Introducing mining engineering to first-year students: The benefits of a digital uplift

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Many programmes use introductory courses to present an overview of various sub-disciplines within a programme. In some cases, the contents are presented by different academics who are experts in their field and are best to enthuse the students to the programme. However, such an approach can have numerous drawbacks. A major disadvantage for the academic in charge of the course and the students is the availability of the teaching staff. The initial scheduling, which depends on the availability of the lecturing staff, is often in an order that is not linear or coherent. Thus, students suffer from the fact that a topic, which may normally be taught early, is pushed towards the end and causes a gap in knowledge. Another drawback is rescheduling lectures during the term due to changes in the availability of the lecturers. This may affect the delivery of assessment tasks. There are a number of ways schools can minimise the impacts of these drawbacks. At the University of New South Wales (UNSW), the UNSW Scientia Education Experience (2025 Strategy) supported excellence in teaching and launched digital uplifts. The initial scheme proposed to digitally uplift one course per school, for which MINE1010 – Mineral Resources Engineering was selected. MINE1010 was strategically selected by the school to get the digital uplift because it is an introductory course to the discipline of mining. It can be taken as an elective by engineering students including engineering students who have not yet selected a major, thus potentially attracting them to the discipline. The digital uplift was used as an opportunity to create digital assets to increase student immersion and to change the pedagogy of the course. These changes eliminated the drawbacks common to introductory courses and led to an improvement in student satisfaction on the quality of the course.

Keywords: Digital uplift, team-based learning, flipped classroom

INTRODUCTION

Introductory courses are common to many university programmes. These courses can be useful for students. They study different topics in a subject where strong connections can be established between the different topics, thus highlighting their inter-dependence. They also serve as a teaser for students who may be attracted to a particular aspect of the programme or a way to discover new fields of interest due to the breadth of the content covered. In some cases, the contents are presented by different academics who are experts in their field and are best to enthuse students in their field of expertise. This approach may, however, have several drawbacks. A major disadvantage for the academic in charge of the course and the students is the availability of the teaching staff. The initial scheduling, which depends on the availability of the lecturing staff, is often of an order that is not linear or coherent. Thus, students suffer from the fact that a topic, which may normally be taught early, is pushed towards the end and leaves, in the meantime, a gap in knowledge. Another drawback is the need to reschedule lectures during the term due to changes in the availability of lecturers. This may affect the delivery of assessment tasks since they are dependent on the topics discussed in the classroom.

The approach previously described has been the practice for MINE1010: Mineral Resources Engineering, offered at the University of New South Wales (UNSW). The course is an elective offered to all engineering students. First-year mining engineering students are strongly encouraged to take the course. It is offered twice a year: once in-person and once in a distance format. The problems previously noted were prevalent in the classroom in which a total of 12 lecturing staff were involved in delivering content. On the other hand, the distance version of the course had one instructor and students viewed online resources available on the web and had to do some reading.

In 2017, UNSW, as a part of UNSW Scientia Educational Experience (2025 Strategy) piloted digital uplifts. The initial aim was to digitally uplift one course for each school. MINE1010 was strategically selected by the school of Minerals and Energy Resources Engineering (MERE). As an elective course, it is believed to be well placed to attract new students to the discipline. Particularly, 'undeclared' students are students enrolled in engineering who are temporally pursuing a general education and using elective courses to explore different majors to then confirm a major. Having an impactful course with quality digital assets was believed to be a key in converting students to mining engineering. MINE1010 was digitally uplifted in 2018 – 2019 and this opportunity was taken to change the pedagogical approach. This paper describes how a digital uplift was a key component of the shift from a didactic model.. The digital uplift was used to create digital assets and implement team-based learning (TBL), which preserved some of the best aspects of the teaching an introductory course with multiple instructors and remediated the major disadvantages. Although they could not be separated, the improvement in the course due to the digital uplift and change in pedagogy was measured through student satisfaction surveys administered by the university.

Digital uplift

Digital uplifts were an initiative by UNSW, which aimed at supporting academics to deliver teaching innovations. Essentially, a digital uplift is used to create digital assets to support teachers and learners. Whilst some lectures can be recorded and viewed online, a range of digital solutions can be deployed to enhance courses. Examples of the use of technology in various courses are recorded field trips with 360° videos (i.e., Google street), animation videos, interactive animation, lightboard, etc.

