Flipped classes and enriched skeleton maps to foster deep and interactive learning in engineering education

S. Attia[1] and P. Detroz[2]

[1]Sustainable Buildings Design Lab, Department ArGEnCo, Applied Sciences, Université de Liège, Belgium

[2]SMART-IFRES, Université de Liège, Belgium

shady.attia@ulg.ac.be

Abstract

This paper reports the initial experience of applying the enriched skeleton mapping technique as innovative and meaningful learning methods within a flipped class teaching setting. Driven by the low confidence and autonomy of many undergraduates; this study focus on stimulating collaboration and interactive learning. The study was performed in a course labeled ‘sustainable building construction technology’ of the Bachelor of Architectural Engineering program at Liege University (Ulg). First year and second year students, were assigned to an experimental group of 27 students and a control group of 8. In the experimental group, students worked together in pairs on mini-concepts and created enriched skeleton maps for the course content. The control group received a regular ex-cathedra course. The results show that students who used the enriched skeleton mapping technique were more engaged and outperformed the control group. Enriched skeleton concept mapping fostered deep learning and resulted in a better understanding of the course mini concepts in addition to the course structure and domain. Students of the enriched skeleton mapping found learning to be more ‘useful, stimulating and more engaging’, whereas students of the congenital ex-cathedra curriculum found learning to be ‘passive and boring’. A combination of both techniques may provide the most effective training for undergraduate engineering students.

1 Introduction

We live in a challenging time where sustainability and circularity of economy are two foundational pillars. In this content knowledge and knowledge development are critical economic factors. Higher education graduates need a deep understanding of sustainability concept and principles and the ability to generate creative ideas, new theories, and new solutions in harmony with nature for a better future. Within the engineering education and particularly architectural engineering, there is a concern to link the teaching and research to the changing labor market. Through our teaching, we seek to train highly qualified students with hands-on knowledge and practical and analytical skills in order to be able to solve problems and to innovate. According to the League of European Research Universities (LERU) the future generation engineering students should be taught respecting the four following recommendations (Dale, 2007):

- New knowledge is the source of innovation;
- Skills are the major contributions in research;
- Knowledge of current market development is important for education;
- The need to integrate projects in education (not only theoretical instruction).

As new faculty member at the Faculty of Applied Sciences of the University of Liège, responsible of undergraduate sustainable building construction technology courses, we had a concern to find fit to purpose teaching methods allowing us to meet the above mentioned challenges of students born around the millennia known as iGeneration. We believe that the ex-cathedra classical teaching method thus proves to be insufficient to prepare our undergraduate students and equip them with experiences and skills on sustainability. The combination of ex-cathedra lectures, constant use of smart phones, tablets and laptops in class and the uncertainty of undergraduates about their study choice and future carrier during the first years turns many of them easily to passive learners. In order to face these challenges we tested the flipped class setting courses from 2014-2016 during courses for freshman architectural engineering students at Liege University in Belgium.

The flipped classroom is an instructional strategy and a type of blended learning that reverses the traditional learning environment by delivering instructional content, outside of the classroom. The flipped classes teaching method is not a new concept at the University of Liège. In his book "*Towards a pedagogical university teaching quality*", Leclercq introduced in (1998) the LQRT method which stands for home reading/questions and answers/testing. He associated this LQRT method with 11 principles that can be associated, even today, with flipped classes' method. This model gained recently a momentum in the University of Liège, which reformulated the relationship of outside classroom activities and preparation time with inside class room activities (Berrett, 2012. EDUCAUSE, 2012; Johnson et al. 2014). With the digital knowledge revolution there is a high potential of flipped classes where students can pick up the course content beforehand by themselves and profit from the time with their professor in class. The immediate in class feedback on in class exercises, computer based quizzes, case studies solving, or practical simulations (like simulating the design process of a complex construction detail) allows the professor to identify where the difficulty lies with students and foster deep learning and interaction.

In this context, the study aims to assess the students' learning experience and level engagement using qualitative and quantitative evaluation methods. The importance of this study is significantly highlighted in fostering deep learning and better understanding of the course subject matter, structure and domain of sustainable building technology. Secondary, the study provides a reflection on the learning methods, students' motivation, engagements and attitudes in this early learning process experience in engineering higher education. With its focus on the design experience and knowledge uptake this article will be of interest to engineers, architects, educators and researchers concerned with engineering education of sustainable development (EESD). The article determines the needs for pedagogical and educational engagement to ascertain and quantify the effort needed to understand and apply sustainability principles of building technology in future curricula. This paper is organized into six sections. The first section identifies the research topic. The second describes similar courses and courses that have been presented at previous EESD conferences aiming to describe the state of the art. The third section identifies the research methods and course evaluation metrics and setting. The analysis of the results and the self-reported survey and questionnaires findings are presented in Section 4. Section 5 discusses the research finding and study limitations along with implications for future teaching and education. The final section provides a summarizing conclusion.

