Challenges of Flipping a Course in Geomatics Engineering

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SUMMARY

In recent years, the flipped classroom teaching and learning approach has attracted the attention of many educators, but in general, its use remains obscure in engineering disciplines. The main goal of this new approach, which is framed by Bloom's revised taxonomy of knowledge categories, is to enhance and enrich the student classroom experience by transforming lecture modules or even individual lectures into online course content. At the same time, this approach frees classroom interaction for active, face-to-face interactions between a teacher and students. The flipped classroom approach may be suitable in project-based and design courses, where the expertise and self-example of the teacher form the foundation of teacher-student interactions in the traditional face-to-face classroom, which is somehow lost in online courses.

Two geomatics engineering courses, each very different in content and learning activities, are discussed in terms of their suitability for adopting the flipped classroom teaching and learning approach. The first is a content-heavy geodesy course that introduces and develops fundamental geomatics engineering knowledge of gravity and geoid, and also teaches basic skills in gravity field modelling. Because of the considerable extent and complexity of the new knowledge being developed, this course is not suitable for online teaching or straightforward flipping. However, by introducing a new component designed and taught in a flipped mode, the course responds to new realities in geodesy, i.e., the overwhelming number of geomatics engineering applications of gravity due to recent advances in space gravity technology.

The second example is an elective and project-based surveying course with heavily weighted fieldwork, project design and execution, and a small number of lecture hours. As this course seems to be a good candidate for flipping, we discuss that remodelling the course should be carefully planned and executed in view of several important factors, such as student prerequisite knowledge and skills, student motivation and resistance, as well as mandatory topics and technical knowledge required by authorities accrediting the surveying program.

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1. KEY ASPECTS OF THE FLIPPED CLASSROOM MODEL

The flipped classroom model is typically defined as "…. a pedagogical model, in which the lecture and homework elements of a course are reversed" (Faculty Focus, 2015). One very common realization of this model uses video-recorded lectures or sections of lectures assigned as individual homework and preparation for face-to-face class time. In addition to video lectures, individual learning activities may include completing assigned readings, reviewing main concepts, gathering background information, or completing self-assessments. The classroom-based, face-to-face interactions between students and their teacher focuses on high-level and collaborative activities such as applying concepts, problem-solving, discussions, interpretations, analyses, and design and project work. As the flipped teaching and learning approach integrates face-to-face group learning and computer-mediated individual learning, it can be interpreted as a form of blended learning and is typically referred to as "inverted learning environment" (Jamieson *et al.*, 2015). Figure 1 depicts the relationships between the various learning methods classified with respect to the use of a computer-mediated environment.

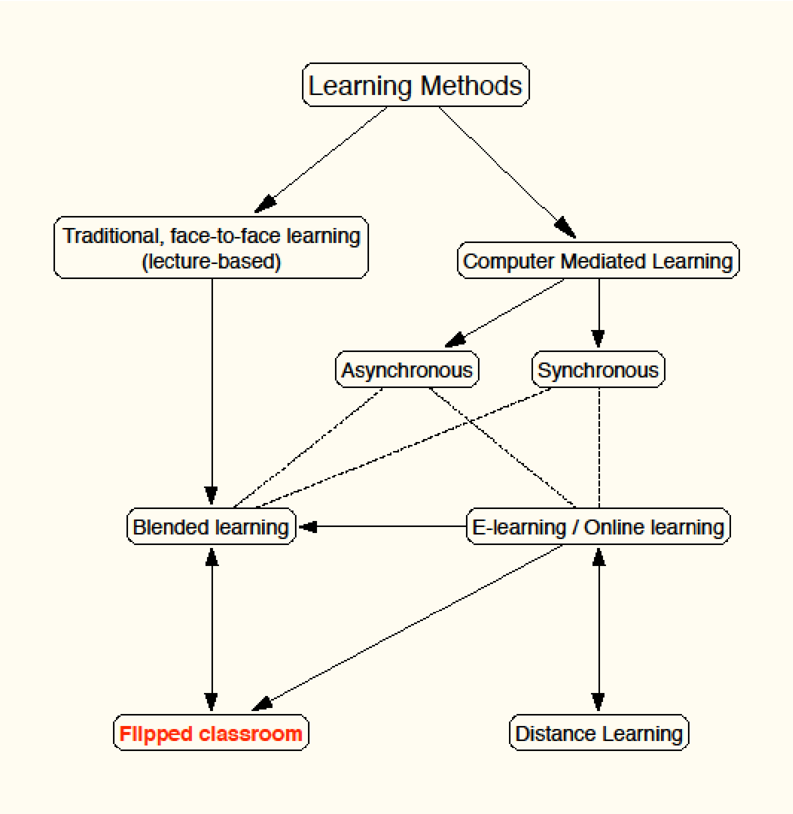

Figure 1 Learning methods classified by the use of a computer-mediated environment

