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Active Student Engagement in Online Stem Classes: Approaches and Recommendations

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ABSTRACT

This paper examines methods of actively engaging students in online university-level STEM courses. It describes a variety of synchronous and asynchronous engagement strategies, cites research supporting their effectiveness, and offers suggestions for maximizing the effectiveness of active engagement regardless of which strategies are adopted to achieve it. Recommended engagement practices include: (1) Take steps to establish and maintain teaching presence (set up mechanisms for regular interactions between you and your students) and social presence (regularly assign tasks that involve synchronous and asynchronous interactions among the students); (2) Make your policies, assignments, and expectations regarding active student engagement and the reasoning behind them explicit and clear to the students; (3) Carry out extensive formative assessment (e.g., synchronous in-class activities, low-stakes online quizzes, discussion boards, minute papers, and midcourse evaluations) and use the results to make continual adjustments in the design and implementation of engagement activities; (4) Anticipate some student resistance to active engagement and take steps to minimize or eliminate it; (5) Take a gradual approach to adopting new engagement strategies rather than attempting to implement every new strategy you hear about in the next course you teach.

Key words: Active student engagement, active learning, online

INTRODUCTION

Courses delivered online constitute a large and rapidly growing component of higher education. In the fall of 2018, roughly 35% of 17 million undergraduates enrolled in two-year and four-year colleges and 40% of 3 million postbaccalaureate students surveyed were taking some online courses (IES National Center for Educational Statistics, 2019). The percentages increased sharply in the spring of 2020, when the COVID-19 pandemic swept through the world and caused a massive switch from face-to-face (F2F) to online classes.

Online instruction has several advantages over traditional F2F instruction. It makes college accessible to a significantly larger number of students at potentially a fraction of the cost of F2F instruction (Pakdaman et al., 2019), especially if the online courses attract large enrollments and can be offered repeatedly. In addition, if the courses are asynchronous, students can attend classes at times convenient for them, work through course material at their own pace, and repeat material as often as they need to. Although online instruction presents technical challenges and other problems such as the difficulty many students have acquiring technology resources, there is no doubt that it will continue to play an important role in education at all levels.

Designing a course, whether F2F or online, involves many activities. An excellent framework for categorizing them is the *Content-Assessment-Pedagogy (CAP) Triangle* outlined by Ruth Streveler and Karl Smith (2020) in this journal issue. For the course to be effective, the knowledge and skills to be learned by the students (the content), the feedback provided to the students on their progress toward achieving that learning (the assessment), and the methods used to transmit the knowledge and provide practice in the skills (the pedagogy) should align closely with one another.

Streveler and Smith review the challenges of formulating and aligning the three apexes of the CAP Triangle in F2F and online environments. There are no significant F2F-online differences in content: courses must be designed to teach specific knowledge and skills whether the environment is F2F, online, or hybrid. Formative and summative assessments must be constructed to test mastery of the targeted knowledge and provide practice in the skills and so must be essentially the same F2F and online; the only differences would be in the tools and procedures used to administer the assessments and to minimize academic misconduct. The primary F2F-online differences have to do with pedagogy—the mechanics of transmitting information, communicating with students, and actively engaging the students in learning. How to do the last of those online is the subject of the present paper.

Several meta-analyses have shown that F2F and online instruction are on average comparably effective at increasing many measures of student performance and attitudes (Bernard et al., 2004, 2009, 2014; Means et al., 2010; Nguyen, 2015; Shachar and Neumann, 2010; Sun and Chen, 2016).

Other meta-analyses have found that blended learning environments, which combine online and F2F instruction, produce slightly higher learning gains than either form of instruction alone (Bernard et al., 2014; Means et al., 2010; Spanjers et al., 2015).

A significant challenge facing instructors during the pandemic has been dealing with classes with both F2F and online students. Bruff (2020) suggests strategies for handling such situations, one of which is to have F2F students and synchronous online students log in to the same presentation software (e.g., Zoom or Webex). The instructor can then set up synchronous interactions among all students no matter how they are accessing the class. Several studies have examined learning outcomes and student satisfaction in environments that allow students the flexibility of attending classes F2F, online synchronously, or online asynchronously (Beatty, 2014, 2019; Lakhal et al., 2014) found no significant differences in student satisfaction and academic performance from one mode of instruction to another.

While the meta-analyses cited above show only minor between-environment differences in course outcomes averaged over many studies, the individual studies within each environment show substantial variations. A probable implication of this finding is that the quality of instruction in a course influences outcomes much more than whether the course is online or F2F, which in turn suggests that research should focus more on identifying best practices in online environments than on cross-platform comparisons (Grandzol and Grandzol, 2006; Kauffman, 2015). That approach will be taken in this paper.

