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DEVELOPMENT ARTICLE

Grounding the flipped classroom approach in the foundations of educational technology

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Abstract The flipped classroom approach is becoming increasingly popular. This instructional approach allows more in-class time to be spent on interactive learning activities, as the direct lecturing component is shifted outside the classroom through instructional videos. However, despite growing interest in the flipped classroom approach, no robust frameworks have been developed for the design or school/faculty-wide implementation of flipped classrooms. The aim of this article is to provide a foundation for the flipped classroom approach in Spector's (Foundations of educational technology: integrative approaches and interdisciplinary perspectives, Routledge, New York, 2016) model of six pillars of educational technology. After reviewing previous discussion of the flipped classroom approach, each pillar (i.e., communication, interaction, environment, culture, instruction, and learning) is discussed in the context of flipped learning. Using Spector's (2016) framework and drawing on relevant theories and empirical findings, 10 recommendations are made. These recommendations are particularly useful for the school/faculty-wide implementation of flipped classrooms. As the foundational framework proposed in this article is only preliminary, further studies (e.g., design-based research) are recommended to increase the robustness of the design framework and ultimately improve educational practices.

Keywords Flipped classroom · Inverted classroom · Instructional approach · Educational technology

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Introduction

Interest in using the flipped classroom (or inverted classroom) approach is increasing in various subject disciplines, such as health (Betihavas et al. 2016; Presti 2016; Ramnanan and Pound 2017) and science, technology, engineering, and mathematics (STEM) education (Huber and Werner 2016; Karabulut-Ilgu et al. 2017; Seery 2015). The flipped classroom approach entails a change to the relative use of in-class and out-of-class time (Abeysekera and Dawson 2015; Bergmann and Sams 2008). This change is facilitated by advancements in educational technology, such as vodcasting, screencasting, and e-learning portals. Instructors are now able to deliver lectures before class meetings via instructional videos (Bergmann and Sams 2008; Snyder et al. 2014) and to assess students' understanding using online quizzes with immediate computerized formative feedback (Mok 2014; Petrillo 2016). In-class time can thus be directed toward active learning and problem-solving activities with the instructor's guidance and peer assistance (Abeysekera and Dawson 2015; Bergmann and Sams 2008; Spector 2016).

Bishop and Verleger (2013) define the flipped classroom approach as an educational technique with two components, namely, individualized computer-based instruction outside the classroom and interactive group learning activities inside the classroom. Abeysekera and Dawson (2015) note that flipped classrooms usually "move most information-transmission teaching" (p. 3) to pre-class contexts using instructional videos, and that in-class learning activities in a flipped classroom "emphasize active learning, peer learning, problem-solving" (p. 3). Together, the two components of the flipped classroom approach can be described as (1) out-of-class individualized computer-based instruction focusing on information-transmission teaching and (2) in-class interactive group learning activities that emphasize peer-assisted learning and problem solving.

Emerging problems of flipped classroom practices

Despite the growing body of research in this area, no frameworks have been developed for the design and implementation of flipped classrooms (Abeysekera and Dawson 2015; Karabulut-Ilgu et al. 2017; O'Flaherty and Phillips 2015; Presti 2016; Seery 2015). Without a robust framework, research on flipped classrooms tends to be context-specific and thus provides inadequate insights into ways of designing and supporting pre- and in-class learning activities (O'Flaherty and Phillips 2015; Seery 2015). It is thus necessary to discuss the pedagogical design and practice of the flipped classroom approach with reference to certain solid foundations (Abeysekera and Dawson 2015; Karabulut-Ilgu et al. 2017; O'Flaherty and Phillips 2015; Presti 2016; Seery 2015). To develop the framework for this instructional approach, relevant theories should also be explored (Abeysekera and Dawson 2015; Bishop and Verleger 2013; Karabulut-Ilgu et al. 2017; Presti 2016).

In addition, some practical challenges have emerged as a result of the increased number of courses offered in a flipped format. In engineering education, for example, this increasing trend of course transformation began in 2012 (Karabulut-Ilgu et al. 2017). The analysis of the effect of the flipped classroom approach can no longer be limited to individual courses (Khanova et al. 2015b). Khanova et al. (2015b) report that some students take multiple flipped courses in one semester. A few of the students surveyed lamented that "if this [the flipped course] was the only class I had, it would have been fine, but obviously, I have other courses to deal with" (p. 1042). The resulting workload negatively affected students' attitudes toward this instructional approach. Regarding the possible effect of concurrent flipped courses, there is a need for school/faculty-wide

approaches to flipped classroom practices (Khanova et al. 2015b; Wanner and Palmer 2015). However, Spector (2016) observes that "[w]hile the notion of flipping the classroom has been around for at least a generation, there are still very few examples of it being done on a large scale or throughout a school system" (p. 190).