A second definition of the flipped classroom model ignores the technicalities and focuses on the strong link with the student-centered and active learning methods. Shifting the focus from the teacher in the traditional lecture-based classroom to the learner in the flipped classroom is perceived as the main advantage of this novel method. Students' classroom experience is enhanced and enriched by active face-to-face interactions between the teacher and students. Moreover, this approach is void from the main deficiency of pure online teaching and learning, i.e., the missing benefits from collaborative, synchronous and hands-on group activities. Shared expertise and guidance by the teacher, which is mostly lost in online courses but preserved in the face-to-face component of the flipped classroom, makes this method suitable for engineering project-based and design courses (Jamieson *et al*., 2015).

As the number of applications of the flipped classroom approach grows, many teachers underline student motivation as the key factor for the success of a flipped course (Faculty Focus, 2015). If students are willing and motivated to accomplish the assigned individual work, then the flipped classroom model usually outperforms the traditional lecture-based teaching and learning in terms of increased student engagement in class activities, better quality of asked questions, deep learning rather than surface learning, better understanding of a design process, and increased course passing rates. On the contrary, if the student motivation is lacking, any attempts by the teacher to flip a course or course modules may be met with resistance and negative attitude, and will eventually result in worse student performance than the traditional classroom model.

In this paper, we discuss the applicability of the flipped classroom model in geomatics engineering education through two third-year courses taught in the Department of Geomatics Engineering at the University of Calgary. These are a geodesy course and an engineering and geodetic surveys course. On the one hand, the content-heavy geodesy course is a good example to investigate whether or not it can be remodelled to fit the flipped learning requirements. On the other hand, the surveying course focuses on hands-on experience, project design, management and teamwork. All of these components are linked tightly to the course outcomes, which challenge any intentions for flipping this course.

2. LEARNING ACTIVITIES IN A FLIPPED CLASSROOM

Learning activities in a flipped classroom are planned and designed within the framework provided by the engineering graduate attributes (Engineers Canada, 2016) and course learning outcomes. Figure 2 shows a diagrammatic depiction of three learning phases in a flipped classroom, and we discuss the associated learning activities herein. These three phases are defined based on the cognitive knowledge categories in Bloom's revised taxonomy (Anderson and Krathwohl, 2001): *remember/understand/*$\rightarrow$ *apply/analyze* $\rightarrow$ *evaluate/create*. The phase of *remembering* and *understanding* defines requisites for the low-level engineering graduate attribute "a knowledge base for engineering" and includes activities such as reviewing course material, acquiring new knowledge of key concepts, identifying keywords, describing algorithms and procedures, as well as retrieving and interpreting specifications and standards. Students can use various tools: watch pre-recorded mini-lectures, complete assigned readings (with guiding questions) of course modules, journal articles, and manuals, and use open education resources.

Activities in the *apply/analyze* phase require specific skills and abilities in engineering disciplines. To be able to execute an algorithm or a procedure, engineering students are typically trained in tutorials or lab assignments. To be able to successfully discuss and debate case studies, analyze real-world applications of key concepts, or present applications, a student would need certain communication skills. In the last phase, *evaluate/create*, students should be able to apply discussed concepts to new applications, design a process, explore and test applications, modify and improve algorithms and procedures based on test results, reflect on their experience and learning outcomes, and provide peer review and feedback. Activities such as writing a small research paper, a technical report, a manual, or providing critique are typical for senior level engineering courses and are related to high-level graduate attributes such as "investigation, design, project management, [and] life-long learning" (Engineers Canada, 2016).