Extensive research has shown that active student engagement in F2F instruction promotes the attainment of almost every conceivable learning outcome (Freeman et al., 2014; Prince, 2004; Theobald et al., 2020). Studies to be cited in this paper show that student engagement is an even more important factor online than in F2F classes. The purpose of this paper is to explore how instructors can engage students in synchronous and asynchronous online environments, with emphasis on education in STEM (science, technology, engineering, and mathematics) disciplines. The paper addresses the following questions:

1. *What is active student engagement? Is it the same thing as active learning?*
2. *How does active student engagement affect students' learning in F2F instruction?*
3. *What types of student interactions occur in online instruction? What are their impacts on students' learning and satisfaction?*
4. *What are specific strategies for engaging students online? How can familiar F2F activities be adapted to online courses?*
5. *What is "remote teaching"? How does it differ from "online teaching"? What strategies increase its effectiveness?*
6. *How can the effectiveness of any online active student engagement strategy be maximized?*

WHAT IS ACTIVE STUDENT ENGAGEMENT? IS IT THE SAME THING AS ACTIVE LEARNING?

The term *active learning* is widely used in education at all levels, but there is no universally accepted definition of it. Many educators use the term to refer to in-class face-to-face instruction in which all students in a classroom are periodically engaged in course-related activities other than just sitting through lectures. For example, "*Active learning engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert.*" (Freeman et al., 2014) Others use the term to denote any course-related student interaction with course content, instructors, and classmates in which the students do more than simply passively receive information. For example, "*Active learning is any approach to instruction in which all students are asked to engage in the learning process*." (University of Minnesota Center for Educational Innovation, n.d.) In this paper, we will replace the term active learning with *active student engagement,* which encompasses all the teaching approaches covered in the second definition of active learning. We make this change partly to avoid the ambiguity of conflicting definitions of active learning and partly because the term "active engagement" can be easily applied to asynchronous online instruction, for which the concept of "in-class activities" in the first definition is meaningless. [Note: More nuanced definitions of engagement are summarized by Chi et al. (2018).]

The answer to the question "Is active student engagement the same thing as active learning?" is therefore "It depends on which definition of active learning is used. If the first and most common definition is used (activity that engages all students in a synchronous class session), then the answer is no: active student engagement covers all synchronous and asynchronous activities, while active learning only includes the synchronous ones. If the second definition of active learning is used, then the answer is yes: both terms refer to all synchronous and asynchronous activities that occur in the course."

HOW DOES ACTIVE STUDENT ENGAGEMENT AFFECT STUDENTS' LEARNING IN F2F INSTRUCTION?

The notion that active student engagement is an important component of effective teaching has gained widespread attention and acceptance in the last few decades, but it is hardly new. Statements to that effect are found in the Talmud and the writings of ancient Greek, Roman and Chinese sages and medieval scientists and philosophers. More recently, empirical educational research and cognitive science have shown conclusively that active engagement in learning is superior to passive reception of information for promoting students' motivation to learn, academic achievement, and persistence in academic programs (Ambrose et al., 2010; Brown et al., 2014; Freeman et al., 2014; Hodges, 2015; Nilson, 2016; Prince, 2004; Theobald et al., 2020; Wankat and Oreovicz, 2015, Ch. 7). For example, Freeman et al.'s (2014) meta-analysis of 225 studies in STEM courses found that the failure rate in lecture-based courses was 1.5 times that in courses where students were actively engaged, and Theobald et al. (2020) found that active engagement reduced achievement gaps between underrepresented minority students and their classmates by 33% and reduced gaps in passing rates by 45%. After reviewing such findings, Clarissa Dirks, co-chair of a U.S. National Academies initiative to reform undergraduate STEM education, concluded that "At this point it is unethical to teach any other way." (Waldrop, 2015, p. 273)

WHAT TYPES OF STUDENT INTERACTIONS OCCUR IN ONLINE INSTRUCTION? WHAT ARE THEIR IMPACTS ON STUDENTS' LEARNING AND SATISFACTION?

Moore (1989) proposed three categories of online student interactions: student-content interactions (SC), such as a student working through an interactive tutorial or simulation; student-student interactions (SS), such as students working on a team project or participating in a discussion board; and student-teacher interactions (ST), such as those that occur in an instructor-facilitated discussion board or during virtual office hours. The interactions may be either synchronous (the instructor and all students are gathered at two or more sites simultaneously for class sessions) or asynchronous (instructional materials reside online and are accessed by students at times convenient to them). This paper will use the SC-SS-ST classification system as an organizational framework. The content of the paper and the references cited all pertain to higher education, but we will retain Moore's use of "teacher" in ST interactions as opposed to the more common (in higher education) "instructor." Although the Moore system was created specifically for online instruction and has been used exclusively in that context, it could equally well be applied to F2F instruction.

The vital role of SS and ST interactions in promoting a wide range of desirable student learning and attitude outcomes was solidly established in Alexander Astin's landmark longitudinal study of F2F education, *What Matters in College* (Astin, 1993). Astin collected data on nearly 25,000 students at 309 institutions, examining the effects of 192 variables relating to institutional and faculty characteristics on 82 outcome variables, including measures of academic achievement, retention in college and specific curricula, career choice, self-concept, patterns of behavior, self-reported growth in skills, and perceptions of and satisfaction with the college experience. The environmental variables that had the greatest impact were the frequency and quality of SS interactions, which produced significant effects on 18 of the top 22 outcomes, and of ST interactions, which produced significant effects on 17 of those outcomes. Many of the interactions studied occurred outside the classroom, but some were course related.

