levels. Outside of the WWC, Dr. Costelloe conducts systemic reviews on Abt's evaluation of the Investing in Innovation Fund (i3) program and serves as the Project Director on several projects, including the Evaluation of Data-Driven Instruction for the U.S. Department of Education (ED) and a Bloomberg Philanthropies–funded evaluation of the What Works Cities program. Prior to joining Abt Associates in 2015, Sarah served as the Director of Research and Evaluation for the Philadelphia Youth Network and as a Research Scientist at the U.S. Department of Education. Dr. Costelloe received her PhD in Education Policy from the University of Pennsylvania.

Kristen Cummings, MA, is a Senior Analyst at Abt Associates and serves as the Deputy Project Director on the WWC-PEPPER contract. Ms. Cummings has experience in project management, collecting and analyzing quantitative and qualitative data, and liaising with project partners and participants. Her other work includes an ED-funded project investigating the Effectiveness of Promising Strategies in Federal College Access Programs and a U.S. Department of Labor-funded project exploring the use of technology-based learning in state workforce systems. Ms. Cummings received her MA in Higher Education from the University of Arizona.

Brian Freeman, MEd, is an Associate at Abt Associates and contributes to study reviews and synthesizing evidence on the WWC-PEPPER contract. Mr. Freeman has significant experience with project and task management; survey sampling, design, programming, and administration; data cleaning and documentation; and descriptive and statistical analysis for large-scale public sector studies. Outside of the WWC, Mr. Freeman has directed the analysis of more than a dozen surveys for the ED, the Corporation for National and Community Service, the U.S. Department of Health and Human Services, and the National Science Foundation. He currently serves as the Project Director on a One8 Foundation-funded project that is programming and administering surveys to thousands of teachers and students across Massachusetts, as well as developing data dashboards for teachers and administrators. Mr. Freeman received his MEd in Education Policy and Management from Harvard University.

Michael Frye, PhD, is an Associate at Abt Associates and serves as the Project Director on the WWC-PEPPER contract. Dr. Frye has more than 10 years of experience conducting evaluations, primarily in the field of education at the K-12 and postsecondary levels. Dr. Frye has been WWC certified since 2012 and has conducted reviews for the WWC Beginning Reading and Early Childhood Education topic areas. Outside of the WWC, Dr. Frye has also led systematic reviews on Abt's evaluation of the Investing in Innovation Fund (i3) program, as well as the Striving Readers program. In addition to leading systematic review tasks, Dr. Frye serves as Deputy Project Director on Abt's Robin Hood College Success Prize study—a randomized controlled trial to test the impact of two technology interventions on the retention and graduation rates of community college students. Prior to joining Abt Associates in 2012, Dr. Frye was a Research Associate at RMC Research Corporation. Dr. Frye received his PhD in Education Research Methods from George Mason University.

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Appendix E: Disclosure of Potential Conflicts of Interest

Practice guide panels are composed of individuals who are nationally recognized experts on the topics about which they are making recommendations. The Institute of Education Sciences (IES) expects the experts to be involved professionally in a variety of other matters that might relate to their work as a panelist. Panel members are asked to disclose these professional activities and institute deliberative processes that encourage critical examination of their views as they relate to the content of the practice guide. The potential influence of the panel members' professional activities is further muted by the requirement that they ground their recommendations in evidence that is documented in the practice guide. In addition, before all practice guides are published, they undergo an independent external peer review focusing on whether the evidence related to the recommendations in the guide has been presented appropriately.

The professional activities reported by each panel member that appear to be most closely associated with the panel recommendations are noted below.

Dr. Nada Dabbagh (Panel Chair) is Professor of Learning Technologies and Director of the Division of Learning Technologies in the College of Education and Human Development at George Mason University. She co-created the Tech Select decision aid, which is referenced and featured as an example in this practice guide. She also co-authored articles referenced in this guide.