A recent study by Wang (2017) further highlights the need of establishing solid and comprehensive foundations for the flipped classroom approach. He identified both first-order and second-order barriers when instructors adopted this instructional approach into teaching practices. The first-order barriers related to the external challenges such as policy and resources, whereas the second-order barriers related to the internal challenges such as instructors' belief and self-confidence (Ertmer 1999; Wang 2017). Clearly, these challenges should be addressed not only at the instructor level but also at the school/faculty level. However, what are some foundations to guide the design and implementation of flipped classrooms in colleges and K-12 schools? This article aims to address this very question.

The aim and organization of the article

This article aims to establish a rudimentary foundation on which the school/faculty-wide implementation of flipped classrooms can be grounded. The flipped classroom approach relies on various educational technologies (e.g., screencasting, e-learning portals, and online discussion forums). Spector (2016) points out that issues related to educational technology are often complicated and involve multiple disciplines. The school/faculty-wide deployment of this technology-enhanced pedagogy should thus be addressed in an interdisciplinary manner and from a systems perspective.

Spector (2016) establishes a foundational model of educational technology comprising six pillars: communication, interaction, environment, culture, instruction, and learning. These pillars cover all of the major aspects of educational technology (Spector 2016). This study attempts to ground the flipped classroom approach in his model of the six pillars of educational technology. The overarching goal of the present work is to propose a set of recommendations for the design and implementation of flipped classrooms based on this framework. In addition to teachers' day-to-day practices, this research effort is particularly useful for the school/faculty leaders who coordinate the flipped classroom practices on a large scale or throughout a school system.

This article consists of four main sections. First, this introduction section has described the current problems of flipped classroom practices and the aim of the present work. Second, the literature review section provides an overview of prior flipped classroom research and conceptual work on the grounding of the flipped classroom approach. In the discussion section, each of Spector's (2016) pillars is discussed with reference to relevant theories and empirical research. Finally, the conclusion section highlights the major contributions of the present work and discusses potential future research on flipped learning.

Literature review

This section first reports how I retrieved the flipped classroom studies. To understand the current research, an overview of the major findings of existing flipped classroom studies is then provided. After that, the previous discussion of the grounding of the flipped classroom

is reviewed alongside recent empirical evidence. Such a review can avoid repeating others' effort to establish the foundations of flipped classrooms as well as enable an extension of the existing grounding.

The way of retrieving flipped classroom studies

The number of published flipped classroom studies has been increasing rapidly since 2012 (Giannakos et al. 2014; Karabulut-Ilgu et al. 2017). Using the search terms "(flip* OR invert*) AND (class* OR learn*)," a search of eight databases (i.e., (1) Academic Search Complete, (2) British Education Index, (3) Business Source Complete, (4) Communication and Mass Media Complete, (5) ERIC, (6) Library, Information Science and Technology Abstracts, (7) Teacher Reference Center, and (8) TOC Premier) was executed from 2012 to October 2016 (the time of writing). The asterisk served as a wildcard so that all forms of the search terms (e.g., flipping, classes, and learning) could be included. Separating the search terms into individual words by using Boolean operators allowed the capture of various relevant expressions such as "flipped English classroom" (Huang and Hong 2016) and "flip your students' learning" (Sams and Bergmann 2013).

After a title and abstract screening, this search found more than 400 peer-reviewed journal articles on flipped learning. In particular, empirical studies were selected for a review because these studies involved authentic offerings of flipped courses. The experiences reported in these studies could inform future practices of flipped classrooms. No restrictions were imposed regarding research contexts so that the established flipped classroom foundations would not be confined to a specific context. A snowballing process (searching for citing and cited articles of the reviewed studies) was executed when necessary (e.g., authors made suggestions referring to some other flipped classroom studies). As a result, the present work draws on 49 empirical studies of flipped learning.

Major findings of existing flipped classroom studies

The growing number of flipped classroom studies has been accompanied by literature reviews on the topic. The literature reviews (e.g., Betihavas et al. 2016; Giannakos et al. 2014; Karabulut-Ilgu et al. 2017; Lo and Hew 2017a; O'Flaherty and Phillips 2015; Presti 2016; Ramnanan and Pound 2017; Seery 2015) can enrich our understandings of the flipped classroom approach. From their synthesis of research findings, flipping a classroom may bring both benefits and challenges for students and instructors.

For benefits of flipped learning, the use of instructional videos enables students to learn at their own pace by pausing or rewinding video lectures (Giannakos et al. 2014; Karabulut-Ilgu et al. 2017; O'Flaherty and Phillips 2015; Ramnanan and Pound 2017). During class meetings, instructors can spend more time on student-centered activities such as individual inquiry, group discussion, and cooperative learning (Giannakos et al. 2014; O'Flaherty and Phillips 2015; Ramnanan and Pound 2017; Seery 2015). Some evidence has been provided that this instructional approach improves students' professional and communication skills (Karabulut-Ilgu et al. 2017; O'Flaherty and Phillips 2015) as well as their engagement and achievement (Giannakos et al. 2014; Lo and Hew 2017a; Presti 2016; Ramnanan and Pound 2017; Seery 2015).

