

ABSTRACT

Sustainability issues are among priorities of global concerns and society expects universities to educate youth and help them reach a certain level of sustainability awareness. New regulations and laws on sustainability put pressure on businesses across all industries and force them to evolve into their more sustainable versions. There is a demand for additional (sustainability) qualifications in graduates when hiring new personnel. Many higher education institutions have started to develop and incorporate sustainability curriculums into their programs to respond to expectations of society and other stakeholders. However, whether these efforts achieve the desired outcomes is not well documented. This study was designed to present an example of a modern management techniques-based inter-disciplinary sustainability curriculum and to provide evidence through pre- and post-education assessment of students' perception of sustainability issues and modern management techniques to address them. A 3-credit 16 weeks long undergraduate level course that horizontally integrated sustainability into a secondary wood products engineering framework has been developed and taught at a U.S. higher education institution and then, success of developed sustainability curricula was measured with a 20-question survey. Results show that course content was successful at increasing sustainability awareness at both overall and individual sustainability pillar levels. At the end, 100% of students were able to develop complete understanding of various modern management techniques and stated that they felt confident to apply learnt skills to real life issues within their profession upon graduation.

INTRODUCTION

This study documents the development of sustainability curriculum driven by modern management techniques at one of the U.S. higher education institutions, Purdue University. For many corporations, sustainability awareness and capability to deliver sustainability solutions to industrial scale problems have become must-have qualifications rather than preferred ones when recruiting new personnel (Hesselbarth and Schaltegger, 2014). Lack of sustainability curriculum at higher education institutions were documented in the literature (Dhingra et al., 2014; Figueiró and Raufflet, 2015; Mather et al., 2011; Tasdemir and Gazo, 2018). The dynamic nature of sustainability innovation forces higher education institutions to re-design and broaden their curricula to become more real-life oriented across all disciplines by establishing connections with industry and other institutions (Tilbury, 2011).

In response to above stated pressing concerns and based on previous findings, a 3-credit hour undergraduate level course that horizontally integrated sustainability into a secondary wood products engineering framework structured around modern management techniques was developed and taught to achieve following objectives:

- (1) To assess changes in perceptions of undergraduate students on Triple Bottom Line (TBL) Sustainability, Global Trends, Industry Evolution, Innovation Waves, Lean, Supply Chain Management, Six-Sigma and Life Cycle Analysis topics as function of developed curricula.
- (2) To contribute to effective development of industry-ready job skills in undergraduate students by teaching them to deliver engineering solutions through critical thinking with help of transdisciplinary and PBL focused approach of the course.

METHODOLOGY

To ensure inter-disciplinary theory coverage and to establish a transdisciplinary interface to satisfy expectation of various stakeholders, a 16-weeks-long course involving both lecture series and project-based hands-on lab sessions were developed and taught as a 3-credit hour course titled "Secondary Wood Products Manufacturing and Sustainability" within the Forestry and Natural Resources Department at Purdue University. Lecture series were given on Tuesdays during one-and-a-half hour long classes while same length laboratory sessions took place on Thursdays.

The course was designed to inter-connect various disciplines to achieve a holistic structure. As illustrated in **Figure 1**, it involved (1) certain Wood Science subjects (wood ID, furniture design, primary and secondary wood products industry, adhesives), (2) Industrial Engineering and Management concepts such as Lean Manufacturing, Supply Chain Management (SCM), Six-Sigma Quality Control and (3) components of Environmental Studies through integration of LCA, sustainable product design and waste management. It also had an integrated Project Based Learning (PBL) component to reach beyond interdisciplinary theoretical structure to ensure transdisciplinary nature by providing various experiences from real-life industry practice with input material from various sectors. A total of eight students (mixture of sophomores, juniors and seniors) voluntarily enrolled in the course advertised through the university catalog. Performance of the students was assessed through 2 comprehensive class projects, 1 mid-term exam and 1 final exam as well as through attendance and participation points. Both at the beginning and at the end of the semester a 20-question survey was conducted to observe impact of developed curriculum on changes in students' perception of modern management techniques and sustainability. The survey had 6-point Likert-Like Scale with two major components; (1) sustainability concepts-oriented block and (2) modern management techniques-oriented block.

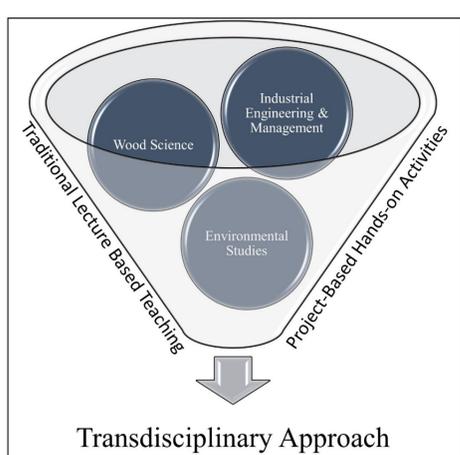


Figure 1. Illustration of transdisciplinary nature of course design.

RESULTS

Over the 16-week assessment period, 100% students' pass rate was achieved. Based on the feedback provided by, overall rating for the course had a median score of 4.8 (mode = 5) on a 5-point Likert Scale. Both median and mode for the evaluation of the instructors were 5.00, based on the same scale. When students were asked whether the course assignments were interesting and stimulating, the overall answer also yielded a median value of 4.8 (mode = 5). The results of the Mann-Whitney analysis for each question of the survey can be observed in **Table 1**. At the 95% confidence level, group medians of post-education survey results were significantly higher from those of pre-education survey results for all 17 survey questions.

