Mind-mapping for Interdisciplinary Sustainable Architecture

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Abstract

Teaching Sustainability is a complex and demanding task requiring a multidisciplinary approach as is clearly demonstrated by the world focus on the UN Sustainable Development Goals (and specially goal 11: Make cities inclusive, safe, resilient and sustainable). The flipped classroom methodology facilitates the necessary discussion for embedding different points of view on the learning process. In this way students can effectively receive out-of-class and in-class opportunities to promote personal learning. However, structuring the huge amount of information handled is a very difficult tasks for students.

In order to develop students' learner autonomy or develop high-level thinking skills to achieve the learning competencies embedded on an Interdisciplinary Sustainable Architecture (ISA) curriculum, the use of mind-mapping learning strategy is known an effective knowledge construction tool for helping students' organizational thinking. Beyond this fact, many previous studies have considered peer assessment as an effective learning strategy to provide students with a teacher's perspective view to think and evaluate knowledge acquisition.

This research presents relevant results on the use of mind-maps with an online peer assessment approach. This tool is embedded as a key element for structuring Sustainability Assessment knowledge within a course based on the flipped teaching methodology. Moreover, an experiment has been conducted to evaluate the advantages and disadvantages of the proposed approach on students' learning analytics such as time involvement and learning reflections. It is important that educators use an online peer assessment learning environment for learners and aim for the goals to help learners become more critical, independent, and autonomous in the development of any Sustainability curriculum.

1. Introduction

Sustainability is a trending topic for our society. It involves many disciplines ranging from basic science to sociology and business, but always involving a technological approach when an architecture curriculum is involved. The purpose of ISA is not only the assessment of current or future cities, but also understanding how buildings and urbanism can contribute to more resilient societal organization in cities. In the twenty first century, the internet and the incipient Internet of things has allowed instant access to unfiltered, ubiquitous information which adds information analysis and its management as key disciplines for ISA development. Therefore, transversal competencies such as peer assessment and knowledge mapping have become important analysis and communication tools for future sustainability professionals. However, in the twenty first century globalization, Architecture curriculums are no longer just a collection of technical tools, but also a space which demands the integration of higher level competencies [1] for developing better organizational skills, creative (and critical) thinking, problem-solving abilities, or even more important team work. To face with such new environments and challenges, students' learning processes have to be

developed through team assessment and include strategies where faculty incorporate multidisciplinary knowledge in a critical environment.

Recent evidences [2] on the complex interaction between competencies development and oral interaction, indicate that flipping classrooms provides more time and interactive environment for teachers and students, and also helps students interact actively and improve speaking and writing skills [3]. The main reason is that by flipping classes students undergo a self-discovery process of learning materials, knowledge grounding leading to personal understanding and leaving all the time available in class for face-to-face instruction for oral team interaction for knowledge acquisition and final writing for memory development.

The classroom is a debate space for teacher-student communication and interaction, as well as group discussion, including peer evaluation [4]. However, Strayer [5] within flipped classrooms there is no proper guiding strategy, it is easy for students to feel frustrated about learning workload or unsuccessful flipping strategy.

Consequently, the development of the students' competency on identifying, defining and organize all relevant concepts within this environment appears as the natural solution for efficient knowledge acquisition. This technique Concept (or Mind) mapping, introduced by Noval and Gowin [6], facilitates active meaningful learning while developing a structure for all relevant information. In the past decade, classroom research [7] has demonstrated the advantage of active teaching for engaging students, followed by a mind-mapping strategy for a successful knowledge integration [8].

On the other hand, although previous studies have pointed out that concept or mind map learning strategies can help students to organize knowledge effectively, there is still the possibility of failure in mind-mapping learning strategy in university classrooms. Some key factors for failure are difficult to accept, the mind-mapping strategy of students themselves, and are unfamiliar with the way of thinking [9]. The result showed that mind mapping mainly benefited the students' writing in the elaboration dimension. Therefore, if the teacher could not only help the students using the mind-mapping tool to generate ideas in their writing process, but also integrate much more supportive guidance with teachers or peers, such as using peer assessment strategy to encourage peers to make reflections and improvements [17].

Due to the above reasons, it is necessary to develop a flipped teaching strategy based on group mind mapping, followed by peer assessment tools to assist students in summarizing, organizing concepts, and assessing others' work for an effective knowledge acquisition [18]. Thus, in this paper, a strategy is proposed for gaining meaningful insight on the mind mapping-based flipped classroom. Moreover, 3 consecutive years of classroom research have allowed a fair understanding of the advantages, and disadvantages, of first the flipped teaching approach, and second the proposed mind mapping approach, by answering the following questions:

1. Do students who learn with the integrated mind mapping-based flipped learning approach have significantly better learning achievement than the students learn without this strategy?
2. Do students who learn with the integrated mind mapping-based flipped learning approach have significantly better learning involvement than others?
3. Do students who learn with the integrated mind mapping-based flipped learning approach have significantly better learner autonomy than their peers?