Multiple studies of online education have found significant positive correlations between SC, SS, and ST interactions and various student learning and satisfaction outcomes (Bernard et al., 2009; Croxton, 2014; Jaggers and Xu, 2016; Means et al., 2010; Nilson and Goodson, 2018). SS and ST interactions in particular help relieve the feeling of isolation that students often feel in online courses by building *social presence*, students' feeling of being with real classmates in a virtual environment (Mykota, 2018; Oh et al., 2018) and *teaching presence*, students' sense that their online instructors are real people who are personally involved in their instruction (Orcutt and Dringus, 2017). Numerous studies show that both social and teaching presence correlate positively with online students' motivation to learn, academic performance, persistence to course completion, satisfaction with online courses and instructors, and intention to enroll in future online courses (Alsadoon, 2018; Arbaugh et al., 2009; Jaggers and Xu, 2016; Kang and Im, 2013; Orcutt and Dringus, 2017; Oztok and Brett, 2011; Richardson et al., 2017; Rubin et al., 2010). Most of the studies have examined asynchronous online courses (as opposed to synchronous and mixed forms), the type for which social and teaching presence are most difficult to establish (Bernard et al., 2009).

As was the case for comparisons of F2F and online instruction, findings of individual studies of the impacts of online SS, SC and ST interactions on learning outcomes vary considerably from one study to another, suggesting that the quality of an interaction is at least as important as its frequency. One system for categorizing the quality of student engagement activities is the ICAP taxonomy (Chi, 2009; Chi and Wylie, 2014; Chi et al., 2018; Fonseca & Chi, 2014; Menekse et al., 2013; Svinicki, 2020), which defines four categories based on the nature of the students' overt behaviors during the activities. Following are the categories in increasing order of their probable effectiveness on learning (the reverse of their order in the acronym for the taxonomy).

- *Passive:* Receiving information without doing anything with it, such as listening to a recording, watching a video, and sitting through a lecture.
- *Active:* Any activity that goes beyond passive reception of information but does not generate new material, such as repeating received information verbatim and underlining or highlighting text.
- *Constructive:* Any individual activity that generates material beyond received information. Examples include solving a problem, explaining a concept, interpreting experimental data, analyzing, critiquing, and designing.
- *Interactive:* Activities that involve exchanges among two or more students, with the contributions of each participant being primarily constructive and a reasonable degree of turn-taking occurring. Examples include discussing, debating, reciprocal quizzing, planning, and troubleshooting.

The ICAP taxonomy is complementary to the SC-SS-ST categorization system in that the effectiveness of an activity in any of the latter categories depends heavily on its ICAP category. For example, students might be watching a video lesson on their computer monitors, an SC (student-content) interaction. If the students are simply observing the video, the activity would be passive; if they occasionally go back and replay parts they had previously observed, it would be active; if they pause the video and write brief summaries of what they just saw and heard (thus generating new material), it would be constructive; and if they work with classmates to construct a summary or draw a concept map of the video content or discuss and resolve points of disagreement, it would be interactive. Research suggests that learning would increase from each of those options to the next one (Chi et al., 2018; Menekse et al., 2013).

WHAT ARE SPECIFIC STRATEGIES FOR ENGAGING STUDENTS ONLINE? HOW CAN FAMILIAR F2F ACTIVITIES BE ADAPTED TO ONLINE COURSES?

Essentially all F2F in-class activities can without much difficulty be adapted to synchronous online instruction, and all F2F out-of-class activities (including homework assignments and student projects) can be adapted to both synchronous and asynchronous online instruction. That is not to say that F2F and synchronous online courses are equivalent. The absence of direct contact between students and their instructors and classmates in online courses leads to lowering of social and teaching presence and, inevitably, occasional class disruptions due to technology failures. Ways to minimize the first problem are discussed later in this paper. The second problem is beyond the paper's scope.

Table 1 lists some online engagement activities along with their SC-SS-ST designations, their ICAP classifications, and whether they are easily adaptable to asynchronous courses. (All of them can be used in synchronous courses.) The activities are sorted by their functions: to present or reinforce course material, provide summative assessment of learning, or provide formative feedback to students and instructors. Every activity involves SC interactions, though for some activities those interactions are secondary to SS or ST interactions. A natural approach to engaging online students is to adapt familiar F2F course activities to an online environment. Table 2 lists such activities that integrate SC with SS and/or ST interactions and reach one of the two highest levels of the ICAP model.

Many of the activities listed in Tables 1 and 2 can be implemented in a synchronous class session using tools in Zoom (Brennan, in press, 2020) or one of its alternatives. For example, you may ask students to (a) raise hands physically or with Zoom's *raise hands* tool to ask a question or volunteer to answer one you asked, (b) submit questions and answers in a *chat* window, (c) vote *yes* or *thumbs up* if you are simply seeking agreement with a statement, (d) vote for one or more of several multiple choice options in a *poll* (when you close the poll, Zoom shows the distribution of responses), or (e) make a question part of a competition using a game-based application such as Kahoot or Quizizz.

