

Industrial Ecology Education

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Industrial ecology (IE) education is a topic that has received attention in institutions of higher education throughout the world. Some universities have been teaching and researching IE for the past 20 years but its scope is still being defined. There is a need to catalogue and exchange experiences of IE teaching and their results. In addition to an extensive literature review, this paper provides a framework composed of content and strategies for teaching Industrial Ecology. This framework is tested in teaching IE as a general education course for undergraduate students at Beijing Institute of Technology (BIT). The methodology applied in this paper is of a descriptive and empirical nature and thus this paper focuses on a practice-oriented perspective in describing the experience at BIT. A range of different strategies, including lectures, group discussions, case studies, role playing games, oral presentations, evaluation, and student feedback have been incorporated into the course. The course received highly positive evaluation by the participating students. Students were impressed by IE's characteristic of interdisciplinarity, way of thinking and practical value. Additionally, the course appears to influence students' values, attitudes, and behavioral intentions. The paper concludes with some thoughts on ways of improving IE education in the future.

Keywords: industrial ecology ; curriculum ; higher education ; pedagogical approach ; circular economy ; China

1. Introduction

Education has been recognized as a vital vehicle for realizing sustainable development ^{[1][2]}. Acting as essential educational institutions, universities should be expected to play a crucial role in transforming our world towards sustainability ^{[3][4]}. Industrial ecology (IE) is arguably one of the key strategies and fields of research for achieving sustainable development especially as it relates to industrial production and consumption ^[5]. It is a field which balances theory and practical application ^[6] and thus can influence real world activities ^[5]. Cockerill ^{[4][7]} argues that IE is seen as an applied approach to address sustainability from multiple perspectives. This contributes to generating "new and imaginative solutions that build on overall sustainability" ^[8] (p. 133). As a result of development during the past 30 years, IE has become a "noticeable presence in education" ^[1] (p. 78) and increasingly integrated into formal education worldwide ^[6]. IE education has received attention in institutions of higher education throughout the world ^{[9][10]}. It is reported that 190 universities and colleges from 46 countries were offering courses and/or programs on IE in 2012 ^[6]. The International Society for Industrial Ecology (ISIE) has listed IE education as one of the key topics in the field. Currently, there is a need to be aware of and exchange experiences of IE teaching and their results ^{[8][11]}, which will facilitate its further development. A few educators have reviewed their experiences of IE education programs and courses in the past 20 years ^{[8][9][10][12][13][14][15][16][17][18][19][20]}.

Globally, although IE education at the undergraduate level is emerging, courses of IE are mainly focused on graduate level within engineering and environmental disciplines ^[6]. Considering the diversity of the IE field itself, the audience for IE curricula should be broader ^{[6][9]}. Some have argued that is necessary to expand IE education to various majors across the university ^{[12][17][21]}. Others have gone so far as to suggest that IE should be introduced to all students at the university in their first or second under-graduate year ^[12]. However, IE education is a topic which has not had much discussion and debate, and there is a shortage of research done on teaching objectives and strategies for undergraduate students. More experiences on IE teaching need to be reviewed and discussed ^{[8][11][17]}.

Based on an extensive literature review, this paper aims to provide a framework composed of content and strategies for IE teaching. Using this framework, we uncovered how IE teaching can be developed at the undergraduate level in an effective way. This framework is tested in teaching IE as a general education course for undergraduate students at Beijing Institute of Technology (BIT). The methodology applied in this paper is of a descriptive and empirical nature and thus this paper focuses on a practice-oriented perspective in describing the experience of BIT.

2. Framework of Teaching IE as a General Education Course for

Undergraduate Students at BIT

The framework of IE teaching for undergraduate students presented in this paper is composed of content and strategies, which is shown in Figure 1.

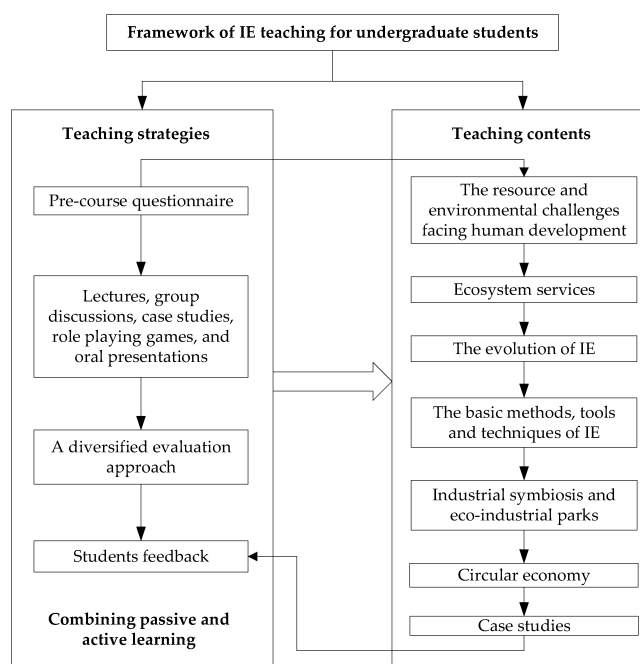


Figure 1. Framework of IE teaching for undergraduate students.

3. Conclusions

Industrial ecology education should be offered to undergraduate students in various majors at universities. It has the potential of linking theory and practice related to sustainable development in a meaningful way. Case study articles are especially useful for inspiring and encouraging students.

The framework for IE teaching presented in this paper was developed to teach undergraduate students at Beijing Institute of Technology as a case study. The integrated teaching strategies adopted in the course have not been described in the academic IE literature. We found that the framework can be successfully applied in an IE course and has effectively enhanced students' understanding of Industrial Ecology.

The teaching content such as industrial symbiosis, eco-industrial parks and ecosystem services with case studies in a combination of active and passive learning were appreciated by the large majority of the students. This can improve student interest in IE and enhance student satisfaction. The course plays an effective role in achieving outcomes such as changing students' values, attitudes, and behavioral intentions. Students appreciated the interdisciplinary lens and incorporation of ecological perspectives into their decision making. Exploring a combination of the course material with students' local situation can further inspire their interest in learning.

The methodology applied in this paper has descriptive and empirical elements. Future research could expand the use of evaluation tools to quantitatively assess student learning outcomes from the IE course. This paper is based on a single university although it relied on experiences from elsewhere. Especially on a graduate course offered at Dalhousie University in Canada. With more research on IE teaching, the results could be compared and generalized. We hope that our research will inspire faculty who are interested in teaching IE around the world to describe their experiences, because of its emphasis on industrial sustainability.

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