Dr. Anthony G. Picciano (Panelist) is a Professor of Education Leadership at Hunter College of the City University of New York (CUNY) and in the PhD Program in Urban Education at the CUNY Graduate Center of the City University of New York. He created a systems model for planning online education that is referenced and featured as an example in this practice guide.

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NOTE: Studies used to support a recommendation are indicated by **bold** text in the references.

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Notes

[1] Although college student enrollment has declined in the last several years, college participation has been on the rise for the past 2 decades (Snyder, de Brey, & Dillow, 2018).

[2] U.S. Department of Education (2017).

[3] Shapiro et al. (2015).

[4] Shapiro et al. (2015).

[5] Kena et al. (2014).

[6] Snyder, de Brey, & Dillow (2018). Also see "Percentage distribution of first-time postsecondary students." Retrieved from **https://nces.ed.gov/programs/digest/d16/tables/dt16_326.40.asp?current=yes** on April 12, 2018.

[7] Pew Research Center (2018b).

[8] EDUCAUSE (2017); McGraw-Hill Education (2017).

[9] Marvin (2018).

[10] Seaman, Allen, & Seaman (2018).

[11] **https://ies.ed.gov/ncee/wwc/Document/284**

[12] Garrison, Anderson, & Archer (2010); Visher, Wathington, Richburg-Hayes, & Schneider (2008).

[13] Kuh et al. (2008); Lillis (2011); Umbach & Wawrzynski (2005).

[14] Richardson, Maeda, Lv, & Caskurlu (2017).

[15] Junco, Heiberger, & Loken (2011).

[16] Fagioli, Rios-Aguilar, & Deil-Amen (2015); Nalbone et al. (2016).

[17] Gilbert & Dabbagh (2005).

[18] Rourke & Anderson (2002).

[19] For an integrated multimodal model for online education, see Picciano (2017).

[20] Some studies report findings for multiple experiments or interventions. In these cases, experiments within one study may receive different WWC evidence ratings.

[21] Bannan-Ritland & Grabowski (2002); Bowen, Chingos, Lack, & Nygren (2014); Chou (2013); Couzin (2016); Evans, Yaron, & Leinhardt (2008); Fratangeli (2009); Galbraith (2014); Kennedy et al. (2013); Lovett, Meyer, & Thille (2008); Trevisan, Oki, & Senger (2010); Yong, Levy, & Lape (2015).

[22] Banks (2004); Coates, Humphreys, Kane, & Vachris (2004); Overmyer (2014); Rhoads (2010); Schunn & Patchan (2009).

[23] For information on how to use accelerated learning models to compress developmental education courses, see the WWC Practice Guide *Strategies for Postsecondary Students in Developmental Education* (Bailey et al., 2016), Recommendation 4 ("Compress or mainstream developmental education with course redesign").

[24] Galbraith (2014).

[25] **http://evaltoolkit.wpengine.com/**

[26] The Open Learning Initiative is a research project hosted by Carnegie Mellon University that develops online educational environments.

[27] Pintrich (2000); Zimmerman (1990, 2000).

[28] Azevedo, Cromley, & Seibert (2004).

[29] Some web-based technologies lack the supports students have traditionally relied on to help them organize and process learning content. For example, online materials sometimes lack page numbers to let learners know how far along they are in their reading.

[30] See Dabbagh & Kitsantas (2005) and Schunk & Ertmer (2000) for additional detail.

[31] Delen, Liew, & Willson (2014); Kauffman, Zhao, & Yang (2011); Lin & Lehman (1999); Sullivan (2016).

[32] Delen, Liew, & Willson (2014).

[33] Kauffman, Zhao, & Yang, (2011); Lin & Lehman (1999).

[34] Dabbagh & Kitsantas (2005); Kitsantas & Dabbagh (2010).

[35] Dabbagh & Kitsantas (2005).

[36] Bailey et al. (2016).

[37] Azevedo, Cromley, & Seibert (2004).

[38] Hattie & Timperley (2007); Schneider & Preckel (2017).

[39] Jones, Crandall, Vogler, & Robinson (2013).