If you want to conduct a think-pair-share or TAPPS activity (see Table 2) or any other synchronous small-group exercise, you can direct the students to communicate with their group partners via private chat or have Zoom sort them into preselected or randomly assigned groups of any size you designate and send the groups to virtual *breakout rooms* for a specified time. When the allotted time has elapsed or you decide to terminate the activity manually, Zoom recalls the students to the main "classroom," and then you call on individual students or groups to report on what they came up with. If the activity involves writing or drawing, the students can use Google Docs or Google Slides or Zoom's whiteboard tool or Google Jamboard (also a whiteboard tool) to do their work and later share it with you and the class. If you want to add quizzes and interactive activities to your slides, you can install Google Pear Deck as an add-in to PowerPoint or Google Slides.

A major concern about asynchronous SS interactions such as discussion boards is the difficulty of getting students to participate in them. Instructors have effectively used course management systems such as Blackboard, Canvas, or Moodle to track student participation, counting results towards a class participation grade. Additional recommendations for increasing student participation in both synchronous and asynchronous activities are given later in this paper in the section on maximizing the effectiveness of active engagement strategies.

Most of the activities listed in Tables 1 and 2 encompass a variety of options. For example, an activity could involve completing one or more steps in explaining a concept, solving a quantitative problem, deriving a formula, constructing a flow chart or circuit diagram, or critiquing a report; a discussion could be synchronous or asynchronous and with or without instructor facilitation; and a team project could be unfacilitated or instructor-facilitated. The number of possible activities STEM instructors may include in their courses is uncountably large. Here are some guidelines for choosing from among them.

- Choose an activity that aligns with one or more of your learning objectives (statements of observable actions students should be able to perform if they have learned what you have been trying to teach). If you want students to master a concept, ask them to explain it in plain language or to answer a multiple-choice question that requires understanding the concept and then justify their answer. If you want them to develop creative and critical thinking skills, use activities that require those skills (e.g. brainstorm options for doing something, then identify the best option and justify your selection). The point is not to require activity for its own sake, but rather to provide guidance, practice, and feedback in your targeted skills.

  Writing clear learning objectives and using them to guide all course planning, delivery, and assessment functions is a fundamental element of effective pedagogy. Felder and Brent (2016,

Table 1. Online student engagement activities.

Function	Activity	SC[a]	SS[a]	ST[a]	ICAP[b]	Activity Type[c]
Presenting information, reinforcing learning, and deepening understanding	Students view video, slide show, or screencast, or complete assigned readings	1			Pass	A,S
	Students take notes on or rehearse presented material, or underline or highlight text	1			Act	A,S
	Students summarize, self-explain, or generate questions about presented materials	1			Con	A,S
	Individual [and small-group] activities: students report results, instructor calls on students to respond, provides feedback, leads discussion (see Table 2)	1	[2]	2	Con [Int]	S
	Think-pair-share—individual activity, students pair to reach consensus, pairs report	2	1	2	Int	S
	Thinking-aloud pair problem solving (TAPPS)—(see Table 2)	2	1	2	Int	S
	Online discussion board with minimal instructor involvement	2	1		Int	A,S
	Online discussion board with moderate instructor involvement	2	1	2	Int	A,S
	Students form study groups and collectively summarize notes or create study guide	1	2		Int	A,S
	Online simulations and virtual laboratories run by individual students	1			Con	A,S
	Online simulations and virtual laboratories done by student teams [possibly with instructor feedback] (see Table 2)	1	2	[2]	Int	A,S
Summative assessment	Individual assignments with delayed instructor feedback	1		2	Con	A,S
	Individual assignments with immediate or delayed automated feedback	1			Con	A,S
	Group assignments and projects	2	1	2	Int	A,S
	Pair programming—students work in pairs to write computer code (see Table 2)	2	1		Int	A,S
Formative assessment	Minute paper—students identify main and muddy points of lesson (see Table 2)	1		2	Con	A,S
	Peer review of student products and presentations	2	1		Int	A,S
	Midterm evaluation of course and instructor followed by instructor's response			1	Con	A,S
	Online formative quizzes with automated or delayed instructor feedback.	1		2	Con	A,S
	ConcepTests—students vote on responses to conceptual questions (see Table 2)	1		2	Con	S
	Peer Instruction—ConcepTest + pair discussion (see Table 2)	1	2	2	Int	S

[a]1 = activity strongly addresses category, 2 = activity somewhat addresses category. Square brackets [ ] indicate group activities.
[b]Pass = passive, Act = active, Con = constructive, Int = interactive. Square brackets [ ] indicate group activities.
[c]A = easily adaptable to asynchronous instruction, S = easily adaptable to synchronous instruction.

Table 2. Familiar face-to-face activities in an online environment.