Principles of team-based learning

Traditional education focuses on teachers and the course material with the objective of transferring information from the teacher to the students (Hrynchak and Batty, 2012). Recent developments in learning theory and a gradual adoption of these theories have changed teaching practices. In recent years, an increasingly greater emphasis has been placed on pedagogies that are student-centred. For instance, the constructivist theory theorises that knowledge is a process that is structured by personal experiences. So, knowledge is subjectively constructed. This approach redefines the role of the teacher and the students in the classroom and the learning process. The consequences of using this approach to teaching are (Hrynchak and Batty, 2012): (i) the instructor becomes a facilitator and students take an active role in learning, (ii) an emphasis on problem-solving to help construct knowledge, (iii) the sharing of experiences through dialogues (e.g. with instructors or other students), and (iv) a reflection on when and how to modify their current knowledge. Hrynchak and Batty (2012) discussed how TBL fits the constructivist theoretical framework. In TBL, modules designed by the instructor are individually learned by students as seen in the first phase of TBL in Figure 1. The second phase is a quiz, generally composed of multiple-choice questions. This quiz is done individually and in a team. This quiz focuses on the recall of factual material. The feedback is an opportunity to discuss some of the lessons, which may be relevant for the application of the knowledge (phase 3) through problem-solving. The application of the knowledge is done in teams, in which students discuss the best approach to the problem at hand. An important portion of the learning occurs and/or is consolidated at this stage. Thus, the TBL approach is designed to give students conceptual and procedural knowledge (Michaelsen and Sweet, 2008). In addition, due to the highly interactive nature of the activities, TBL has also been linked to increased critical thinking (Huggins and Stamatel, 2015; Espey, 2018).

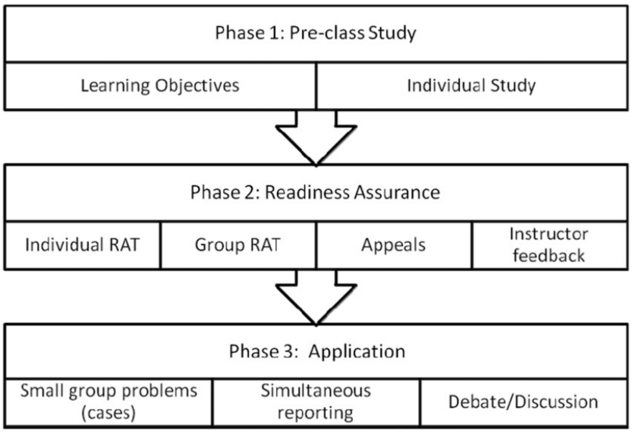

Figure 1. Schematic representation of the three phases of the TBL process.

Students study the materials provided by the instructor. This is followed by a phase of readiness assurance (RAT = readiness assurance test). The third phase is the application of the knowledge (Hrynchak and Batty, 2012).

A few additional comments should be made on the composition of the teams and the application exercises. The teams are made by the instructor and should distribute the students fairly, based on their background (Michaelsen and Sweet, 2008) and the research subject itself (Chin *et al.*, 2021). This practice is, among other factors, to avoid grouping people with an advantage (e.g. previous related work experience) and minimise barriers of team cohesiveness, in which established relationships (subgroups) affect the team. For TBL, the application exercises should follow the 4 Ss, which are significant (concept's usefulness), same problem, specific choice, and simultaneous report (Michaelsen and Sweet, 2008).
TBL has been implemented in a range of disciplines. In an introduction to the engineering class, a majority of students (86%) had a favourable experience with TBL (Wang and Mott, 2015). Beyond the perception of the students, it has been found that a majority of teams outperform their best team members (Michaelsen and Sweet, 2008; Najdanovic-Visak, 2018).

As teaching practices evolve and tertiary education is placed in a different context, e.g. lockdown, TBL is tried and adapted accordingly (dos Santos Belmonte *et al.*, 2022). As such, TBL has been increasingly used online and was successfully implemented for the study of mathematics (Caridade, 2021). Others (Kerestes *et al.*, 2021) have incorporated gamification to distance TBL in order to improve engagement. The game was used to address likely misconceptions. Noteworthy is that TBL itself was noted to increase motivation in an online environment (Eladl *et al.*, 2022).