[40] Bowen, Chingos, Lack, & Nygren (2014); Evans, Yaron, & Leinhardt (2008); Lovett, Meyer, & Thille (2008); Perez & Solomon (2005); Yourstone, Kraye, & Albaum (2008).

[41] Moreau (2009); Schunn & Patchan (2009).

[42] Jones, Crandall, Vogler, & Robinson (2013).

[43] Bruff (2009).

[44] Mazur (1997); see also Li (2007).

[45] Li (2007); Moreau (2009).

[46] Hattie & Timperley (2007).

[47] See *Ed Tech Developer's Guide*, published by the U.S. Department of Education's Office of Educational Technology and available for download at **https://tech.ed.gov/developers-guide/**. The guide is designed for developers, startups, and entrepreneurs and highlights critical needs and opportunities to develop digital tools and apps for learning.

[48] Several of the obstacles in this section are described by the Vanderbilt University Center for Teaching, in its online overview to "Classroom Response Systems ('Clickers')" at **https://cft.vanderbilt.edu/guides-sub-pages/clickers**.

[49] Mazur (1997); McKeachie (2002).

[50] Driscoll (2000); Johnson, Johnson, & Smith (1998); Savery & Duffy (1995).

[51] Spinello & Fischbach (2008).

[52] Barab et al. (2009).

[53] Spinello & Fischbach (2008).

[54] WWC staff who worked on this practice guide were members of the What Works Clearinghouse Postsecondary Education, Postsecondary Preparation Evidence and Reporting (WWC-PEPPER) team. This contract is funded by IES and led by Abt Associates.

[55] Handbooks for the updated WWC Standards and Procedures (Version 4.0) were publically available at the time of release of this Practice Guide. However, the reviews of studies that contribute to recommendations in this Practice Guide were conducted prior to the updated WWC Standards and Procedures being in place. Therefore, the reviews for this Practice Guide were conducted under Version 3.0 of the WWC Standards and Procedures.

[56] Junco, Heiberger, & Loken (2011).

[57] Fagioli, Rios-Aguilar, & Deil-Amen (2015); Nalbone et al. (2016).

[58] The baseline equivalence standard is an assessment of how similar the intervention and comparison groups are prior to the period of the study. For more information, see the *WWC Procedures and Standards Handbook, Version 3.0* (pp. 15-16).

[59] Fagioli, Rios-Aguilar, & Deil-Amen (2015); Junco, Heiberger, & Loken (2011).

[60] Fagioli, Rios-Aguilar, & Deil-Amen (2015); Nalbone et al. (2016).

[61] Junco, Heiberger, & Loken (2011).

[62] Fagioli, Rios-Aguilar, & Deil-Amen (2015); Junco, Heiberger, & Loken (2011).

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[66] Fagioli, Rios-Aguilar, & Deil-Amen (2015); Nalbone et al. (2016).

[67] Fagioli, Rios-Aguilar, & Deil-Amen (2015).

[68] Some studies report findings for multiple experiments or interventions. In these cases, experiments within one study may receive different WWC evidence ratings.

[69] Bannan-Ritland & Grabowski (2002); Bowen, Chingos, Lack, & Nygren (2014); Chou (2013); Couzin (2016); Evans, Yaron, & Leinhardt (2008); Fratangeli (2009); Galbraith (2014); Kennedy et al. (2013); Lovett, Meyer, & Thille (2008); Trevisan, Oki, & Senger (2010); Yong, Levy, & Lape (2015).

[70] Banks (2004); Coates, Humphreys, Kane, & Vachris (2004); Overmyer (2014); Rhoads (2010); Schunn & Patchan (2009).

[71] Banks (2004); Bowen, Chingos, Lack, & Nygren (2014); Coates, Humphreys, Kane, & Vachris (2004); Lovett, Meyer, & Thille (2008); Overmyer (2014); Schunn & Patchan (2009); Yong, Levy, & Lape (2015).

[72] Lovett, Meyer, & Thille (2008).

[73] Bowen, Chingos, Lack, & Nygren (2014).

[74] Lovett, Meyer, & Thille (2008).