Method	Online Activity	SC[a]	SS[a]	ST[a]	ICAP[b]	Mode[c]
	Individual					
In-class individual activity	In response to an instructor prompt, students individually complete any activity that requires them to reflect on course content (answer a question, start a problem solution, etc.). Instructor calls on students to respond orally or electronically and leads discussion of responses. See Felder and Brent (2016, pp. 76–78) for STEM-relevant activity prompts.	1		2	Con	S
Minute paper	Students identify main or muddy points after viewing online lesson and post their response anonymously via discussion board, chat window, text message, email, etc. Instructor views responses and addresses common issues in the next lesson or by posting to a discussion board (Felder & Brent, 2016, p. 62).	1	2	2	Con	A,S
ConcepTest	Students view multiple-choice conceptual question during class session and individually vote for correct response using a polling tool such as those provided by Webex and Zoom (Mazur, 1996). Instructor responds synchronously, clarifying misconceptions. Find STEM ConcepTests by entering "conceptest chemistry," "conceptest polymer membranes," etc.) into a search engine or, for several branches of engineering, in the Concept Warehouse (Koretsky et al., 2014).	1		2	Con	S
Just-in-Time-Teaching (JiTT)	Students view multiple-choice questions before a synchronous class session and individually post their answers online, preferably anonymously. Instructor views their responses before the session and adjusts the session content to address common errors and points of confusion. (Simkins and Maier, 2009)	1		2	Con	S
Simulations and laboratories	Individual students [or groups] use process simulations, remotely operated or virtual labs, or at home lab kits to study system behavior and run experiments (Atiq et al., 2015; Corter et al., 2011; Faulconer and Gruss, 2018; Koretsky et al., 2014).	1	[2]		Con [Int]	A,S
	Group					
In-class small-group activity	In response to an instructor prompt, student groups complete any activity that requires them to reflect on course content (brainstorm, other activities named in the first row). Instructor calls on students to respond orally or electronically and discusses their responses. See Felder and Brent (2016, pp. 76–78) for possible activity prompts.	2	1	2	Int	S
Think-pair-share	Students complete any generic individual activity (see above), pair with another online student synchronously (e-mail, breakout room), and come to consensus on a response to share with the class when called on by the instructor (Felder and Brent, 2016, p. 114).	1	2	2	Int	S
Thinking aloud paired problem solving (TAPPS)	Students in pairs solve a problem, one student vocalizing their thinking (Zoom, Skype, phone, etc.), the other student asking questions and providing prompts if the first student gets stuck. Students periodically switch roles (Felder and Brent, 2016, pp. 121–122).	2	1		Int	S
Pair Programming	One student writes computer code, partner checks, corrects, thinks strategically. Students frequently alternate roles (Williams and Kessler, 2002).	2	1		Int	A,S

Table 2. (Continued).

Method	Online Activity	SC[a]	SS[a]	ST[a]	ICAP[b]	Mode[c]
	Group					
Peer Instruction	After completing online ConcepTests (see above) individually, students discuss the correct solution with a classmate (e-mail, chat, text, etc.), come to consensus, and vote online again. Instructor responds synchronously, moving on when the response distribution indicates that most students have the correct answer (Mazur, 1996).	2	1	2	Int	S
POGIL (Process Oriented Guided Inquiry Learning)	Students in teams work through online content and pre-prepared guiding questions. Instructor monitors responses and adjusts next class session as needed (Simonson, 2019).	1	2	2	Int	S
Cooperative Learning	Students complete team assignments under specific conditions including individual accountability and positive interdependence (Felder and Brent, 2007; 2016, Ch. 11). Students often work alone but periodically meet synchronously online.	2	1	2	Int	A,S
Problem-Based Learning	Student teams complete authentic, open-ended problems, often under conditions similar to cooperative learning (see above). Students access relevant content through video lecture and online readings and interact online (breakout rooms, e-mail, etc.) synchronously and asynchronously. Instructor provides formative and summative assessment electronically. (Savery, 2015)	2	1	2	Int	A,S

[a]1 = primary category, 2 = secondary category. Square brackets [ ] indicate group activities.
[b]Pass = passive, Act = active, Con = constructive, Int = interactive. Square brackets [ ] indicate group activities.
[c]A = easily adaptable to asynchronous instruction, S = easily adaptable to synchronous instruction.

Ch. 2) outline and illustrate how to write and apply learning objectives, and Felder and Brent (n.d.-a) present an online tutorial and self-test on the topic.

- Use the ICAP model to guide you towards engagement strategies at the constructive and interactive levels (not that it's wrong to sometimes have students watch videos as part of your engagement strategy).
- Remember that asynchronous online activities such as discussion boards offer some advantages over F2F and online synchronous group activities. Asynchronous activities provide more time for individual reflection, actively involve a larger percentage of the class, and keep individual students from dominating discussions. If you are converting a course from F2F to online and you plan to make it primarily synchronous, consider including at least some asynchronous activities beyond simple assignments to take advantage of the benefits they offer.

WHAT IS "REMOTE TEACHING"? HOW DOES IT DIFFER FROM ONLINE TEACHING? WHAT STRATEGIES INCREASE ITS EFFECTIVENESS?

A recently created distinction between forms of online courses is that between "online teaching" (or "online learning") and "remote teaching" (or "emergency remote teaching"). Remote teaching refers to instruction in an F2F course that has abruptly been shifted online, as happened to millions of courses at all educational levels around the world in March 2020. Online teaching means instruction designed from the start to take place online, or possibly in a previously F2F course that has been taught online often enough to have the technical and pedagogical kinks worked out. Hodges et al. (2020) summarize the differences between the two course categories.

While outcomes of remotely-taught courses should never be compared directly to those of well-designed and delivered online courses, research has begun to contribute to our understanding of the issues faced by students and instructors when abrupt shifts to online teaching occur. The National Science Foundation and the Bill and Melinda Gates Foundation sponsored a study of college teaching during the pandemic (Means & Neisler, 2020, pp. 14–15), with a national sample of 1008 undergraduate students in 717 four-year and 271 two-year institutions who responded to a survey regarding their experiences in remotely-taught courses.