Course uplift

Implementation

At the end of 2018, MINE1010 underwent a digital uplift. The digital uplift aimed at providing financial assistance to develop digital assets to assist teaching. Given that the pre-class preparation consists in an individual study using content provided by the instructor, it follows that a digital uplift can be utilised to implement a TBL pedagogy. TBL has various variations as reported in the literature (Haidet *et al.*, 2014). The process used in MINE1010 follows that presented in Figure 1, but lacks some of the specific details. For this reason, details of the changes and variations of the TBL approach are pointed out.

The first step of implementing TBL was to determine the skills the students had to gain in the course (Michaelsen and Sweet, 2008). This is a part of the 'reversed design' that TBL requires (as opposed to the learning objectives emerging from the materials being taught). That is, learning outcomes, which demonstrate what the students can accomplish, were formulated. To this end, the revised Bloom's taxonomy (Anderson and Krathwohl, 2000) was employed and is illustrated in Figure 2. The taxonomy consists of six scaffolded layers. While the lower layers can demonstrate superficial learning, the higher layers provide students with opportunities to provide evidence of deeper learning through complex creative tasks. This deeper level of learning lends itself well to engineering tasks.

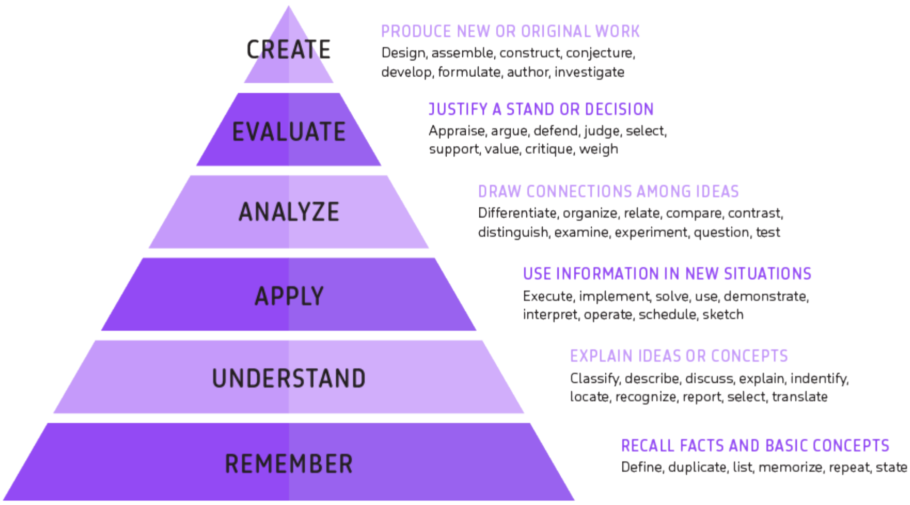

Figure 2. Revised Bloom's taxonomy Anderson and Krathwohl (2000).

MINE1010 being an engineering course, it was decided that the application exercises would be a major component of the course. Formulating the learning outcomes using the upper levels of the revised Bloom's taxonomy means that realistic tasks can be developed. Some examples of tasks are:

- Select an appropriate mining method:
  In a feasibility study, a mineral deposit is evaluated for its development potential. A choice on a mining method must be made based on the geological features of the deposit and the characteristics of the mining methods. Students are given a scenario with a set of constraints and write a short report on the best mining method to be employed.
- Write a risk assessment:
  Students are shown that risk assessments are everywhere in the mining industry. Some examples are in mining operations plan, mine planning, and mine safety, which may have different hazards to evaluate (e.g. environment, safety). Students are asked to come up with an activity and write a (safety) risk assessment for that activity.
- Design a mineral processing flowsheet:
  Minerals (valuable and waste) are separated based on differences in properties. Some preparation is required (e.g. comminution) and post separation processes may also be required (e.g. dewatering). The task of designing a process flowsheet for mineral processing is complex. Here, students are given a mineral and must design a basic mineral processing flowsheet.