[75] Bannan-Ritland & Grabowski (2002); Chou (2013); Couzin (2016); Evans, Yaron, & Leinhardt (2008); Fratangeli (2009); Galbraith (2014); Kennedy et al. (2013); Rhoads (2010); Trevisan, Oki, & Senger (2010).

[76] Couzin (2016).

[77] Chou (2013); Evans, Yaron, & Leinhardt (2008); Galbraith (2014); Kennedy et al. (2013); Lovett, Meyer, & Thille (2008); Trevisan, Oki, & Senger (2010).

[78] Bannan-Ritland & Grabowski (2002); Banks (2004); Bowen, Chingos, Lack, & Nygren (2014); Couzin (2016); Fratangeli (2009); Overmyer (2014); Rhoads (2010); Schunn & Patchan (2009); Yong, Levy, & Lape (2015).

[79] Coates, Humphreys, Kane, & Vachris (2004).

[80] Bowen, Chingos, Lack, & Nygren (2014).

[81] Bannan-Ritland & Grabowski (2002) [tests two interventions]; Bowen, Chingos, Lack, & Nygren (2014); Chou (2013); Couzin (2016); Evans, Yaron, & Leinhardt (2008); Fratangeli (2009); Galbraith (2014); Kennedy et al. (2013); Lovett, Meyer, & Thille (2008); Trevisan, Oki, & Senger (2010); Yong, Levy, & Lape (2015).

[82] Banks (2004); Bowen, Chingos, Lack, & Nygren (2014); Lovett, Meyer, & Thille (2008); Overmyer (2014); Schunn & Patchan (2009); Yong, Levy, & Lape (2015).

[83] Coates, Humphreys, Kane, & Vachris (2004).

[84] Bannan-Ritland & Grabowski (2002); Chou (2013); Couzin (2016); Evans, Yaron, & Leinhardt (2008); Fratangeli (2009); Galbraith (2014); Kennedy et al. (2013); Rhoads (2010); Trevisan, Oki, & Senger (2010).

[85] Delen, Liew, & Willson (2014); Kauffman, Zhao, & Yang (2011); Lin & Lehman (1999); Sullivan (2016).

[86] Delen, Liew, & Willson (2014); Kauffman, Zhao, & Yang (2011); Lin & Lehman (1999); Sullivan (2016).

[87] Sullivan (2016).

[88] Delen, Liew, & Willson (2014); Kauffman, Zhao, & Yang (2011); Lin & Lehman (1999).

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[90] Sullivan (2016).

[91] Delen, Liew, & Willson (2014); Kauffman, Zhao, & Yang (2011); Lin & Lehman (1999).

[92] Bowen, Chingos, Lack, & Nygren (2014); Evans, Yaron, & Leinhardt (2008); Lovett, Meyer, & Thille (2008); Perez & Solomon (2005); Yourstone, Kraye, & Albaum (2008).

[93] Moreau (2009); Schunn & Patchan (2009).

[94] Jones, Crandall, Vogler, & Robinson (2013).

[95] Jones, Crandall, Vogler, & Robinson (2013); Moreau (2009); Yourstone, Kraye, & Albaum (2008).

[96] Jones, Crandall, Vogler, & Robinson (2013).

[97] Perez & Solomon (2005).

[98] Bowen, Chingos, Lack, & Nygren (2014); Evans, Yaron, & Leinhardt (2008); Lovett, Meyer, & Thille (2008); Schunn & Patchan (2009).

[99] Evans, Yaron, & Leinhardt (2008); Jones, Crandall, Vogler, & Robinson (2013); Lovett, Meyer, & Thille, 2008; Yourstone, Kraye, & Albaum (2008).

[100] Bowen, Chingos, Lack, & Nygren (2014); Jones, Crandall, Vogler, & Robinson (2013); Moreau (2009); Perez & Solomon (2005); Schunn & Patchan (2009).

[101] Bowen, Chingos, Lack, & Nygren (2014).

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[103] Moreau (2009).

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