2. Experimental plan and methodology

2.1. Reseach population implementation

The course on "Non Traditional Materials for Architecture" provides a relevant test bed for assessing students' learning performance and perceptions due to its independence from the traditional curriculum (besides being optative) which gives the students, and faculty, more innovative opportunities. This course belongs to the Graduate degree in Building Engineering at Universitat Politecnica de Valencia (UPV) and is taught during the second semester of the last degree year. During the last three years the course has been taught, first on the traditional lecture based approach (course 2016-17), second following the Flipped Classroom methodology (course 2017-18), and on the last intake (course 2018-19) including for performance assessment the mind-mapping approach. Students are scored also on their learning styles to check any deviation due to a significant change on the student population.

The compared course evaluation taken from the corresponding syllabuses (table I) shows the main items evaluated on the different approaches all having the same weight on the final score. The course was taught by the same faculty all years.

Table 1. Nontraditional Materials in Architecture Course

Traditional	Flipped	Flipped+MindMaps
Lab practice	Lab practice	Lab practice
Class project	Class project	Class project
2 exams	Class exercises	Mind-maps

On the table the explanation for the evaluation items is explained on the next paragraphs:

- Lab practice: evaluation of the lab group solutions to exercises related to the lab work,
- Class project: team development of a proposed alternative solution to a building using nontraditional materials. The project develops all points introduced on the theory class applied to the practical case proposed. Besides the written document with all the details, the students make a joint executive presentation (5 minutes) of the project relevance.
- Exams: short questions to evaluation knowledge acquisition on the theory sessions of the course.
- Class exercises: individual solution of short numerical and logical questions for real cases.
- Mind-maps: individual mind-maps (using the e-tool Mindmup) presenting, and defining, all concepts presented in class in a connected graph. The students have to include relevant application examples from the Internet.

2.2. Students learning styles analysis

For statistical significance, it is agreed that experiments of different student populations are comparable when their learning styles can be considered as stable [14].

For evaluating the learning styles, the Felder-Soloman questionnaire [10] was used on all occasions. This decision was based on the adequacy of this test, according to Ruey-Shiang [11], for ensuring first a similar

type of student population each year, and second the right learning styles for good flipped teaching performance [12].

On table 2, the comparative learning styles per course are shown ensuring a relevant value (above 2) for one third of the population which gives a certainty of 95% for the hypothesis of equivalent populations according to ISO/TS 17503:2015 .

Table 2. Learning styles percentage of the students per course

Learning Style	Traditional course 2016-17	Flipped course 2017-18	Flipped+MindMaps course 2018-19
Active > 2	42	38	41
Intuitive > 2	39	46	45
Visual > 2	60	52	59
Global > 2	40	49	38

2.3. Methodology for the analysis

In order to evaluate the 3 proposed research questions, the corresponding output variables considered were:

1. Average of class performance score. This is the best evaluation we can obtained for the overall learning achievement.
2. Average of student satisfaction in the course. Under the research conditions learning involvement is directly connected to student satisfaction according to Narjaikaew [15]. The student satisfaction is measured at UPV by an individual (UPV controlled) survey.
3. Average of mind-map evaluation. Learner autonomy is especially relevant when their own creativity (individual concept-map evaluation) is measured [16].

3. Results and analysis

3.1. Experimental results

On table 3, the evaluation of the different items described on point 2.3 is presented for the course on each of the years considered for the research.

Table 3. Experimental results for the course each year

Indicator	Course 2016-17	Course 2017-18	Course 2018-19
Course average score ± std. dev.	6,3 ± 0,2	7,0 ± 0,1	8,1 ± 0,1
Average student satisfaction ± std. dev.	7,4 ± 0,4	8,1 ± 0,2	8,6 ± 0,1
Average individual score ± std. dev.	5,3 ± 0,3	5,8 ± 0,2	7,1 ± 0,1

3.2. Analysis of the research questions

From the results shown above, it is clear that the combination of flipped teaching and mind-map individual work is an excellent option for optative technical courses. After the introduction of flipped teaching relevant progress is evident as expected for the delivery of complex non-mathematically based disciplines [17]. Later enhancements due to individual mind-maps are especially relevant on multidisciplinary topics [18].

The student satisfaction develops a clear increase of results both as a group or individually which shows also a relevant increase in student autonomy. Additionally, the smaller standard deviation indicates that the conclusions are more representative for the group.