However, the use of the flipped classroom approach may bring a few challenges. Among the major challenges are the considerable start-up investment required from instructors, students' unreceptiveness to flipped learning, and technical problems (Betihavas et al. 2016; Giannakos et al. 2014; Karabulut-Ilgu et al. 2017; Lo and Hew 2017a;

O'Flaherty and Phillips 2015; Ramnanan and Pound 2017). Nevertheless, instructors can manage these challenges by taking appropriate measures. For example, they can flip their courses gradually, at a pace tolerable to their students; offer students a full introduction to the new instructional approach; and provide students with sufficient technical support (Betihavas et al. 2016; Lo and Hew 2017a).

Previous discussion of the grounding of the flipped classroom

Understanding the previous discussion of the grounding of the flipped classroom approach is the key to position and extend the existing grounding. Bishop and Verleger (2013) argue that the flipped classroom approach stems from Vygotskian theories. Abeysekera and Dawson (2015) develop a theoretical model of the flipped classroom approach, predominantly using self-determination theory and cognitive load theory.

Vygotskian perspective

According to Bishop and Verleger (2013), student-centered learning theories and models can justify a shift in direct lecturing from inside the classroom to outside. In this way, more in-class time is freed up for student-centered learning activities. They continue to argue that student-centered learning is grounded in the theories of Vygotsky (1978), which emphasize the essential role of social interaction in learning. Maciejewski (2016) describes the social features of his flipped mathematics classroom. Having more in-class time available for interactions, his students can devote this time to the group discussion of problem-solving exercises. Maciejewski (2016) explains that this kind of social interaction facilitates the development of their mathematical understanding. Hao (2016) also uses Vygotskian theories to underpin his flipped classroom design. With Vygotsky (1978), he believes that learning with peers is more effective than individual learning, and thus uses a group-based learning approach in his flipped classroom. His students confirm that working in groups promotes their learning due to peer assistance. Further details are provided in the "Learning pillar" section.

Self-determination theory

Abeysekera and Dawson (2015) focus on a motivational perspective and argue that the flipped classroom approach draws on self-determination theory (SDT). From the perspectives of SDT, autonomy, relatedness, and competence are the three innate psychological needs of human beings (Ryan and Deci 2000). According to Ryan and Deci (2000), the satisfaction of these basic needs influences intrinsic motivation, "the inherent tendency to seek out novelty and challenges, to extend and exercise one's capacities, to explore, and to learn" (p. 70). If these needs are supported in school, students are more likely to engage with learning (Fredricks et al. 2004).

Abeysekera and Dawson (2015) hypothesize that the flipped classroom approach can satisfy students' need for autonomy, relatedness, and competence. Although few researchers have specifically attempted to test their hypothesis, Zainuddin and Halili (2016) find some empirical evidence to support this hypothesis. Davies et al. (2013) and McGivney-Burelle and Xue (2013) note that students in a flipped classroom can learn at their own pace, which promotes their sense of autonomy. The flipped classroom approach can satisfy students' need for competence; empirical findings suggest that this instructional

approach increases students' self-perceived knowledge (Galway et al. 2014) and self-efficacy in learning (Enfield 2013).

Cognitive load theory

Abeysekera and Dawson (2015) also argue that the use of self-paced video lectures in the flipped classroom gives students an opportunity to manage their cognitive load. Schultz et al. (2014) report that "most students had a favorable perception about the flipped classroom noting the ability to pause, rewind, and review lectures" (p. 1334). From the perspective of cognitive load theory (Clark et al. 2005), this kind of self-paced lecturing helps students to manage their cognitive load, and thus facilitates their learning (Abeysekera and Dawson 2015; Seery and Donnelly 2012; Turan and Goktas 2016).

Recent empirical studies (e.g., Akkaraju 2016; Turan and Goktas 2016) have explained the reduction in cognitive load as a result of the flipped classroom approach in terms of pre-training and the availability of instructional guidance. Akkaraju (2016) states that students in a flipped classroom can process new information before class meetings. This kind of pre-training reduces the mental effort required from students for information processing inside the classroom, and thus decreases their cognitive load (Mayer and Chandler 2001; Mayer and Moreno 2003). In addition, Turan and Goktas (2016) found that students in a flipped classroom reported lower cognitive loads than those in traditional classrooms. They argued that instructor and peer guidance during in-class activities helps reduce cognitive load and promote student learning (Artino 2008; Moreno 2004).

Discussion: toward the six pillars of the flipped classroom approach

Recall that there is a need for school/faculty-wide approaches to guide the design and implementation of flipped classrooms (Khanova et al. 2015b; Wanner and Palmer 2015). Wang (2017) further points out that the implementation of flipped classrooms requires "the concerted effort of both teachers and school leaders and policymakers" (p. 10). In fact, the flipped classroom approach relies on educational technology which is informed and supported by multiple parties and disciplines (Spector 2016). According to Spector (2016), educational technology rests on the following six foundation pillars.