2 State of the Art

2.1 Personal Observation

Driven by the low independence and autonomy of postgraduate students at the Faculty of Applied Sciences at the University of Liege (ULg) the author opted to adapt the enriched skeleton map as an interactive and self-regulated learning teaching technique. The passive role of many students in class, their basic reading performance and full dependence on the professor triggered the idea of applying the inversed class concept. My observation about students in higher education in engineering schools is that many of them aren't triggered enough to achieve deeper, meaningful learning. They often demonstrate a basic approach to factual learning with limited knowledge processing. In practical project conditions many of them often reveal the deficiencies of insufficient meaningful learning. The problems get magnified when most professors opt to examine student's ability to memorize context free knowledge, presentation skills or linguistic skills. In fact, many professors learn little about student assessment and evaluation (Zlatkin-Troitschanskaia, et al 2015). On the other side, the labor market's main critique to fresh graduates is their inability to use their knowledge and their lack of methodological skills (Zlatkin-Troitschanskaia, et al 2016). Therefore, middle and large companies create their own assessment centers to measure candidates' abilities of complex problems and case study solving, contextualization and correlation creation and the ability to apply their field knowledge.

At ULg the main author had the opportunity to teach courses on Sustainable Building Construction Technology in Bachelor year one and two followed by an architectural studio in Bachelor year three. In the architectural studio, students are expected to apply the knowledge and skills developed in their first and second year courses. The studio is project oriented reflecting student understanding, knowledge retention and skills mastering regarding sustainable architecture and building construction technology (Attia 2015a and 2016ab). However, we observed in the last year's low knowledge retention and inability to apply the first year and second year courses content in the third year studio. Therefore, we conducted this study to stimulate deep learning and trace the root cause of this problem.

2.2 Past research

There is a limited body of literature examining the effects of introducing blended and interactive centered teaching methods in the engineering curricula on the students' knowledge and skills and final learning outcomes (Pereira et al. 2007 and Tune et.al 2013). For this study, three screening criteria were used to review conference and journal articles to a focused set of representative studies: (a) representing domain knowledge by concept maps; (b) effectiveness of using blended learning; and (c) research that focus on architectural and engineering curricula.

For examples, the paper of Elen (2011) aimed to identify the reasons to move towards the flipped classroom. The engineering schools of Belgian Universities invested in the last 20 years in IT infrastructure and possess a solid infrastructure that allows faculty and students to pursue their teaching activities online and offline. The physical class room and course material hardcopies are not any more the only medium for learning activities. The ease of using and accessing electronic content by all students through Blackboard (eCampus at Ulg), online courses and MOOCs facilitate blended learning. Today, we have variant pedagogical choices as faculty and do not need only to stick to ex-cathedra. In literature, we find several publications recommending (High Level Group, 2014) us to diversify out teaching method and look for the most fit to purpose (in this case learning outcomes) choices. Examples of that include reinforcing the link between theory and practice, motivating students, promoting self-learning, providing quantity and quality feedback, stimulate interaction and support active learning (Marée 2013). In their research on the choices fit to purpose docimological approach, Gilles et al. 2011 demonstrated the influence of contextual variables and more precisely constraints (number of student time resources available, assistants available, etc.) on those choices. But in recent years, the level of constraints on university faculty has continued to grow. The pedagogical mutation represented by flipped classes intertwines with economic, sociological, technological, administrative, structural transformation (Barber et al. 2013, Rege Colet and Romainville, 2006).

3 Method

The author provided the course handouts at the beginning of the semester and required from students to develop weekly an Enriched Skeleton Map (ESM) (see section 3.2) before and during each class (Marée 2013). The study was performed within the Sustainable Building Construction Technology Course 1 by the freshmen of the Bachelor of Architectural Engineering program (N=27 in 2014 and 2015) and the third year civil engineering students (N=8 in 2014 and 2015).