The survey first asked the students to rate their satisfaction with an F2F course they had started to take and the online version of the course they abruptly switched to. Sixty-three percent of the 1008 survey respondents reported on a STEM course. Their levels of satisfaction with the course before and after the switch are shown in Table 3.

Table 3. Student satisfaction with F2F and remote instruction.

Satisfaction level	F2F	Remote
Very satisfied	51	19
Somewhat satisfied	36	40
Somewhat dissatisfied	9	27
Very dissatisfied	3	13

The survey then showed a list of eight research-proven online instructional practices and asked the students to identify which ones were used by their remote course instructors. These are the practices:

1. Assignments that ask students to express what they have learned and what they still need to learn
2. Breaking up class activities into shorter pieces than in an in-person course
3. Frequent quizzes or other assessments
4. Live sessions in which students can ask questions and participate in discussions
5. Meeting in “breakout groups” during a live class
6. Personal messages to individual students about how they are doing in the course or to make sure they can access course materials
7. Using real world examples to illustrate course content
8. Working on group projects separately from the course meetings

While the total percentage of students satisfied with the remote course (either very or somewhat) dropped from 87% (F2F) to 59% (remote), the satisfaction rates varied dramatically with the number of the recommended teaching practices used in the course: 74% for 6–8 practices, 61% for 3–5 practices, and 43% for 0–2 practices. These findings provide excellent guidelines for designing online courses.

MAXIMIZING THE EFFECTIVENESS OF ONLINE ACTIVE STUDENT ENGAGEMENT STRATEGIES

The meta-analyses cited in the preceding sections demonstrate that even if a student engagement strategy generally works well, the variability in its effectiveness from one implementation to another may be significant. In some circumstances, the strategy may even be counterproductive. For example, if an instructor assigns online group projects and provides no guidance in dealing with team dysfunctionalities, the students might have been better off working individually. An implication of this observation is that how well an online course is taught can have dramatic effects on the course outcomes, regardless of which engagement strategies the instructor adopts.

Many authoritative references list teaching methods that correlate positively with students' performance in all fields (e.g., Ambrose et al., 2010; Chickering and Gamson, 1987, 1999; Nilson, 2016; Weimer, 2013) and specifically in STEM courses (Felder and Brent, 2016; Hodges, 2015; Wankat and Oreovicz, 2015). Other references deal specifically with online courses (Junk et al., 2011; Ko and Rossen, 2017; Nilson and Goodson, 2018, Ch. 1, 4; Vai and Sosulski, 2016), and still others suggest strategies based on modern cognitive science rather than empirical research (Brown et al., 2014; Dunlosky et al., 2013; Oakley, 2014). The paragraphs that follow offer four recommendations drawn from one or more of those references that instructors should consider implementing to maximize the effectiveness of any online activities they conduct.

Recommendation 1: Establish Teaching Presence and Social Presence Early in a Course and Maintain Them throughout the Course.

Several studies attest to the positive impact of teaching presence on students' performance in and attitudes toward online instruction and identify teacher behaviors that contribute to teaching presence (e.g., Baker, 2010; Croxton, 2014; Jaggers and Xu, 2016; Orcutt and Dringus, 2017; Pearson, n.d.; Sheridan and Kelly, 2010). All those studies agree that if you are teaching an online course, you should take steps to establish teaching presence from the outset. For example, you might:

- Send a welcome message to all enrolled students describing the course, its importance in the curriculum and the course discipline, and the types of scientific, industrial, and societal problems the course material may help to solve.
- Post a short video introducing yourself, perhaps mentioning your background, research, personal interests, and why you are enthusiastic about teaching the course.

- In the first week of class, require all students to send you a short message containing some facts about themselves and their interests and statements about what they hope to get out of the course. Schedule a short get-acquainted video chat with each student in the first two weeks.
- Communicate course structures and policies explicitly and clearly, including course learning objectives, information about assignments and tests, and how course grades will be determined.
- Announce how students can contact you with questions (e.g., with postings on the class computer interface or discussion boards or with text or email messages).

Thereafter, you might take additional steps to maintain your presence throughout the course. For example:

- Deliver weekly announcements to the class in short videos.
- When individual students raise questions or identify points of confusion by directly communicating with you, promptly respond to them. When you identify common points of confusion from direct communications, quizzes, assignments, minute papers, or exams, promptly address clarifications to the entire class by email or postings to discussion boards. In the latter case, first give other students opportunities to respond.
- Hold virtual office hours during which you commit to be available to receive students' questions and requests.
- Periodically acknowledge your awareness that students have demands on their time other than your class and emphasize your availability to help.
- Contact students who are struggling in the course, try to determine what the problem is, and offer suggestions for what they might do to remedy it.
- Even if the course is primarily asynchronous, try to arrange several synchronous sessions, such as review sessions before exams.

Some of these ideas—especially those that involve direct communication with individual students—may be impractical in courses with very large enrollments.

Also take deliberate steps to create social presence in your online courses. In general, any activity that involves SS interactions serves this purpose. Mykota (2018) sorts social presence-creating activities into three categories:

- *Establishing Social Presence:* Institute SS-related course design features such as discussion boards, team projects, and policies regarding respectful communications among students.
- *Introducing Social Presence:* Conduct SS-related class activities in the first week of the course such as having students share photos and biographies and forming small discussion groups based on common interests.