1. Communication: the way information is represented, transmitted, received, and processed.
2. Interaction: the human–human and human–computer interactions in supporting learning.
3. Environment: the context where learning and instruction take place.
4. Culture: the varied sets of norms and practices of different communities.
5. Instruction: the process of facilitating learning and performance.
6. Learning: the stable and persisting changes in students' knowledge, skills, attitudes, and/or beliefs.

Building on Spector's (2016) framework of the six pillars, Bishop and Verleger's (2013) and Abeysekera and Dawson's (2015) groundings constitute the communication and learning pillars of the flipped classroom approach. I propose an extension of this grounding based on Spector's (2016) framework. Each of the six foundation pillars addresses a

Table 1 Key recommendations of the flipped classroom approach

Pillars and recommendations	Key supporting resources
Communication	
1. Introduce the flipped classroom approach to students and obtain parental consent	Khanova et al. (2015a), Porcaro et al. (2016) and Wang (2016)
2. Use cognitive theory of multimedia learning to inform the production of instructional videos	Lo and Hew (2017b) and Mayer (2014)
Interaction	
3. Create a discussion forum for online interactions	Bhagat et al. (2016) and Westermann (2014)
4. Provide online quizzes on video lectures with computerized feedback	Brown et al. (1997), Mok (2014) and Pannabecker et al. (2014)
Environment	
5. Provide human resources and technical resources to support flipped classroom practices	Lage et al. (2000), Miller (2016), Vaughan (2014) and Wanner and Palmer (2015)
6. Adopt a school/faculty-wide approach to flipped classroom practices	Khanova et al. (2015b) and Wanner and Palmer (2015)
Culture	
7. Cultivate a classroom culture for learner-centered instruction	Bernard (2015), Brown (2012), Marcum and Perry (2015) and Van Sickle (2016)
Instruction	
8 Utilize established models as the framework for flipped classroom design	Gilboy et al. (2015), Jensen et al. (2015), Miller (2016) and Sams and Bergmann (2013)
Learning	
9. Provide optimally challenging learning tasks with instructor's guidance	Flynn (2015), Niemiec and Ryan (2009), Pannabecker et al. (2014) and Vygotsky (1978)
10. Use peer-assisted learning approaches during class meetings	Crouch and Mazur (2001), Jungić et al. (2015), Vazquez and Chiang (2015) and Vygotsky (1978)

particular dimension of the design and implementation of flipped classrooms. Table 1 first overviews the key recommendations for the flipped classroom approach in each pillar.

Communication pillar

Communication is critical to the effective planning and application of educational technology (Spector 2016). This has two implications for the flipped classroom approach. First, the implementation of flipped classrooms involves a range of stakeholders, such as instructors, students, and parents. Communication between instructors and other stakeholders should be facilitated. Second, Mayer's (2014) cognitive theory of multimedia learning can be used to guide the production of instructional videos to enhance information transmission.

Recommendation 1: introduce the flipped classroom approach to students and obtain parental consent

Promoting students' understanding of the flipped classroom approach is important, as they may not be familiar with this instructional approach (Mok 2014; Porcaro et al. 2016;

Reddan et al. 2016). As a result, some students initially react negatively to flipped courses (Clark 2015; Mason et al. 2013; Schultz et al. 2014). To prepare students for flipped learning, Khanova et al. (2015a) introduce their course structure and explain the rationale for using the flipped classroom approach one week before the course starts. Porcaro et al. (2016) even regarded the "preparation of the students before semester begins" (p. 347) as a critical stage in implementing a flipped course. During this stage, teachers ensure that their students understand the reasons for the instructional change and what students are required to do during a flipped course. In summary, instructors can cover the following issues when introducing the flipped classroom approach to students.

1. Objectives and activities involved in the flipped classroom approach (Al-Zahrani 2015).
2. Rationale for using the flipped classroom approach and possible advantages (Betihavas et al. 2016; Gilboy et al. 2015; Khanova et al. 2015a; Porcaro et al. 2016).
3. Instructors' expectations of students (Gross et al. 2015; Reddan et al. 2016).
4. Course logistics such as where and how to access flipped learning materials (Gaughan 2014; Seyedmonir et al. 2014).

In addition, parents' understanding of the flipped classroom approach should be ensured (Wang 2016). Anderson and Brennan (2015) report that some parents misunderstood their children's flipped undergraduate calculus course, "believing the course to be fully online" (p. 867). The parents were frustrated and made a complaint to the faculty coordinator. In his Grade 11 Chinese language course, Wang (2016) attempted to incorporate mobile learning into his flipped classroom. However, some of his students lamented that "they only had very limited time to use the system for learning because their parents [did] not like them to use mobile phones too often" (p. 406). To better inform parents, a letter eliciting parental consent can be sent to introduce the purposes and learning activities of the flipped classroom.