4. Discussion

From the evidence presented on this paper, a simple path to deliver effectively sustainability competences has been introduced. Flipped teaching has been proved here as a very effective methodology for scientific topics with low mathematical burden, as well as the use of mind-maps for structuring multidisciplinary disciplines. The procedure can be easily extrapolated to other fields where the multidisciplinary approach is a key element of the message.

5. Conclusions

Although there has been considerable progress in the incorporation of Sustainable Cities into the curricula of higher education institutions (HEIs) in Europe, particularly on competences for sustainable development and on pedagogical approaches, there has been limited research on the connection between how courses are delivered (pedagogical approaches) and how they may affect sustainability competences.

This paper has presented the results from an academic research into the best delivery practice for Sustainability through flipped teaching and mind maps. The acquisition of sustainability competences, and the related pedagogical approaches, are key to achieve sustainability. It is also relevant to take note of the increased work load by faculty in charge.

Follow-up research, could provide insights on how to better use, rethink, redesign, and combine these with other pedagogical approaches to provide a more sustainability-oriented education.

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References

1. Fuertes-Camacho, M.T.; Graell-Martín, M.; Fuentes-Loss, M.; Balaguer-Fàbregas, M.C. Integrating Sustainability into Higher Education Curricula through the Project Method, a Global Learning Strategy. Sustainability 2019, 11, 767.

2. Gallego-Álvarez, I.; Lozano, M.B.; Rodríguez-Rosa, M. Analysis of Social Sustainability Information in a Global Context According to the New Global Reporting Initiative 400 Social Standards. Sustainability 2019, 11, 7073.

3. Zainuddin, Z., Zhang, Y., Li, X., Chu, S., Idris, S. and Keumala, C. (2019), "Research trends in flipped classroom empirical evidence from 2017 to 2018: A content analysis", Interactive Technology and Smart Education, Vol. 16 No. 3, pp. 255-277.

4. Sams, A., & Bergmann, J. (2013). Flip your students' learning. Educational Leadership, 7, 16-20.
5. Wilson, D. Exploring the Intersection between Engineering and Sustainability Education. Sustainability 2019, 11, 3134.

6. Novak, J.D.; Gowin, D.B. Learning how to learn; (1984) Cambridge University Press.

7. Kerrigan, J. Active Learning Strategies for the Maths Classroom, College Teaching (2018), 66:1, 35-36.

8. Hwang, G.J., Shi, Y.R., Chu, H.C. A concept map approach to developing collaborative Mindtools for context-aware ubiquitous learning. British Journal of Educational Technology (2011), 42, 5, 778-789.
9. Felder, R. M., Soloman, B. A. (1999). Index of learning styles questionnaire. Available online: URL: (accessed on 3 December 2019) https://www.webtools.ncsu.edu/learningstyles/; https://www.researchgate.net/publication/228403640_Index_of_Learning_Styles_Questionnaire.
10. Ruey-Shiang S. The Learning Performance of Different Knowledge Map Construction Methods and Learning Styles Moderation for Programming Language Learning (2019). Journal of Educational Computing Research, 56, 8, 1407-1429.

11. OECD 2017. The OECD Handbook for Innovative Learning Environments. OECD, Publishing. Paris.
12. Moyer, J.C., Cai, J., Wang, N., & Nie, B. (2011). Impact of curriculum reform: Evidence of change in classroom practice in the United States. International Journal of Educational Research, 50, 87-99.
13. Samsudin, D.; Hardini, T. The influence of learning styles and metacognitive skills on students' critical thinking in the context of student creativity program. International Journal of Education 11, 2, 117-124.

14. Narjaikaew, P., Emerat, N., Arayathanitkul, K., & Cowie, B. (2010). Magnetism teaching sequences based on an inductive approach for first-year thai university science students. International Journal of Science and Mathematics Education, 8, 891-910.

15. Sejpal, K. (2013). Models of teaching: the way of learning. International Journal of Research in Humanities & Social Sciences, 2, 18-24.

16. Suh, H.; Han, S. Promoting Sustainability in University Classrooms Using a STEM Project with Mathematical Modeling. Sustainability 2019, 11, 3080.Gray, S.; Sterling, E.J.; Aminpour, P.; Goralnik, L.; Singer, A.; Wei, C.; Akabas, S.; Jordan, R.C.; Giabbanelli, P.J.; Hodbod, J.; Betley, E.; Norris, P. Assessing (Social-Ecological) Systems Thinking by Evaluating Cognitive Maps. Sustainability 2019, 11, 5753.

17. Colaux, C., Beckers, Y., Brostaux, Y., Charles, C., Claessens, C., Heinesch, B., Sindic, M., Degré, A. Soft Skills: how to make the young engineers aware of their new talents?. Proceedings EESD2018.

18. Jensen, C.D. Piloting the flight, a systems methodology for sustainability education. Proceedings EESD2018.