- *Sustaining Social Presence:* Conduct SS-related class activities throughout the course such as small-group activities in synchronous class sessions, continuing interactions on threaded discussion boards, and peer feedback on drafts of project reports.

Mykota (2018) and Oh et al. (2018) offer additional suggestions for establishing and maintaining social presence.

Recommendation 2: Make Your Expectations Clear to The Students.

A common complaint of students in online courses is their difficulty understanding exactly what their instructors want them to do, especially if the students are new to online instruction. In F2F classes, they can easily get clarifications directly from the instructors and from one another, while doing so online is generally less straightforward.

We have already mentioned the importance of clarifying your course structures and policies in the first week. Other possible sources of confusion have to do with the knowledge and skills you expect the students to develop, especially if your assignments and exams require skills likely to be new to many of them. Following are techniques you can use to minimize difficulties of this nature.

- *Write learning objectives and share them with your students*. We previously discussed learning objectives in the context of selecting student engagement activities, but objectives are critical components of every aspect of course design. Once again, learning objectives are statements of observable tasks the students should be able to complete if they have learned what you have tried to teach them, where "observable" means the instructor can either see the students doing the tasks or see the results of the students having done them. An objective might look like: "The student should be able to…" (or in a study guide, "To do well on the next exam, you should be able to…") followed by an observable action verb and a statement of what the student should be able to do. For example, an acceptable objective is "The student should be able to calculate one of the variables voltage, current, and resistance, from given values of the other two."

  A limitless number of observable action verbs might be used in learning objectives, such as *define, explain, calculate, derive, optimize, critique*, and *design*. Frequently used but unacceptable (because they are unobservable) verbs include *know*, *learn*, *appreciate*, and *understand*. Objectives are particularly important when high-level thinking skills such as critical and creative thinking and problem-solving skills such as estimating, troubleshooting, and designing are involved. A particularly effective way to share your objectives with the students is to distribute them as study guides for course examinations (Felder and Brent, 2016, pp. 23–30).
- *Provide extensive formative assessment.* Formative assessment—gathering information about what students know and don't know for the purpose of improving learning and teaching rather than to determine grades—correlates strongly with student achievement (Hattie, 2009). If a

class is synchronous, conducting in-class activities can give both the students and the instructor valuable feedback regarding what the students do and don't understand. In asynchronous courses, interspersing online presentations (lecture clips, videos, slide shows, screencasts, etc.) with low-stakes online quizzes (which count little or not at all toward the course grade) and providing timely feedback on the quiz responses serves the same purpose.

Two powerful formative assessment tools—*minute papers* and *midterm evaluations* (Felder and Brent, 2016, pp. 62–63 and 102–103)—call on students to report anonymously on features of a lesson (minute paper) or of the course and instructor (midterm evaluation) that have helped or hindered their learning. In both cases, the instructor looks through the responses, notes common ones, and responds to them either in the next class session (synchronous) or in a subsequent message to the class or posting on the course website. One or more midterm evaluations should be part of every course, be it F2F, online, or hybrid. The inferior alternative is to wait for the end-of-course evaluation to identify problems that might have been addressed if the instructor had known about them earlier.

- *If student participation is important to you, incentivize it.* Simply providing opportunities for interaction in online classes does not guarantee you will get it from all students. For example, if you set up a discussion board and encourage your students to take an active role in posting ideas and responding to others' posts, and then you never bring up their participation again, you may be seriously disappointed in how few students participate after the first week or two. If their participation is important to your teaching strategy, then make it one of your course grading criteria, provide guidance on what makes posts useful (e.g., "Can someone help me understand ____") and not useful (e.g., "I'm confused about everything in this chapter"), and consider requiring a minimum number of posts to get full participation credit.

  Also consider giving slight additional credit for posts that are particularly insightful or use sources beyond what was expected. If early in the course you give the class examples of posts that received such credit (keeping their authors anonymous), you should see improvements in the average quality of subsequent submissions.
- *Use rubrics to grade assignments that require judgment calls from the grader* (Felder and Brent, 2010). A grading rubric lists criteria the grade will be based on (such as accuracy, completeness, quality of writing, etc.) and assigns a maximum value or rating to each criterion. A good rubric clarifies your expectations and can make grading efficient, consistent (the grader gives the same grade to work of the same quality submitted by different students), and reliable (different graders give the same grades to equivalent submissions). Reliability is especially high if two graders independently fill out rating forms and then reconcile their ratings.

Once you have prepared a rubric, you can use it to train students in the required skills by giving them a sample completed assignment with lots of flaws. The students first grade the assignment using the rubric, then pair up to compare and reconcile their ratings for each criterion. Finally, you show them the ratings you would have given the assignment and discuss your reasoning. The students will emerge with a good picture of what you are looking for and warnings about attributes of their work that will lower their grades, and their first assignments will generally be much better than assignments you have received in previous course offerings. To provide additional skill training, you could also ask the students to self-evaluate their first few assignments using the rubric.