These are examples of application exercises that have been designed for the course. It should be noted that this implementation differs from the standard implementation of application exercises in TBL. Whilst the problem is significant, the other Ss are only loosely applied. Opting for higher level tasks requiring to create or design something implies that students are not given specific choices. They instead come up with the best possible solution. In addition, the same problem is given to the students, e.g. design a mineral processing flowsheet; however the commodity assigned to each team is different. Noteworthy is that the assignment process of the various commodities to the teams was transparent. An Excel spreadsheet was set up with the different scenarios. The scenarios are assigned a random number (in the classroom by updating the spreadsheet). The ranking of the scenarios based on the random numbers determines the assignment of the scenarios to the teams. While the implementation of application exercises was a direct outcome of the use of the TBL pedagogy, it was not a natural outcome of the digital uplift (which nevertheless was an enabler for TBL). That being said, the digital uplift provided the tools to make those application exercises available to the distance version of the course through the university's learning management system (LMS) (i.e. Moodle). All students meet online, and the instructor assign students to virtual classrooms in which they can discuss as teams.

Another aspect of the TBL is the readiness assurance tests (RATs), whether individual (i-RAT) or as a team (t-RAT). The role of the RATs is to ensure that students came to the session with the necessary preparation, which achieves two major functions: (i) student accountability with their teammates to come ready and (ii) prepare students for the application exercises. As such, the RATs were designed to test the lower levels of the revised Bloom's taxonomy. It aimed at addressing important concepts and correcting misunderstandings, as well as filling gaps in the foundational learning of the students before they can tackle the application exercise. Here, the digital uplift assisted in creating a bank of questions, which could be used for the RATs. The quiz is delivered online through the university's LMS.

RATs were not implemented for the distance version of the course. Instead, students are required to write questions on each of the weekly topics through the LMS. Once the period for writing questions on a topic is closed, students take a quiz, which is made up of the questions they have produced, and leave constructive feedback to their peers. Marking is based on the quality of the questions, the feedback given to their peers, and the quiz. This adaptation of TBL to an online environment has several objectives. Pedagogically, students are encouraged to write good questions, which is one of the most effective ways to learn through a process called retrieval (Weinstein *et al.*, 2019). While this approach has the advantage of not compromising the integrity of the RAT questions for future cohorts, the best questions created by distance students can be used to increase the bank of questions for the RATs.

Finally, one of the major outputs of the digital uplift was the recording of lectures and other educational content. This is an essential component of the TBL approach as students do pre-class study. To this end, the content was reviewed so that only the relevant materials aligned with the learning outcomes were preserved. A major advantage of having recorded lectures was the ability to have the experts previously teaching the course to deliver their lecture and then present them in a coherent order. In addition, questions were inserted in the videos in order to increase student interaction with the material as shown in Figure 3.

