New Perspectives in Science Education
International Conference
NEW PERSPECTIVES in SCIENCE EDUCATION
Edition 4

Linking Environmental Research Programs and Teaching in a Higher Technological Education Institute

Vayos G. Karayannis[1], Evangelia N. Lakioti[2], Asimina E. Domopoulou[3]
Department of Environmental Engineering, Technological Education Institute of Western Macedonia (Greece)
[1]vkarayan@teiwm.gr, [2]elakioti@med.uth.gr, [3]adomopo@teiwm.gr

Abstract
The development of a strong relationship between scientific research and teaching in higher technological education, as complementary learning procedures rather than separate components, is increasingly considered a particularly valid approach to strengthen research activities, to qualify academic teaching for innovation and entrepreneurship, and, especially, to enhance students' understanding and motivation. In the present work, a case study is presented on the linkage of an environmental research program with academic teaching in a Higher Technological Education Institute (of Western Macedonia, Greece). The undergraduate students of the Environmental Engineering Dept. are progressively introduced during the courses to recent research progress and critical thinking, via the integration of continuously renewed research published in peer-reviewed journals into the educational procedure. They were familiarized, in particular, during the courses with a research program ("ARCHIMEDES III") taking place in the Department on safe management, recycling and valorization of industrial solid wastes into value-added ceramic products. Their awareness regarding the investigation of new applications of this category was recorded and evaluated using an appropriate questionnaire. In order to develop a meaningful nexus between research aims and course concepts, the experimental procedure was fully demonstrated to the students during relevant laboratory courses, and resulting research findings were broadly discussed in the classroom. Moreover, some students carried out their undergraduate thesis on scientific topics in close relation with the research project goals, assisting the research team members in conducting part of the experiments, thus supporting their thesis. Students' feedback reflects the success of transferring learning community values and strategies to increase the benefit for student participation and learning in higher technological education, while also contributing to widen information, publicity and dissemination of the research program activities and results to the society. Bringing research and real applications in academic teaching appears a challenge that can further enlarge the development of research-based curricula, leading teachers and students to work together towards collaborative learning, for enhancing the quality and outcomes both of the research endeavor and the learning experience, this being a promising perspective for higher technological education.

1. Introduction
Study into the relationship between research and teaching in higher education is long lasting. The development of a strong nexus between scientific research and teaching is increasingly considered a particularly valid approach to strengthen research activities, to qualify academic teaching for innovation and entrepreneurship, and, especially, to enhance students' understanding and motivation [1-3]. However, curricula often remain too theory-focused in higher education, reflecting a disconnection between classroom teaching and research endeavors as well as real applications of science and technology in everyday life [4,5]. Nowadays, research and teaching constitute core characteristics of higher education and their links are regarded as complementary in enhancing the quality of student learning. On the other side, little previous research has also investigated possible conflicts associated with bridging these two aspects [6]. For example, the interests of research-active academic staff are sometimes highly specialized, and opportunities for their work to be included in fairly generalized undergraduate courses remain usually limited [7]. Actually, the identification of the communications needs between science teachers, researchers and industry appears to be a rather delicate issue towards the enhancement of the interest by students for scientific research progress during their studies [4]. Thus, the relationship teacher-researcher needs to be broadly interrogated. It is argued that this relationship depends, to a certain degree, on how the terms 'research' and 'teaching and learning' are conceptualized [8]. Naturally, recent advances in science education study provide an enriched base on which earlier questions might beneficially be reconsidered [1]. Therefore, it appears necessary to turn from such stimulating questions to real solutions.

Linking research and teaching is a challenge of international interest. In several countries, acknowledgement of the need to link teaching and research has led to the development of institutional strategies to achieve this goal [7]. Certainly, the complex nature of this nexus, which may take many different forms and may be found in all types of higher education institutions, should be thoroughly explored [8]. One of the most profound implications according to recent science education studies is the way academic institutions and teachers perceive this relationship as well as its potential to enhance the quality and outcomes of the learning experience [1,7]. It should be noticed that students generally exhibit relatively increased research awareness and experience in advanced years of study, whereas first-year students have limited opportunities to engage in research, which results in lower levels of research culture [9]. Therefore, there is much place for improvement, and such links should be systematically built into the curricula. Nevertheless, the extent to which the establishment of such a successful relationship rests simply on the incorporation of research findings into the undergraduate classroom is questionable [7]. Moreover, there is little knowledge about how programs address research for undergraduate students, as emphasis is rather put on teacher-led research than real student involvement [3].