Recommendation 2: use cognitive theory of multimedia learning to inform the production of instructional videos

Although the use of instructional videos can facilitate students' self-paced learning (Abeysekera and Dawson 2015), several challenges may arise (Table 2). For example, students may feel bored when watching videos if their instructors speak in a monotone (Snyder et al. 2014; Zainuddin and Attaran 2016). In addition, students are generally disengaged when watching long instructional videos (Gaughan 2014; Khanova et al.

Table 2 Challenges of using instructional videos and related design principles

Challenges	Design principle and description
Students are disengaged when watching long videos (Gaughan 2014; Khanova et al. 2015b)	Segmentation principle: divide each video lecture into a series of short videos lasting 6 min each
Students feel bored because instructor speaks in a monotone (Snyder et al. 2014; Zainuddin and Attaran 2016)	Personalization principle: use a conversational rather than a formal style (e.g., "I" and "you")
Students do not take notes while watching videos (Gaughan 2014; Hotle and Garrow 2016)	Signaling principle: highlight (e.g., underline) essential materials to direct note taking

2015b). For example, Gaughan (2014) reported that few students were willing to watch the longest video (40 min) in her flipped history course.

Mayer's (2014) cognitive theory of multimedia learning can be used to guide the production of instructional videos (Lo and Hew 2017b; Morgan et al. 2015). Mayer (2014) formulates 12 design principles for multimedia instruction. In the context of flipped learning, Lo and Hew (2017b) demonstrate their use of some of these principles to produce instructional videos. For example, as shown in Table 2, they divide each video lecture into a series of short videos lasting 6 min each (segmentation principle), and their verbal instructions are presented in a conversational style (personalization principle) rather than as a third-person formal monologue. According to Mayer (2014), these design principles can facilitate students' cognitive processing and thus enhance the effectiveness of multimedia instruction.

Interaction pillar

Human–human (i.e., student-instructor, student–student) and human–computer (i.e., student-computer, instructor-computer) interaction are enabled in a technology-supported learning environment (Spector 2016). Spector (2016) points out that technology plays an important role in facilitating these two kinds of interaction in flipped classrooms. Specifically, he focuses on formative feedback on student learning in the interaction pillar.

Recommendation 3: create a discussion forum for online interactions

In contrast with their counterparts in traditional classrooms, students in flipped classrooms cannot interrupt their instructor to ask questions or seek further elaboration while watching instructional videos. Some students have been frustrated by the inability to ask questions during their out-of-class learning (Hotle and Garrow 2016; McGivney-Burelle and Xue 2013; Schultz et al. 2014). Bhagat et al. (2016) thus suggest creating a discussion forum for online question and answer sessions. Both the instructor and the students can leave messages or comments in response to enquiries made about video lectures. Westermann (2014) points out that instructors' feedback on forum posts is important to clarify misunderstandings (i.e., student-instructor interaction). He also asks his students to post their writing assignments on the forum and comment on each other's work (i.e., student–student interaction). This extends human interactions into a virtual environment.

Recommendation 4: provide online quizzes on video lectures with computerized feedback

As a method of formative assessment, feedback is "most effective when it is timely, perceived as relevant, meaningful, encouraging and offers suggestions for improvement" (Brown et al. 1997, p. 51). Spector (2016) highlights the supportive role of computer-generated messages in technology-enhanced learning. Computer-generated feedback (i.e., student-computer interaction) can provide students with immediate guidance on their performance (Mok 2014; Critz and Knight 2013). Mok (2014) incorporated online quizzes with computerized feedback into pre-class learning activities. Several simple multiple-choice or fill-in-the-blank questions were given. Upon submission of the quizzes, computerized feedback was provided immediately for students' self-checking. Mok (2014) argues that his students liked the quizzes because the computer-generated feedback alerted

them to misunderstandings. Based on this feedback, students were able to purposely review the video lectures according to their needs.

Technology can also help instructors monitor student learning in video lectures. If the pre-class exercises or quizzes are delivered through a learning management system (e.g., Moodle or Blackboard), the instructor is able to trace students' performance in these learning areas (i.e., instructor-computer interaction). The resulting data allow the instructor to understand students' mastery of pre-class learning content. The instructor can thus "tailor the in-class session to the needs of the students" (Pannabecker et al. 2014, p. 143). For example, the instructor can discuss questions that students are unable to manage (Flynn 2015) and adjust in-class learning activities to match students' ability (Love et al. 2014).

Environment pillar

The environment pillar involves various interrelated components such as learners, instructors, support staff, instructional materials, learning activities, tools, and technologies (Spector 2016). Spector (2016) argues that a systems-thinking perspective should be adopted to model the education environment as a holistic system. In the context of flipped learning, support at the institutional level and a school/faculty-wide approach to flipped classroom practices are essential (Wanner and Palmer 2015).