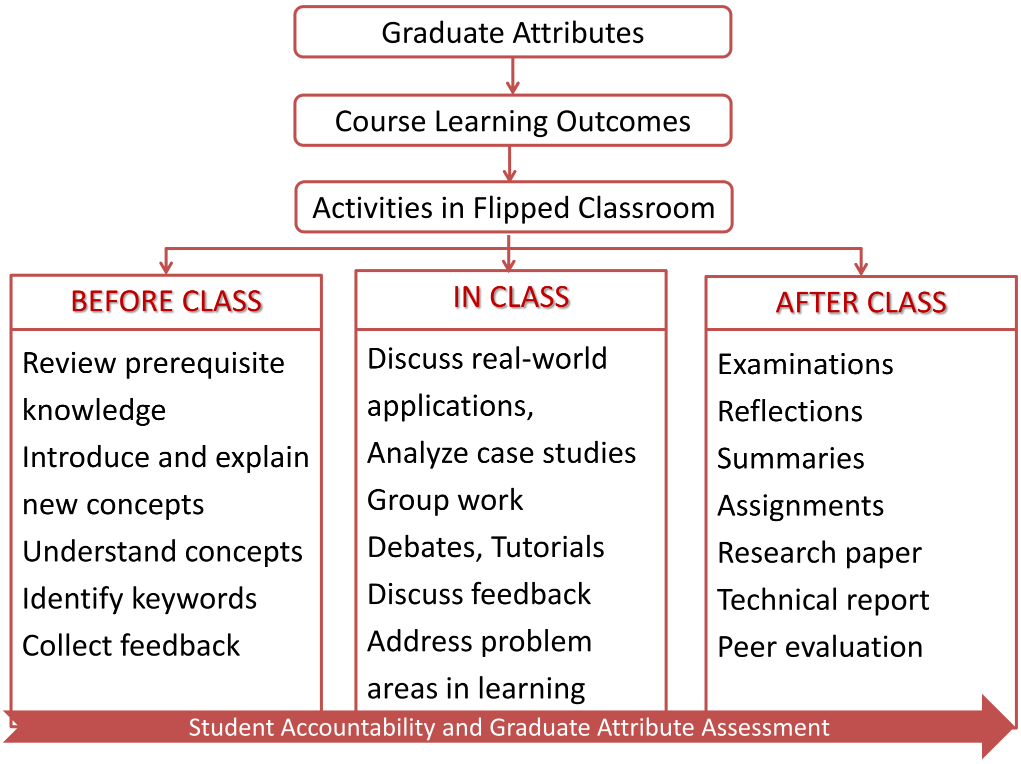

Figure 2 Activities in the flipped classroom teaching and learning approach (modelled after University of Adelaide, 2017)

Student accountability and teacher feedback can be viewed as central elements connecting the three phases of student learning. Online quizzes, self-assessments and review questions with answers, small summaries and essays are all appropriate techniques for assessing student learning as a result of the individual, "before-class" learning tasks. Teacher feedback and brief summaries during or after face-to-face class activities such as discussions, analyses, debates, and presentations can be a valuable assessment tool in engineering disciplines. Critical assessment of test results of applied procedures, and plans for improvement and future work are also common evaluation tools in project-based and design courses. Although reflection as an assessment tool is widely used by the humanities, it can be modified for use in engineering. For example, students can reflect on accomplished learning objectives in tutorials, lab assignments, hands-on experience, projects, and design processes.

3. GEOMATICS ENGINEERING EXAMPLES

Two examples of flipping course components in geomatics engineering courses are presented and discussed in this section. A shared attitude exists among engineering teachers that engineering courses are hard to teach online and may not be suitable for flipping due to the important hands-on experience in engineering classrooms. Fundamental and content-heavy engineering courses may also create challenges if taught online or in a flipped mode. In both cases, it is worth exploring the idea that key concepts can be learned individually through “before-class” work and applied in a group during “in-class” work.

3.1 Geodesy

In the current undergraduate curriculum in the Department of Geomatics Engineering, *Geodesy* is designed and taught as a senior-level fundamental course, which focuses on gravity and geoid modelling. Key concepts related to gravitational attraction, potential, level surfaces, height datums and heights, global and local geoid models, and GPS/GNSS-geoid levelling are introduced, learned and practiced in a traditional way of teaching and learning based on lectures and individual or group lab assignments. The assessment of student learning also follows the traditional approach, where examinations weigh the most.

The advent and operation of the dedicated satellite gravity missions has led to significant advances in gravity and geoid modelling used in numerous geomatics engineering applications: geo-hazard monitoring and mitigation, connecting local and continental height datums, crustal deformation studies, inertial navigation, studies of ground water depletion, monitoring of sea level changes, to name a few. To reflect these new realities in geodesy and related engineering applications and to provide students with more real world applications, a new course component is introduced and executed in a flipped classroom mode. At the beginning of the geodesy course, students are given a “before-class” assignment to watch a few selected videos produced and distributed by two space agencies. Through this individual assignment, the students become familiar with terms and some key concepts used in gravity studies and gravity observations by the dedicated satellite missions, as well as with various applications of gravity in engineering. The output of this assignment is a set of keywords identified by the students and used in searching the web to find and collect information about one application of gravity. Then, the students are asked to use the information they have acquired to write a short essay and to indicate their interests in gravity and geodesy. The largest weight in the assessment rubric is given to the content and engineering/scientific relevance.