Students are likely to gain most benefit from research when they are actively engaged. For that purpose, various forms of inquiry-based learning have been proposed so far [8]. Particularly, transfer of learning-community values and strategies is endorsed to build stronger ties between these two aspects of higher education into the classroom, so that students successfully see them as complementary rather than separate components [5]. Bringing real case-studies and practical examples from the research institutes into the classroom, or, even better, bringing students inside the research center is also suggested for fostering interest and curiosity of students into scientific research [2]. Moreover, a fruitful framework can be created for students, academics and industry partners by synthesizing work-integrated learning, research and teaching through the establishment of industry-oriented student projects based on work-integrated learning theory. Such attempts may vary from a minor assignment project to a medium submission, e.g. a final-year project, to more comprehensive research work including MSc or PhD research [10].

In the present paper, a case-study is presented on the linkage of an environmental research program with academic teaching in a Higher Technological Education Institute (Western Macedonia, Greece). This work aims at exploring strategies and highlighting specific issues to achieve optimal research-teaching links within the environmental science and technology, and enable a better understanding of methods that govern the modern scientific procedure, towards teaching students how knowledge is built rather than simply transferring knowledge to them, while also contributing to broaden information, publicity and dissemination of the outcomes of the current research program to the society.

2. Linking environmental research programs and teaching

In order to satisfy the progressive nature of learning and to maximize the potential of the research-teaching linkage for a successful outcome, a strategy for linking research and teaching systematically across an entire curriculum is necessary. For establishing such a research-teaching nexus in the Technological Education Institute of Western Macedonia, Greece, with particular reference to the Environmental Engineering Department, the following approach is proposed:

The undergraduate students are progressively introduced into the classroom to recent research progress and critical thinking, via teacher-led integration of continuously renewed research results to the educational procedure.

Moreover, extensive use of scientific literature databases (including Scopus, ScienceDirect, Springerlink etc.) is promoted, in close cooperation with the teacher, for undertaking by all students, individually or in group work, of a research-oriented semester project concerning the study-in-depth, understanding, writing of an extended summary and presentation into the classroom of research articles recently published in peer-reviewed journals, in several courses, mainly including “Industrial Pollution Control Technology”, “Recycling Technologies”, “Management of Hazardous & Toxic Wastes”, “Physicochemical Processes” and “Environment and Society”.

Particularly, the students were familiarized with a **Research Program** ("ARCHIMEDES III") taking place in the Department on safe management, recycling and valorization of industrial solid wastes in the development of new value-added and eco-friendly ceramic products, towards sustainability. Besides the environmental aspects, the economic advantages due to the low cost of the waste by-products should be taken into account. The large amount of ceramics produced also supports this action.

Specifically, fly and bottom ashes derived from lignite-fed power stations of Northern and Southern Greece (highly-calcareous and siliceous respectively), coal fly ash from circulating fluidized bed (CFB)

combustion, steel industry by-products (slags), waste glass cullet and olive kernel ash were beneficially utilized as secondary resources than as wastes.

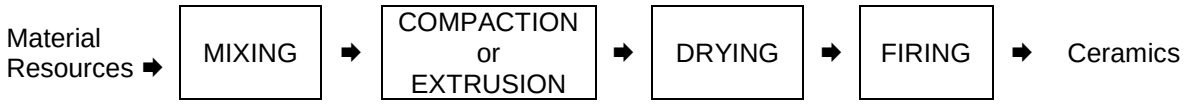

Figure 1: *Schematic diagram of the experimental procedure followed for the synthesis of ceramics.*

(a) (b)

Figure 2: *Specimen preparation in the laboratory: cold pressing/compaction of material resources using hydraulic press (a) and firing/sintering of the compacts in a controlled chamber furnace (b).*

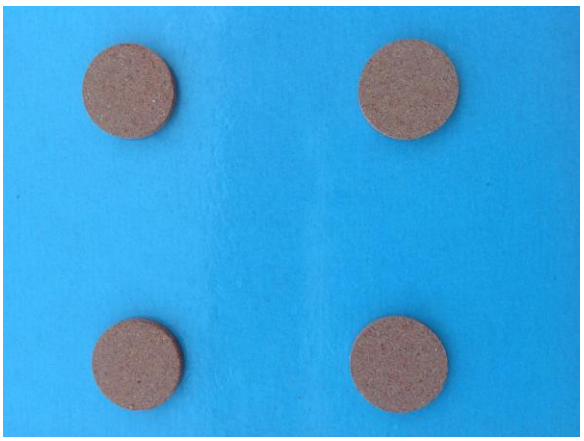

Figure 3: *Indicative photographs of 13 mm diameter ceramic specimens prepared from fly ash-glass cullet (0, 5, 0 and 15 wt.%) mixtures fired/sintered at 900^{o}C for 2h (a, b, c and d respectively).*

In order to develop a meaningful nexus between current research program aims and course concepts, the experimental procedure was fully demonstrated to the students during aforementioned laboratory courses, and the research goals and resulting findings were broadly discussed.