Recommendation 5: provide human resources and technical resources to support flipped classroom practices

The implementation of flipped classrooms relies on school investment (Huang and Hong 2016). Wanner and Palmer (2015) even assert that such implementation may become infeasible "if there is no institutional support in the form of teaching assistants or available learning spaces" (p. 365). Human resources and technical resources are the two major areas in which an institute can offer support. In terms of human resources, information-technology (IT) staff can be assigned to provide technical support for flipped classrooms. For example, Gaughan (2014) recalls her experience of creating her first instructional video. As video production was not her area of expertise as a history teacher, she sought the support of the IT department. With step-by-step assistance from IT staff, Gaughan (2014) was empowered to operate her flipped classroom by producing and uploading her own instructional videos. At Vaughan's (2014) university, regular meetings with IT specialists were arranged to facilitate the implementation of flipped classrooms. Furthermore, faculty in-service training in the use of educational technology such as learning management systems, mobile learning, and video production can be provided (Miller 2016).

In terms of technical resources, more IT facilities on campus can increase the accessibility of computer-based learning materials and thus create a flipped learning environment (Lage et al. 2000). These IT facilities allow students to complete pre-class learning activities on campus when class preparation is not feasible at home (Critz and Knight 2013; Schultz et al. 2014). Inside the classroom, some instructors (e.g., Flynn 2015; Jungić et al. 2015; Vazquez and Chiang 2015) have reported using an interactive technology system (e.g., Clickers) to instantly collect students' responses. Mattei and Ennis (2014) report that with the support of their faculty, they were able to provide each student with an iPad for in-class activities. Although such IT facilities require school investment, advancing technological infrastructure can facilitate the implementation of flipped classrooms and improve the teaching and learning environment.

Recommendation 6: adopt a school/faculty-wide approach to flipped classroom practices

From the systems-thinking perspective, school/faculty leaders should adopt a school/faculty-wide approach to implementing flipped classroom practices. Wanner and Palmer (2015) suggest that the deployment of this instructional approach should be "at least faculty-wide" (p. 365). If students take multiple flipped courses in the same semester, it may be difficult for them to prepare adequately for all of their classes, due to time pressure (Khanova et al. 2015b; Wanner and Palmer 2015). As in the traditional classroom, instructors should estimate and maintain the course workload when flipping their courses (Lo and Hew 2017a). In addition, school/faculty leaders should be given a holistic overview of how courses in their schools/departments are designed and implemented. Better coordination between concurrent flipped courses and specific attention to students' overall workloads are necessary (Khanova et al. 2015b).

Culture pillar

Spector (2016) states that technological innovations may not work well in all education contexts due to cultural differences. In the context of flipped learning, Seery (2015) reports that university students studying chemistry liked the flipped classroom approach. However, some K-12 students still held a conventional view of learning and reacted negatively to the instructional change (Lo and Hew 2017a). Wang (2016) further observes that "students in Asian countries [are] used to exploring learning information through instructors instead of engaging in self-directed learning" (p. 411). Therefore, instructors should cultivate a classroom culture for learner-centered instruction (Marcum and Perry 2015; Van Sickle 2016).

Recommendation 7: cultivate a classroom culture for learner-centered instruction

As noted by Bernard (2015), the flipped classroom approach leads to "Learning Culture transitions from teacher-centered instruction to a learner-centered approach" (p. 3). Some preparation work can be done to transform a passive into an active learning culture. For example, Marcum and Perry (2015) demonstrate the learning activities (e.g., small-group discussion) used in the first few lessons of their flipped undergraduate law course. They first arranged some group activities without accompanying video lectures. The goal of the lessons containing these activities was to set "the rhythm of the course" (p. 272) and familiarize their students with the level of participation required in a flipped classroom. In this way, their students became progressively accustomed to the learning culture.

Van Sickle (2016) also recommends cultivating a classroom culture of learner-centered instruction. Although the flipped classroom approach enhanced her students' achievement, student perceptions of her flipped algebra course were not as good as those of her traditional classroom. She explains that the flipped classroom required students to express their ideas and attempt difficult tasks in front of their peers. In such a learner-centered environment, students may make mistakes and feel embarrassed (Van Sickle 2016). Therefore, Van Sickle (2016) confirms the vital role of instructors in establishing a classroom culture in which students are empowered to take risks and make mistakes. Following Brown (2012), instructors can provide feedback on students' efforts, recognize their strengths, and

discuss with them ways of resolving school challenges and fulfilling their potential for success.

Instruction pillar

According to Spector (2016), the instruction pillar "encompasses various instructional approaches, models, and strategies" (p. 24). Few studies to date have grounded their flipped classroom designs in an instructional model framework (Abeysekera and Dawson 2015; O'Flaherty and Phillips 2015). Instructors can consider developing flipped courses based on established models such as Bloom's revised taxonomy (Anderson and Krathwohl 2001) and the 5E instructional model (Bybee et al. 2006).