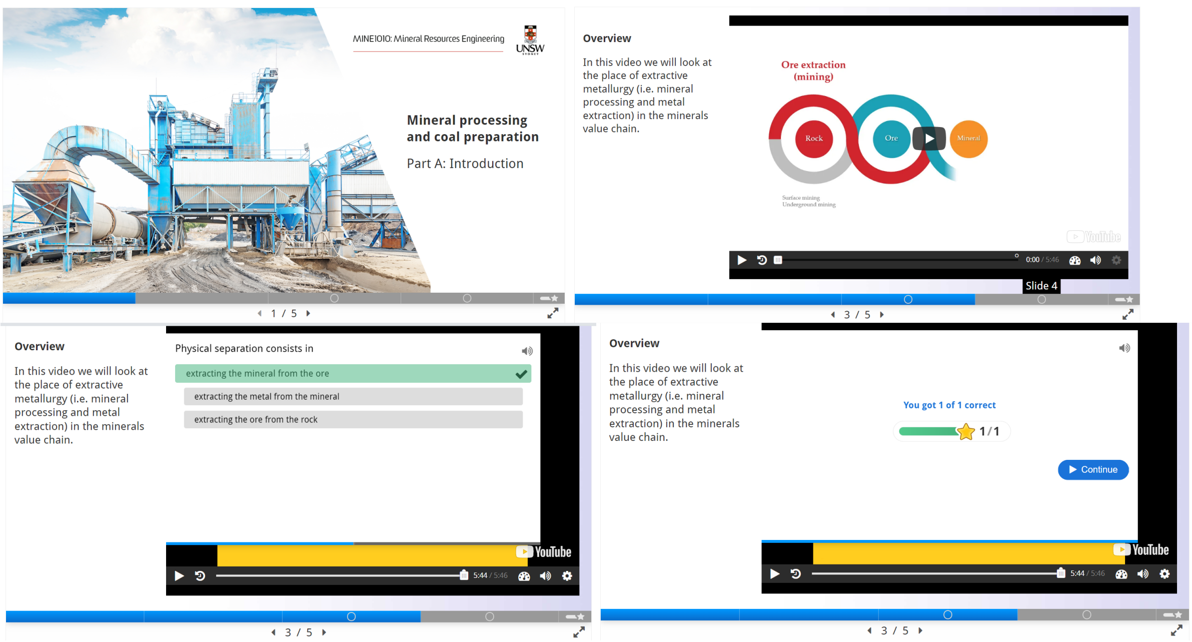

Figure 3. Example of interactive lessons in the H5P environment. (Top-left) Lesson title page, (top-right) embedded video recording, (bottom-left) quiz embedded in the video, and (bottom-right) quiz result.

Since the school wanted to enthuse students, a great deal of effort was devoted to providing students with an immersive environment. MERE has been a leading developer of virtual reality modules in the mining discipline (Mitra and Saydam, 2013). These modules are used for teaching in an Advanced Visualisation and Interaction Environment (AVIE) casting a 360° image and, when available, 3D images. Using the digital uplift, a number of modules were made accessible using a browser. Students can take mini-field trips and visit mine sites as seen in Figure 4. The browser version allows instructors to add notes and students can travel between different locations. Since these modules are 360°, students can click and drag to change the view and look around.

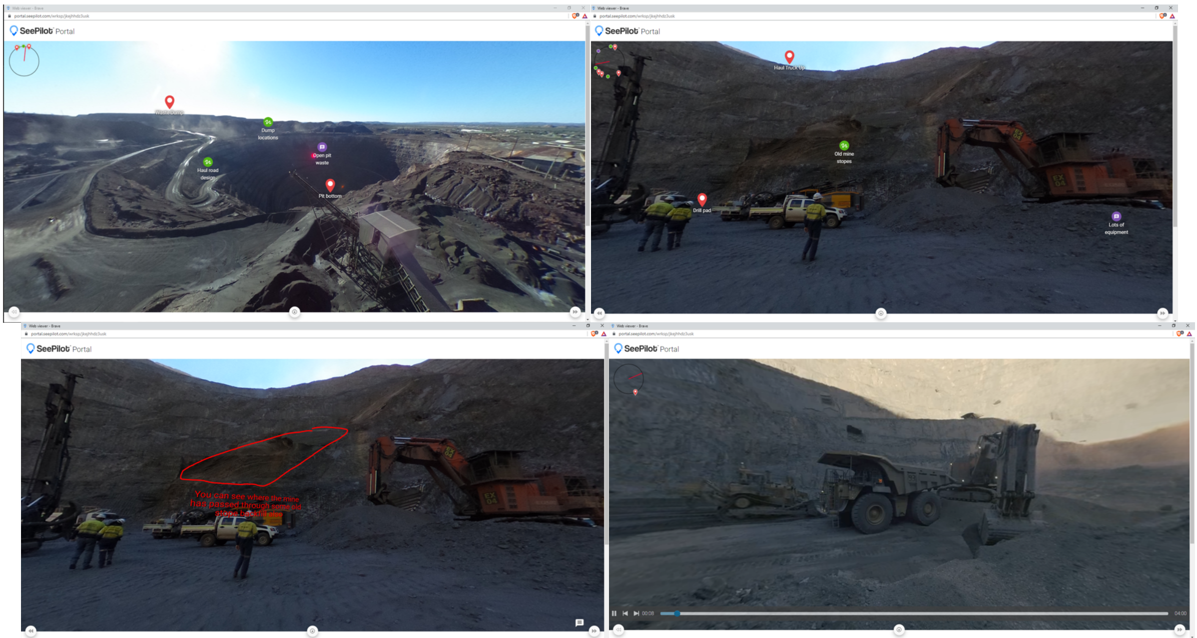

Figure 4. Example of a virtual reality module in a browser. (Top-left) Mise site with markers, (top-right) bottom pit, (bottom-left) annotation, and (bottom-right) embedded video.