During the relevant laboratory courses, students participated in carrying out representative stages of the experimental procedure, thus enhancing their motivation and learning skills, and reflecting positive experiences of the research culture.

In addition, their awareness and acceptability regarding the investigation of new applications of this category was recorded and evaluated using an appropriate questionnaire [11]. Their aspiration for an improved human health and quality of life, especially in areas with environmental degradation, from

possible application of new recycling activities towards sustainable use of material and energy resources, along with the potential for creation of new jobs, was pointed out, while also their very positive view with regard to further implementation of relevant research programs should be emphasized.
Furthermore, some students opted for carrying out their undergraduate thesis on scientific topics in close relation with the research project aims, assisting the research team members in conducting part of the experiments, thus better supporting their own research thesis.
Undergraduate students of the Department actively involved in the research program report greater inspiration, depth of learning and understanding of the topic and practical applications.
By incorporating research programs into teaching procedures particularly in higher technological education, a solid framework is established, integrating research findings to theoretical education for supporting designed curricula.

3. Concluding remarks

- Students' feedback from their participation in an environmental research program reflects the success of transferring learning-community values as an effective teaching strategy to increase the benefit for student learning in higher technological education, while also contributing to widen information, publicity and dissemination of the research program activities and results to the society.
- Bringing research and real applications in academic teaching appears a challenge that can enlarge the development of research-based curricula, leading teachers and students to work together towards collaborative learning, for enhancing the quality and outcomes both of the research endeavor and the learning experience.
- Further initiatives should be undertaken to raise a research culture profile among students and strengthen research activities, this being a promising perspective for higher technological education.

Acknowledgements

This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program **ARCHIMEDES III** (Scientific coordinator: Assoc. Professor Vayos G. Karayannis): Investing in knowledge society through the European Social Fund.

References

[1] M. Malcolm. A critical evaluation of recent progress in understanding the role of the research-teaching link in higher education. *Higher Education*, 67 (2014) 289-301.
[2] F. Taponecco, U. Fritsch, M. Mühlberger, K. Amor. EURAC Junior: Bringing science and research into the classroom. In: *Proc. of the 2nd Edition of the International Conference "New Perspectives in Science Education"*, Florence, Italy, March 14-15, 2013, ISBN 978-88-6292-351-4.
[3] E. Munthe, M. Rogne. Research based teacher education. *Teaching and Teacher Education*, 46 (2015) 17-24.
[4] N. Robin. How to communicate science with secondary science teachers? Bridging science education with science research. In: *Proc. of the 3rd Edition of the International Conference "New Perspectives in Science Education"*, Florence, Italy, March 20-21, 2014, ISBN 978-88-6292-469-6.
[5] R.J. Romsdahl, M.J. Hill. Applying the learning community model to graduate education: linking research and teaching between core courses. *Teaching in Higher Education*, 17 (6) (2012) 722-734.
[6] W. Pan, D. Cotton, P. Murray. Linking research and teaching: context, conflict and complementarity. *Innovations in Education and Teaching International*, 51 (1) (2014) 3-14.
[7] C. Boughey. Linking teaching and research. An alternative perspective? *Teaching in Higher Education*, 17 (5) (2012) 629-635.
[8] M. Healey. Linking research and teaching to benefit student learning. *Journal of Geography in Higher Education*, 29 (2) (2005) 183-201.
[9] R. Spronken-Smith, R. Mirosa, M. Darrou. 'Learning is an endless journey for anyone': undergraduate awareness, experiences and perceptions of the research culture in a research-intensive university. *Higher Education Research & Development*, 33 (2) (2014) 355-371.

[10] J.(C.) Xia, C. Caulfield, S. Ferns. Work-integrated learning. Linking research and teaching for a win-win situation. *Studies in Higher Education*, (2014) Article in Press, http://dx.doi.org/10.1080/03075079.2014.882302.

[11] E.N. Lakioti, P.H. Litsiou, P.E. Samaras, V.G. Karayannis. Social acceptance of industrial solid waste recycling. In: *Book of Abstr. of the PRE XII – 12th International Conference on Protection & Restoration of the Environment*, Skiathos island, Greece, June 29 – July 3, 2014, ISBN 978-960-88490-5-1.