3.1 Curriculum design

The course “Sustainable Building Construction Technology” is aiming to address sustainable architecture and conceptual design from a technical, constructive and material science perspective (ARCH3258-A, 2015). During the study semester we explore the basic and concepts of building construction approaches and technologies in order to serve architectural projects. This course is designed to deeply study sustainable building techniques and principles. The course explores the construction elements, and constructive approaches in parallel to performance of the various building materials and their implementation in construction. The course is structured into three main parts: 1) Design and materials, 2) construction timeline on site and 3) thermal bridging details. The topics will be presented in logical order to achieve a deep understand and ideal representation of sustainable building construction technology. The following topics are studies during this course:

- Sustainable design and construction, and life cycle assessment of buildings.
- The anatomy of buildings (spatial, structural and material)
- Building construction systems (bearing walls and wood frames, foundations, walls, slabs, beams, roofing)
- Building materials (classification, usage and properties)
- Construction timeline
- Thermal bridging details

At the end of this course the student should be able to:

- Observe and represent building construction details.
- Learn the systems and methods for a supporting structure and envelope systems.
- Learn the main building materials and their technical implementation.
- Read, interpret and draw technical schemes.
- Apply, link and propose different technical concepts based on different structural systems.

3.2 Enriched Skeleton Mapping

ESMs, in contrast to the skeleton concept map of Novak and Cañas (2008), are the visualization of the conceptual structure of a specific knowledge domain. Each concept in the ESM contains (1) annotated factual information that elaborates on the concept and (2) an attached worksheet to formulate the meaning of the concept (Marée et al. 2012). The skeleton concept maps are enriched with multimedia content and a worksheet to provide scaffolds to improve students' knowledge construction (Attia 2015b, (Marée 2013). Using multimedia rich content (text, video clips, technical drawings, 3D models (Lupion Torres, 2009), pictures and animations) students developed 12 mini concepts under the collaborative interaction and argumentative logic (Attia 2015b). Students were expected to organize their interaction and collaborative learning through the use of roles, activities, and sequencing of activities and translate that into ESMs.

3.3 Assessment of students' self-reported behaviours

The students were divided into two classes. The first group was used as a control group of third year civil engineering students (N=8, 4 women, 4 men, aged 20-21 years). The control group received the regular ex-cathedra classes during the first four weeks of the semester with a weekly quiz and class discussion. The lectures were structured as a linear sequence of slides following the course themes and structure explained earlier. On the other side, first year students (N=27, 14 women, 13 men, aged 17-18 years) received flipped classes and developed ESMs and mini concepts. Each week students had to work during two sessions. In the first session, a general multi-layered skeleton map was drawn collaboratively on the class board. Through argumentative debating and consensus based discussion the multi-layered skeleton map was created based on the previously read lecture handouts. Then the second session followed by dividing the class in group of two where each group has to enrich the skeleton map with a multimedia rich content. Every week a student was responsible to draw and share the class developed ESM using MindManager program on ULg Blackboard (eCampus). The theoretical content was the same for both classes and the two teaching methods were applied and administered until the end of the semester.

The effect of the ESM on the quiz grades and students' interaction was measured. Both groups had the same multiple choice tests three times during the 12 study weeks including the final examination. The evaluation of the exam was based Bloom's taxonomy that requires understanding, application, analysis and evaluation (Bloom 1956).

4 Results

4.1 Assessment of students' knowledge, skills, and attitudes

The differences between the groups of scores were measured. According to the overall means the quiz grades of the second group improved at least by 28 percent and the students reported their increased interest in the course. The course attendance was 100% during the last 6 weeks and some students arrived half an hour earlier to the class to rehearse the weekly map. The finally produced ESMs were evaluated regarding their content quality and were graded independently.

At the completion of the course, 22 (81%) of students agreed that the ESM improved their ability to meet the learning objectives either well or very well. Eighty-five percent, on average, agreed strongly that the curriculum and learning modalities were useful in to apply their knowledge in the ESM. Ninety-two percent, on average, agreed or strongly agreed that the curriculum would be of benefit to their future career, and on average 78% recommended that the curriculum be continued for future architectural school classes.

4.2 Curriculum Evaluation

As students worked together as pairs we had the impression that the ESM helped them in scoring higher during the multiple choice questions exams. The positive feedback of students by the end of the course provided through an online questionnaire confirms the increased interest, knowledge uptake and independence. One of the interesting results was that students required less guidance and engaged in high quality discussions.

5 Discussion

All members of the engineering academic world, including architectural engineers, should be able to recognize the importance of applying the blended learning in their curricula. Students should be able to systematically apply self-regulated interactive learning methods for the core subjects with a thorough understanding of content. Our results demonstrate that an undergraduate flipped course based on ESMs and mini concepts development were well received and led to some changes in first-year architectural engineering students ‘knowledge, skills, and attitudes. We believe there are several sets of factors that contributed to these results. The first is the curriculum itself, including the course content, instructor effectiveness, educational modalities, timing and integration topics within the overall curriculum, planned redundancy, and evaluation methods. The second comes from other formal or informal learning experiences within the pre-architectural and architecture study years, including hidden curriculum.