Recommendation 8: utilize established models as the framework for flipped classroom design

Several instructors (e.g., Gilboy et al. 2015; Miller 2016; Sams and Bergmann 2013) have utilized Bloom's revised taxonomy (Anderson and Krathwohl 2001) as a framework for course planning. Bloom's revised taxonomy is arranged in a cumulative hierarchical framework of learning objectives: remember, understand, apply, analyze, evaluate, and create. The mastery of these learning objectives at lower levels is a prerequisite to the mastery of higher-level learning. Gilboy et al. (2015) and Sams and Bergmann (2013) use instructional videos before class meetings to deliver learning items on remembering and understanding. Face-to-face lessons are then directed toward advanced learning activities related to the higher levels of Bloom's revised taxonomy (i.e., apply, analyze, evaluate, and create). In particular, Gilboy et al. (2015) redesigned their courses following a template developed by the university's faculty associate. The template encouraged their faculty to map the learning items within a course topic onto each level of Bloom's revised taxonomy. Thanks to a strategic course redesign, their faculty was able to achieve all of the levels of Bloom's revised taxonomy in their flipped classroom practices.

The 5E instructional model developed by Bybee et al. (2006) has also been used to design flipped classrooms (e.g., Jensen et al. 2015). This instructional model is based on various teaching and learning models and theories. An instructional sequence is proposed for course design and lesson planning. As summarized in Table 3, the sequence consists of five instructional phases: engagement, exploration, explanation, elaboration, and evaluation. Jensen et al. (2015) deliver the engagement, exploration, and explanation phases outside their classroom. With the guidance of instructional videos, their students had to "explore the phenomenon and discover patterns, offer explanations, and analyze data" (p. 4) before class meetings. Time in class was spent on elaboration and evaluation. The students were asked to solve novel problems by applying the concepts learned in the video lectures. Next, quizzes were given to evaluate the students' learning outcomes. Jensen et al. (2015) conclude that the 5E instructional model can offer an active learning and constructivist approach in both flipped and traditional classrooms.

Learning pillar

Learning is the act of acquiring new abilities, attitudes, beliefs, knowledge, and skills (Spector 2016). Bishop and Verleger (2013) propose that the flipped classroom approach is grounded in Vygotsky's theories. Specifically, Vygotsky (1978) defines the zone of

Table 3 Possible framework for the flipped classroom approach with 5E instructional model

Phase	Description
Out of class	
Engagement	The instructor uses learning activities to elicit students' curiosity and activate the prior knowledge required to learn the new topic
Exploration	Students gain experiences related to the learning items through activities such as preliminary investigation
Explanation	Based on students' experiences of engagement and exploration, the instructor introduces new knowledge and skills to their students
In class	
Elaboration	The instructor reinforces students' understanding and improves their skills by offering additional activities. The students are required to apply what they have learned to solve novel problems
Evaluation	The students assess their own understanding and ability. The instructor evaluates the students' learning progress and their learning outcomes

proximal development (ZPD) as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (p. 86). This has two implications for the flipped classroom approach. First, instructors should provide and guide optimally challenging learning tasks. Second, peer-assisted learning approaches should be used during class meetings.

Recommendation 9: provide optimally challenging learning tasks with instructor's guidance

The difficulty of flipped learning activities should be within students' ZPD. Otherwise, it would be too difficult for students to achieve desirable learning outcomes (Vygotsky 1978). In the context of flipped learning, students may feel negative if the in-class learning tasks are too difficult for them (Van Sickle 2016). In fact, Flynn (2015) points out that students' pre-class learning data can provide "evidence (in the form of pre-class test results) of their knowledge and abilities before they came to class" (p. 202), and thus offer "a starting point for creating in-class activities" (p. 202). For example, instructors could provide a brief review of ways to address students' mistakes in pre-class exercises at the beginning of lessons (Love et al. 2014; Mok 2014). From the SDT perspective, Niemiec and Ryan (2009) advocate providing optimally challenging tasks, as students only engage in learning activities that they can handle. Instructors can design their learning activities based on student performance in pre-class assessments (Flynn 2015; Pannabecker et al. 2014).

In addition, Niemiec and Ryan (2009) suggest providing relevant information for students' improvement. By moving some of the direct lecturing outside the classroom, instructors can spend more in-class time circulating around the classroom to offer individualized feedback (Mason et al. 2013; Schultz et al. 2014; Vaughan 2014). Optimal challenges together with the instructor's guidance are conducive to students' sense of competence, which enhances their motivation to learn (Ryan and Deci 2000).