The “in-class” activities include a discussion and analysis of selected examples of gravity applications in geomatics engineering, as these examples are used later on to illustrate key concepts in lectures. The flipped course component is extended by group work on a small research question followed by a group presentation and a short research paper. All of these activities are done in a controlled environment, i.e., students are grouped based on their essays and indicated interests, references cited by students are reviewed and approved by the teacher, and a draft paper is submitted for a review. As it is designed in two stages, this flipped course component reflects the growth in student learning during the term. It also saves a significant amount of lecture time that is now utilized in a better way to target active and deep learning through the inclusion and facilitation of a research-based creative process.

3.2 Geodetic and Engineering Surveys

The second example of a flipped course component is from the senior-level elective course, *Geodetic and Engineering Surveys*. It is the third surveying course for students enrolled in the concentration in cadastral surveying in the Department of Geomatics Engineering. This is a project-based course, where students gain experience in survey project design and management, planning field procedures and logistics, teamwork, and leadership. Lectures are designed such that they support the project-related work by extending fundamental surveying concepts and introducing new concepts in support of the high precision control survey work undertaken in this course. Data precision and accuracy, mitigation of systematic errors in survey observations, and quality control of survey works are heavily emphasized and practiced. The link between the lectures and projects is created by practical tutorials completed before the projects.

As the course is focused on hands-on experience with survey technologies under the guidance of the course instructor and a teaching assistant, the question can be asked: "Is this course suitable for flipped learning?" The answer is positive because the course is designed in a way that follows the logic of the cognitive knowledge categories in Bloom's revised taxonomy reviewed above:

- *Remember/understand*: find and review survey concepts introduced in the prerequisite fundamental surveying course; find facts and information related to survey technologies; understand, classify and explain new survey concepts, facts and procedures;
- *Apply/analyze*: execute survey procedures; test the new concepts and technologies during the tutorials; analyze and compare outcomes of the applied procedures and concept testing;
- *Evaluate/create*: design and plan a survey project, project specifications and quality control procedures; modify survey procedures to meet designed specifications; evaluate individual and team work.

Traditional lectures, in which teaching builds on prerequisite knowledge to introduce new knowledge, is a logical candidate to be modified in an online course component through pre-recorded lectures and to be completed as a "before-class" assignment. At least two factors should be taken into account when such a transformation is intended: (a) the amount of new knowledge introduced in lectures versus the amount of prerequisite knowledge, and (b) student motivation and possibly resistance towards the flipped classroom model. In both cases, caution should be exercised. The amount of new knowledge should not overwhelm students, and therefore pre-recorded lectures are typically not longer than 10-15 minutes. However, limiting a lecture to 10-15 minutes may come at the price of not covering all topics in the survey program required by the accrediting authorities. Student motivation and resistance may be of less concern in this course as many students have prior surveying experience and are highly motivated to pursue a career as a professional land surveyor. This scenario can be modified to allow more flexibility in terms of the amount of online lecturing versus the amount of face-to-face lecturing. This proportion can vary every year so that the amount of "before-class" work can be adapted to the skills and motivation of the specific group of students. In either scenario, more time is made available for important in-class activities related to the hands-on student experience.

4. CONCLUSIONS

We have presented the main ideas behind the flipped classroom teaching and learning method, which is viewed by many as a compromise between the online education not suitable in engineering disciplines having significant hands-on student experience, and the preferred mode of traditional face-to-face lecturing. In spite of the (maybe) popular idea that it is nothing more than some sort of a hybrid approach to teaching and student learning, this method combines the main advantages of the online and face-to-face approaches - that is, the time-flexible, individual learning via online course components and "before-class" activities on the one hand, and the collaborative, active and deep learning via in-class activities, on the other hand.

We have argued that flipping a course or even a course component should be planned and executed carefully since various factors can impact student learning in this new environment. However, we have also discussed that even one new flipped course component can enhance learning and enrich the student experience in two courses that are quite different in terms of teaching methods. As these courses hypothetically exemplify two very contrasting teaching and learning approaches, we believe that more geomatics engineering courses can be taught in a flipped mode. This should be accompanied by in-depth research of the impact on student learning.

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BIOGRAPHICAL NOTES

Elena Rangelova, PhD, is an instructor in the Department of Geomatics Engineering, Schulich School of Engineering at the University of Calgary. Her pedagogical interests are mainly in blended teaching and learning and deep learning approaches and their implementation in undergraduate geomatics engineering education.

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