5.1 Curriculum characteristics

Our analysis identified aspects of the curriculum that worked well for our first-year architectural engineering students. We believe that presenting the flipped course content at Bloom’s (1956) taxonomy of higher order thinking skills (understand, apply, analyse, evaluate, create) and the interactive nature of the learning modalities contributed to the improved responses after students participated in the curriculum. For example, the most improvement was seen in items addressed by ESM development sessions, such as the mini concepts discussions and the bi-weekly follow up corrections, where students applied knowledge and practiced skills. Conversely, students’ improved mastering of content delivered solely by reading, such as concepts and principles of sustainable building construction technology reported in slides, or in their enriched maps. These results and the curriculum evaluation suggest that interactive self-regulated learning may achieve deeper learning and more lasting impact of students’ knowledge, skills, and attitudes, as well as improved student satisfaction with the curriculum. The effect of the ESM on the quiz grades and students’ interaction was significant. Some student showed resistance during the early weeks until the whole class got used to the ESM concept. The following items list the advantages of the ESM:

- This method increases the interactivity, all students are actively involved.
- Students work collaboratively. This work environment reduces the competition that can be seen between students. The objective of this collaboration is to develop and sharpen their knowledge and not to select the best student (van Boxtel et al., 2002).
- It combines various teaching techniques: the confrontation with peers, oral presentations, debate, discussion, research ...
- It increases the autonomy of the students, their productivity and creativity. Indeed, once the lecture notes published, they are already out of date because of new techniques or new publications have been possible. The ESM allows students to interact and produce additional equipment compared with lecture notes autonomously and creatively (Cañas et al., N.d.).
- This method allows overcoming the limitations of the course using data available beyond the lecture notes in order to obtain up-to-dated knowledge (Tergan et al., 2006).
- This method is promising to develop skills in relation to classical ex cathedra lectures and podcasts.
- Education has more to coaching, coaching the active and independent student learning rather than transmissive teaching.

5.2 Study design, questionnaire, and evaluation tools

Limitations in our study design, questionnaire, and evaluation methods also may have blunted the effects of our curriculum on student's learning. A stronger study design would have included a control group of Ulg students or students from same study year and specialisation. However, the study remains limited due to the lack of evidence based evaluation of the effectiveness of this technique. The next step of the study will investigate the ability to apply objective and comparative evaluation to assess the effectiveness of this teaching technique. Suggested improvements included changes in the timing of the curriculum, shorter sessions, less lecture and more personal follow up sessions, more guidance on communication issues. Ultimately, our study is limited due to the small population size, and the self-reported outcomes, rather than using observational methods to determine their actual performance or measuring retention outcomes with respect to the course content.

6 Conclusion

The effect of the ESM on the quiz grades and students' interaction was significant. Some students showed resistance in early weeks until the whole class got used to the ESM concept. The quiz grades improved at least by 20 percent and the students reported their increased interest in the course. The course attendance was 100% during the last 6 weeks and some students arrived half an hour earlier to the class to rehearse the weekly map. In conclusion, the positive feedback of students by the end of the course provided through an online questionnaire confirms the increased interest, knowledge uptake and independence. One of the interesting results was that students required less guidance and engaged in high quality discussions. On the other side, following the flipped class method as an innovative teaching method in class faced resistance and required determination and continuous persistence from the authors. However, the study remains limited due to the lack of evidence based evaluation of the effectiveness of this technique. The next step of the study will investigate the ability to apply objective and comparative evaluation to assess the effectiveness of this teaching technique using a control group from the same class and involve other teachers in the study.

7 Acknowledgement

The author gratefully acknowledge Ton Maree from TU-Eindhoven and Jan Hensen for their dedication to explain and apply the ESM concept, Guirec Ruellan for his assistance in teaching, the IFRES (Institut pour la Formation et la Recherche en Enseignement Supérieur) Faculty of Applied Sciences, Argenco Department, and all students who participated in the curriculum.

8 References

ARCH3258-A, 2015. Sustainable Building Construction Technology Ia Course, Course Syllabus, Liege University, Accessed 01.05.2016, Available at: https://my.ulg.ac.be/portail/CE/fiche.do?as_id=251447&tkRfhId=14630719522336LRL1

Attia, S. 2015a. Yearbook 2014-2015 Ateliers d'Architecture III: Logement collectif durable et conception régénérative, SBD Lab,Liege, Belgium, ISBN: 978-2930909004.