Question	Post-Education Median	Pre-Education Median	Lower Bound for Difference	W-Value	P-Value (Not Adjusted for Ties)	P-Value (Adjusted for Ties)
1a	5.00	3.00	1	96.00	0.002	0.002
1b	5.00	3.00	2	100	0.000	0.000
1c	6.00	4.00	1	95.50	0.002	0.001
1d	5.50	3.00	2	100	0.000	0.000
2	5.00	3.00	1	100	0.000	0.000
3	6.00	2.50	3	100	0.000	0.000
4	6.00	3.00	2	100	0.000	0.000
5	5.00	3.00	2	100	0.000	0.000
6a	5.00	3.50	1	100	0.000	0.000
6b	6.00	4.00	1	98.00	0.001	0.001
6c	5.50	4.00	1	97.00	0.007	0.005
6d	5.00	4.00	1	100	0.000	0.000
6e	5.00	3.50	1	98.00	0.001	0.001
6f	5.00	3.00	2	100	0.000	0.000
7a	6.00	3.00	2	100	0.000	0.000
7b	5.00	3.00	1	100	0.000	0.000
7c	6.00	5.00	0	84.50	0.046	0.024

Table 1. Mann-Whitney non-parametric hypotheses test results for pre- and post-education group medians.

All tests were run at alpha (α) = 0.05 on a sample size (n) of 8.

Based on the answers provided for questions from 1a to 1d of pre-education surveys, only 12.50% of students stated that their familiarity with sustainability concepts was above average, while 87.50% of them stated that their familiarity level was moderate or less as shown in **Figure 2A**. Similar observations were present for individual sustainability pillars. Lack of understanding and knowledge was also present in students in terms of global trends, innovation waves and industry evolution and modern management techniques as can be seen in **Figure 2B**. At most 50% of students were having moderate familiarity with above stated concepts.

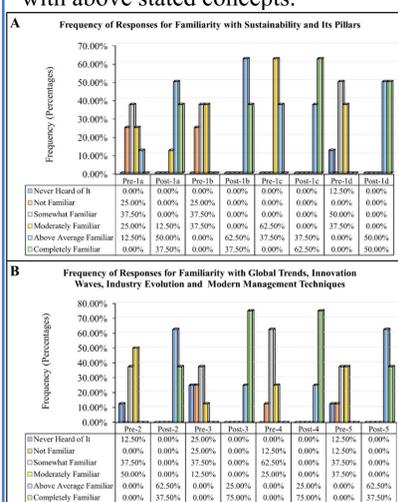


Figure 2. (A) Frequency of responses for familiarity with sustainability and its pillars. (B) Frequency of responses for familiarity with global trends, innovation waves, industry evolution and modern management techniques.

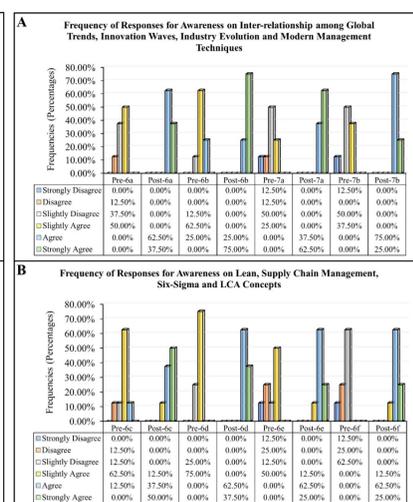


Figure 3. (A) Frequency of responses for awareness of inter-relationship among global trends, innovation waves, industry evolution and modern management techniques. (B) Frequency of responses for awareness on lean, supply chain management, six-sigma and LCA concepts.

As shown in **Figure 3A**, pre-education survey results revealed that only 50% of students were slightly aware of inter-relationship among concepts under investigation. Questions 6c, 6d, 6e and 6f tested students' understanding of lean manufacturing, sustainability, six-sigma and LCA concepts at individual level. In the pre-education survey, 75% of the students agreed with having a good understanding of lean manufacturing and supply chain management concepts, whereas the frequency of those who claimed to have a good understanding of six-sigma concepts was 50% as given in **Figure 3B**. No students agreed with having a good understanding level of LCA concepts as 62.50% of students slightly disagreed with such claims in the best-case scenario.

In contrary to the pre-education survey, results of post-education surveys showed that (1) 100% of students had at least above average familiarity with sustainability, its pillars and modern management techniques, (2) 100% of students at least slightly agreed with the claim of "having a good understanding of lean, supply chain management, six-sigma and LCA concepts."

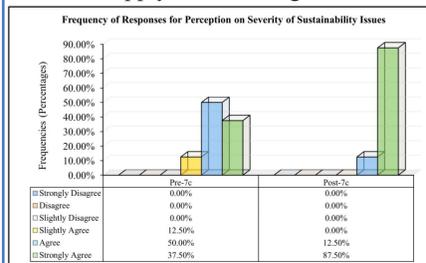


Figure 4. Frequency of responses for perception on severity of sustainability issues.

CONCLUSIONS

Overall, based on inferential and descriptive statistics presented and discussed above, it can be concluded that the study achieved all of the stated objectives. The developed course was successful in (1) combining inter-disciplinary material to tackle sustainability issues, (2) delivering a sufficient level of instruction for better sustainability awareness, (3) contributing to development of job-ready skills and self-confidence in future job candidates and leaders to ensure a positive impact on global sustainability issues upon graduation. This study is expected to be used as reference point for those willing to develop similar courses or curricula for university-wide adoption. Future research opportunities include but are not limited to repetition of the study with a new group of students in the upcoming years, comparing survey results of lecture only courses with those of course involving both lecture series and hands-on (laboratory) activities, comparing the contribution of online course offerings with on-campus education and discovering the opinion of employers on integration of modern management techniques-driven sustainability and hands-on activities into college classes to enhance job-ready skills of future job candidates.

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