Outcome
At the end of every term, the university runs an anonymous survey called MyExperience for students to give feedback on course quality and instructor performance. The survey is administered at the end of the term before the final exam period and is on a voluntary basis. Satisfaction is measured on a six-point scale from strongly disagree (1) to strongly agree (6). The authors took over the course shortly before the digital uplift. They had access to three course reports before the uplift and four course reports following the uplift, which constitutes the data presented in this section. Figure 5 (left) shows the mean satisfaction score for the course from the statement: 'Overall, I was satisfied with the quality of the course.' It can be seen that the mean score increased by over 1 point following the digital uplift. This translated into an increase from 68% to 93% of student satisfaction, i.e. the percentage of respondents giving a score of moderately agree, agree, or strongly agree. Noteworthy is that the largest increase in satisfaction was among students taking the distance version of the course (Figure 5 right).

A t-test was used to determine if the increase in the aggregated mean satisfaction scores for the various delivery modes were significantly different before and after the uplift. The hypotheses tested were $H_0: \mu_{yes} - \mu_{no} \geq 0$ and $H_1: \mu_{yes} - \mu_{no} < 0$. The p-value was 0.08793, which means that at a significance level of 0.1 (or a confidence of 90%) the mean score for the digitally uplifted version of the course was superior to the course before the digital uplift.

It is important to note that the statistic does not necessarily show an increase in satisfaction due to the digital uplift. Compounded with this change is the change in teaching pedagogy. Nevertheless, the digital uplift, which enabled the change in pedagogy resulted in improved student satisfaction on the quality of the course.

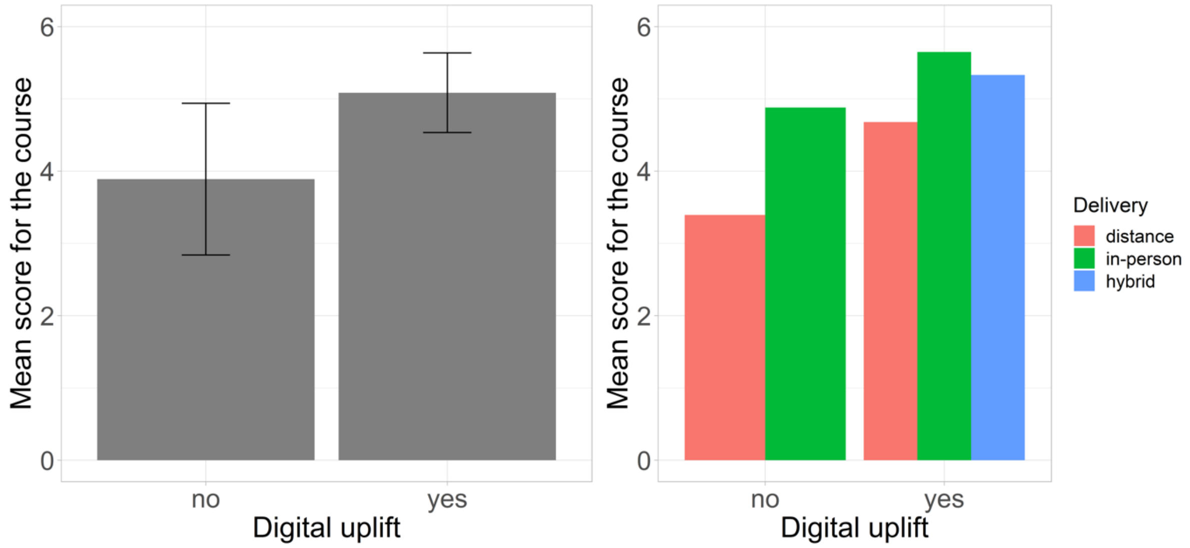

Figure 5. (Left) Mean satisfaction score for MINE1010 before and after the digital uplift and (right) satisfaction scores based on the delivery mode. The error bars represent one standard deviation.