Attia, S. 2015b. Le concept d'« Enriched Skeleton Map » dans le cadre des classes inversée en sciences appliquées, 27e colloque de l'ADMEE – Association pour le développement des méthodologies d'évaluation en éducation. Université de Liège: https://vimeo.com/117565191

Attia, S. 2016a. Yearbook 2015 Ateliers d'Architecture III: Logement collectif durable et conception régénérative, SBD Lab, Liege, Belgium, ISBN: 978-2930909028.

Attia, S. 2016b. Introducing regenerative design and circularity into architectural and engineering curriculum, Proceedings of the 7th International Conference on Engineering Education for Sustainable Development, Bruges, Belgium.

Barber, M., Donnelly, K., & Rizvi, S. 2013. An Avalanche is Coming, Higher education and the revolution ahead. Institute for Public Policy Research.

Berrett, D. 2012. How 'flipping'the classroom can improve the traditional lecture. The chronicle of higher education, 12.
Bloom S., Engelhart, M. 1956. The Classification of Educational Goals: Handbook. Cognitive Domain; by a Committee of College and University Examiners.
Cañas, A.J., Novak, J.D., Vanhear, J., n.d. Using enriched skeleton concept mapping to support meaningful learning.
Colet, N. R., & Romainville, M. 2006. La pratique enseignante en mutation à l'université. De Boeck Supérieur.
Elen, J., 2011. Het hoger onderwijs zal blended zijn of niet zijn [L'enseignement supérieur sera hybride ou ne sera pas]. Adresse au VLHORA (Vlaamse Hogeschoolenraad)-studiedag, Bruxelles, Belgique.
EDUCAUSE Learning Initiative, 2012. 7 Things you should know about Flipped Classrooms. Educause , Creative Commons.
EU, 2014, High Level Group on the Modernisation of Higher Education European Commission, 2014. Report to the European Commission on New modes of learning and teaching in higher education. Luxembourg: Publications Office of the European Union.
Gilles, J. L., Detroz, P., & Blais, J. G. 2011. An international online survey of the practices and perceptions of higher education professors with respect to the assessment of learning in the classroom. Assessment & Evaluation in Higher Education, 36(6), 719-733.
Johnson, L., Adams Becker, S., Estrada, V. and Freeman, A. 2014. NMC Horizon Report: 2014 Higher Education Edition. Austin, Texas: The New Media Consortium.
Leclercq, D. 1998. Pour une pédagogie universitaire de qualité. Sprimont : Mardaga.
Lupion Torres, P., 2009. Handbook of research on collaborative learning using concept mapping. IGI Global.
Novak, J. D., & Cañas, A. J. (2008). The theory underlying concept maps and how to construct and use them.: Institute for Human and Machine Cognition. Pensacola.
Marée, T. J., van Bruggen, J. M., & Jochems, W. M. (2012). Using enriched skeleton concept mapping to support meaningful learning.
Marée, T., van Bruggen, J., & Jochems, W. 2013. Effective self-regulated science learning through multimedia-enriched skeleton concept maps. Research in Science & Technological Education, 31(1), 16-30.
Pereira, JA. Pleguezuelos E., Merí, A., Molina-Ros, A., Molina-Tomás, MC., Masdeu, C. 2007. Effectiveness of using blended learning strategies for teaching and learning human anatomy. Medical Education, 41(2):189-195
Tune, JD., Sturek, M., Basile, DP. 2013. Flipped classroom model improves graduate student performance in cardiovascular, respiratory and renal physiology. Advan. in Physiol. Edu. 37, 316-320.
Tergan, S.-O., Gräber, W., Neumann, A., 2006. Mapping and managing knowledge and information in resource-based learning. Innov. Educ. Teach. Int. 43, 327–336.
Van Boxtel, C., van der Linden, J., Roelofs, E., Erkens, G., 2002. Collaborative concept mapping: Provoking and supporting meaningful discourse. Theory Pract. 41, 40–46.
Zlatkin-Troitschanskaia, O., Blömeke, S., & Pant, H. A. (2015). Competency research in higher education: Conceptual and methodological challenges and perspectives for future interdisciplinary research. Peabody Journal of Education, 90(4), 459-464.
Zlatkin-Troitschanskaia, O., Pant, H. A., Kuhn, C., Toepper, M., & Lautenbach, C. (2016). Messung akademisch vermittelter Kompetenzen von Studierenden und Hochschulabsolventen: Ein Überblick zum nationalen und internationalen Forschungsstand (Vol. 1). Springer-Verlag.