Recommendation 10: use peer-assisted learning approaches during class meetings

Collaboration with capable peers is important in learning (Vygotsky 1978). In flipped classrooms, more in-class time can be spent on small-group activities such as peer instruction (Jungić et al. 2015; Vazquez and Chiang 2015; Weaver and Sturtevant 2015), group-based learning (Hao 2016), and cooperative learning activities such as think-pair-share (Flynn 2015; McLaughlin et al. 2013) and jigsaw activities (Gilboy et al. 2015).

Crouch and Mazur's (2001) model of peer instruction can be incorporated with educational technology (e.g., Jungić et al. 2015; Vazquez and Chiang 2015). Several steps are involved in peer instruction to facilitate peer discussion and sharing regarding questions. Vazquez and Chiang (2015) require their students to answer each question twice. First, students are required to work out their own answers and submit their first attempts. The students then discuss their answers or seek help from their peers before their second submission. Meanwhile, instructors can provide feedback or hints according to student performance (Jungić et al. 2015; Vazquez and Chiang 2015). Vazquez and Chiang (2015) report on the use of an interactive technology system called Clickers to enhance peer instruction in a large flipped economics classroom. Although their class had more than 900 students, the Clickers system enabled the instructor to collect responses from all students and analyze the results immediately. According to Jungić et al. (2015), student responses usually converge to the correct answer after peer interaction. Their students confirmed that listening to others' explanations and sharing their own understanding of problems enhanced their learning.

Conclusion and recommendations for future research

This article grounds the flipped classroom approach in Spector's (2016) framework of six pillars of educational technology. Based on relevant theories and empirical studies of flipped classrooms, 10 recommendations are proposed (see Table 1). The proposed recommendations shed light on possible improvements to the design and implementation of flipped classrooms. This article particularly offers school/faculty leaders a holistic view of flipped classroom practices in K-12 and higher education. For example, the necessity of institutional support is emphasized in the analysis of the environment pillar, suggesting that human resources and technical resources should be supplied to support the implementation of flipped classrooms (Recommendation 5), and that a school/faculty-wide approach to flipped classroom practices should be adopted to enhance coordination between concurrent flipped courses (Recommendation 6).

Whilst the discussion of Spector's (2016) six-pillar framework as a foundation for the flipped classroom approach is still preliminary, this grounding is solid and comprehensive. Some relatively neglected aspects of the flipped classroom approach can now be addressed. Currently, most flipped classroom research focuses on course-level implementation in which the effect of multiple concurrent flipped courses may be overlooked (Khanova et al. 2015b; O'Flaherty and Phillips 2015). Notably, very few studies have reported on large-scale implementation of flipped classrooms (Miller 2016; Spector 2016). How can we enact and launch the flipped classroom approach at the institutional level using Spector's (2016) framework? If the implementation is supported by the school/faculty, will the efficacy of the flipped courses be fostered or impeded? How dynamic and sustainable will the strategic-top-down approach be to flipped classroom practices?

Reporting on a campus-wide implementation of the flipped classroom approach, Miller (2016) notes a few challenges related to the gap between policy and practice. Before implementing the intervention, her university hired an instructional designer to offer faculty training and support curriculum development for flipped courses. However, Miller (2016) shows that a majority of the faculty neither used the resources provided by the instructional designer (e.g., a learning management system) nor included pre-recorded lectures as required by the administration. This finding highlights the need for provoking active dialogue between instructional designers and practitioners.

The proposed foundation can lead to a potential improvement in the design and practices of flipped classrooms. However, further empirical studies are required to improve its feasibility and refine the recommendations made. Design-based research is thus recommended to increase the robustness of the design framework and improve educational practices (McKenney and Reeves 2014). This research approach can be used to generate usable knowledge and solutions to problems in school-based applications (Amiel and Reeves 2008; Anderson and Shattuck 2012; McKenney and Reeves 2014). However, only a few design-based studies of the flipped classroom approach (e.g., Egbert et al. 2015) have been published.

It is useful to analyze the characteristics of design-based research (see Amiel and Reeves 2008; Anderson and Shattuck 2012; McKenney and Reeves 2014) to advance the flipped classroom approach. For example, design-based research evolves through multiple iterations that enable researchers to advance the design frameworks and theoretical agendas underpinning interventions. As Egbert et al. (2015) concludes, additional iterations are required to validate a flipped classroom design for English language teacher education. In addition, design-based research emphasizes the partnership between practitioners and researchers throughout the research process. Amiel and Reeves (2008) point out that the use of educational technologies may result in substantial and potentially unpredictable changes. They go on to argue "the necessity of recognizing the voice of practitioners as invaluable to the design process" (p. 36). Practitioners should work collaboratively with researchers to identify problems, establish research goals, and refine problems, solutions, and design principles (Amiel and Reeves 2008). Although this article lays some groundwork for guiding flipped classroom practices, further research is necessary to strengthen the proposed foundations of the flipped classroom approach.

Compliance with ethical standards

Conflict of interest The author declares that he has no conflict of interest.

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