You can find rubrics for almost any type of assignment (written and oral reports, essays, critical thinking analyses, and so on) by entering the assignment type followed by "rubric" in a search engine.

Recommendation 3: Anticipate Student Resistance and Take Steps to Minimize or Eliminate it.

Active student engagement strategies put more responsibility on students for their own learning than traditional lectures do. In synchronous online courses, some engagement strategies require students to ask and answer questions in class, possibly exposing what they don't know to their instructor and classmates. Other strategies such as cooperative and problem-based learning require significant and—to many students—unfamiliar and uncomfortable levels of self-directed teamwork. When students first encounter these features of active engagement, not all of them are enthusiastic and some may be overtly resistant. If instructors fail to anticipate and plan for this resistance, it can negatively affect the students' attitudes toward the course and instructor and possibly their performance in the course.

Several authors have examined student resistance to active learning and recommended strategies for dealing with it (Felder and Brent, n.d.-b; Felder and Brent, 1996; Felder and Brent, 2016, pp. 126–127; Finelli et al, 2018; Tharayil et al., 2018; Weimer, 2013, pp. 199–213). The gist of the recommendations is to communicate the rationale for using the activities (which includes the research showing that students learn more through engagement and get better grades), show awareness that you are asking students to take more responsibility than they might be accustomed to, solicit student feedback on their experiences after enough time has elapsed for the students (and you) to become accustomed to the activities, and don't be too concerned if a few students remain resistant to the bitter end.

Recommendation 4: Take a Gradual Approach to Adopting New Engagement Strategies.

Tables 1 and 2 include a wide range of strategies for actively engaging students online, and their number would be enormous if we listed all of their variations. The idea is not to adopt every conceivable strategy starting next Monday, which would overwhelm both you and the students, but to select one or two strategies that look reasonable and try them. Don't just try them once—especially if the strategies are unfamiliar to you and are likely to be unfamiliar to many of the students—but enough for both you and the students to get accustomed to them. If a strategy seems to be working well, keep using it; if it doesn't, have someone knowledgeable check how you are implementing it, try their suggestions, and if doing so fails to help, stop using it. Next course you teach, try another one or two strategies. It should not take more than two or three course offerings to reach a level and quality of student engagement that meets your expectations.

Although several of the four given recommendations pertain specifically to online instruction (particularly the first one relating to teaching presence and social presence), all of them are also relevant to and strongly supported by research on face-to-face instruction. Instructors who have learned to implement these strategies online would be well advised to continue doing so when they return to their F2F classrooms.

CONCLUSIONS

There is nothing radically different between research-proven best teaching practices for face-to-face courses and those for online courses, but the need for adoption of some of the latter practices may be greater owing to the technical and interpersonal challenges associated with online environments. Online classes particularly benefit from explicit instructional objectives, detailed grading rubrics, frequent formative assessments that clarify what good performance is, and above all, clear expectations for active student engagement and strategies to achieve it.

Recommended planning procedures for F2F and online courses are also similar (Felder & Brent, 2016, Ch. 2–4). Planning should begin with construction of a syllabus that includes the major topics to be covered, the approximate time allocated to each topic, the course learning outcomes (the knowledge and skills the students should have by the end of the course), and the course-level learning objectives (the observable tasks the students should be able to carry out that demonstrate their mastery of the specified outcomes). The detailed planning for each topic should involve defining the content to be covered, formulating learning objectives that address the content, redefining the content to cut down on material not addressed in the objectives, and planning student engagement activities that provide practice and feedback in the knowledge and skills specified in the objectives.

Active student engagement, classified by Moore (1989) into student-student, student-teacher and student-content interactions, correlates positively with student performance and satisfaction in online courses. The ICAP taxonomy provides a good system for judging the likelihood that an engagement strategy in any of those three categories will promote learning effectively. In increasing order of effectiveness, student engagement may be *passive* (the student is a passive recipient of information), *active* (the student does something with the information but does not generate new material from it), *constructive* (new material is generated), or *interactive* (new material is generated interactively with other students). We advise instructors new to active student engagement to initially introduce a limited number of constructive and interactive activities that align with their learning objectives, and gradually add additional activities in subsequent course offerings.

We also encourage teachers of online classes to design instruction and assignments to drive student participation in the desired activities rather than trusting that the activities will occur spontaneously. For example, rather than simply hoping students will contribute regularly to discussion boards, encourage participation through assignment and grading policies; rather than hoping students will think conceptually, post conceptual questions on discussion boards and include concept questions on formative quizzes; rather than hoping students will assume individual accountability in team projects, build in accountability using cooperative learning techniques.

In addition to these guidelines, our advice for adopting active engagement strategies online is to take steps to establish and maintain teaching and social presence, anticipate and plan for some student resistance, and get formative feedback along the way to catch problems while they are small. As with face-to-face instruction, when you teach an online course the one thing you can be certain of is that you won't get it right the first time. If you adopt the suggested gradual approach, however, adopting a small number of new strategies in each course offering and never venturing too far from your comfort zone, the other thing you can be sure of is that the course will steadily improve. That is all you need.

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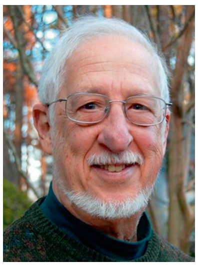

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