The success of the uplift in organising the course (including the change to TBL) can also be appreciated through some of the student feedback:

- All the content is present and can be accessed through Moodle. The animation in the video improved the understanding (2019 T3)
- I felt that there was a strong bond between our team because of the way he structured the course (2019 T3)
- Every week was well planned and structured to create a clear learning path. The mix of tasks (application exercise, tutorials, quiz) gave many opportunities to revise knowledge (2020 T3)
- The application exercises and assignments were very engaging. I thoroughly enjoyed them as it examined multiple different factors that mining exists and their effects. (2020 T3)
- I love the community that was formed by the small in-person class, everyone is each other's friend and we were able to create a really strong learning community, especially after completing the t-RAT where we would share our answers (2021 T1)
- Application exercises provided a good chance to reinforce learning and expand research skills (2021 T1)

Learnings and recommendations

Implementing TBL required a great overhaul of the course. Although many positive changes have been made, continuous improvement of the course led to minor changes since the uplift and future changes are being considered. These learnings can be categorised as belonging to the TBL approach itself or related to the digital assets. The latter will be discussed.

It is known that student engagement in distance course is less than their in-person counterparts and collaborative learning is affected (Dumford and Miller, 2018). The digital uplift allowed application exercises to be conducted in teams in the distance version of the course. As such, students were placed in a virtual collaborative environment, which required them to work synchronously together to achieve a goal, e.g. produce a report with their recommendation for a mining method. This is important in forming of a learning community albeit at a sub-group level (i.e. team) as opposed to the classroom level.

When gathering digital assets for a course, online content can be a good place to start since there are already high-quality videos on platforms like YouTube. Short animation videos were found to be very effective in getting the students to visualise concepts. However, longer videos, which can be used to substitute lectures, were ineffective. Students noted that they liked to have basic lecture notes to which they could add their notes, which is consistent with the literature (Wang and Mott, 2015).

Most future work to enhance the digital assets is related to the lectures. The lectures were broken down in smaller segments. However, students feel that the segments are still too lengthy. Future updates of the content will focus on micro-learning. Micro-learning is more adapted for today's learning in which people may have limited time and seek 'knowledge on demand' (Jomah *et al*., 2016). Here the strategy is not to reduce the content but to divide it in short bursts of information. As such, students can better manage their time to study (i.e. they can use a short 15 minute break to watch a few videos) and can easily refer to topics as needed without having to find a specific segment in a larger video.

One aspect that is lacking in TBL (or more generally on relying on digital assets where students get information) is that students cannot ask questions while being exposed to the material. A forum was created in which students can ask questions anonymously. This forum, however, has not been widely used for questions on lecture contents. This may be due to the asynchronous element of the question and the answer to the question.

Finally, the lectures and various videos were separated/interrupted by questions. These questions aimed at providing some interactivity and making sure students understand the content. Despite these questions, in-class students sought to get more opportunities to practice through more examples. They feel that there is little they can do to prepare for the RATs. In fact, they would need more opportunities to practise retrieval of information, as previously mentioned. For this problem, questions from the distance students can be used. Whilst high-quality questions, i.e. those with a context and appealing to higher levels of the revised Bloom's taxonomy, are integrated into the question bank, the questions using the lower levels of the taxonomy, e.g. remember, can be used by the students to practise retrieving information. This is a good practise for then answering more complex questions.

CONCLUSIONS

The digital uplift enabled a change in pedagogy, which resulted in a more coherent course and a course better suited to be delivered online. Student feedback was positive regarding the structure of the course and the collaborative aspect of the course. In fact, a significant improvement in student satisfaction was noted. Noticeably, the satisfaction of distance students increased (although not statistically significant, probably due to the small dataset). It is nevertheless believed that the digital uplift was key in that regard, since one of the major difficulties in an online environment is to provide students with content of high quality.
However, despite digitally uplifting the course and creating a number of assets, a number of improvements can be pursued regarding the lecture materials. These include micro-learning and more opportunities to interact with the lecture content (and the instructor regarding the lecture content).

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