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Using Elements of the Impact of Materials on Society (IMOS) Course to demonstrate the potential of a systems approach in Sustainability Education in Greek Secondary Schools

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ABSTRACT

The need to improve Education for Sustainable Development (ESD) provision in Greek secondary schools offers opportunities for innovation. This study shows results of applying a more integrated, collaborative and interactive approach, developed by using elements of the Impact of Materials on Society (IMOS) course. The modules and techniques selected for teacher training and classroom implementation are presented and responses from participants are summarised. Positive feedback from the two teacher training activities and two in-class sessions with students demonstrates the potential of this approach. The paper offers evidence that a systems approach to ESD is promising and worthy of further investigation.

INTRODUCTION

Education for Sustainable Development (ESD) in Greece has been part of the primary and secondary school curriculum for more than 25 years, but functioning on a voluntary basis for both teachers and students [1]. The topics covered in ESD address environmental, social and economic issues and methodologies incorporate experiential and hands-on learning that target cognitive, emotional and behavioural aspects of the student's personality [2].

Materials education, on the other hand, is incorporated poorly in the secondary school curriculum, despite being clearly linked to ESD and many sustainability issues. While some efforts have been initiated out of individual teachers' or schools' incentive to introduce students to nanomaterials and applications of materials in innovative technologies through participation in EU funded projects or collaborations with Universities [3, 4, 5], the link to ESD has not been fully explored. Using this as an opportunity, a set of educational activities for secondary school teachers and students was developed and tested to promote active and collaborative learning for ESD. Feedback was also collected for satisfaction, usability and engagement.

THEORY

Structure and pedagogical approach of the educational material

The central theme of the educational scenario was electronic devices, and more specifically mobile phones. Electronic devices contain rare earth elements -a class of critical materials-, have complex life cycles and are associated with environmental, social and economic issues [6]. In order for the educational material to cover the complexity of the topic and simultaneously engage the participants in active learning [7]; learner-centred, collaborative and exploratory approaches were used. The learning objectives were in accordance with UNESCO's ESD learning objectives regarding Sustainable Development Goal 12: Responsible Consumption and Production [8].

The Impact of Materials on Society (IMOS) course has been developed for first year university students who study engineering at the University of Florida and has been running for 6 years with positive results [9]. Some elements of the course modules have been used here to bridge materials education with ESD for the purpose of developing a meaningful and engaging educational material for secondary school implementation and teacher training. The outline is presented in Table I and content is available online [10].

Table I. Activities of the educational scenario

Interest raising section	Articulation of opinions	Questionnaire about mobile phone use	Rare Earth Elements
Life cycle analysis of electronic devices	Entanglement with electronics	Planned obsolescence	Circular economy
Role – playing activity	E-waste problem	Green mobile phone of the future	Teachers' feedback

Teacher training and classroom implementation

The two workshops for secondary education science teachers took place in March 2017 and the middle and high school implementations in May 2017. The teacher training sessions lasted approximately 3 hours and the student sessions 5 teaching hours each. Fifty-five science teachers participated in the seminars; the majority were middle and high school science teachers. In total, 48 students participated in the implementation phase of the project; 24 of them were middle school (13-14 years old) and 24 high school students (16-17 years old).

RESULTS AND DISCUSSION

Understanding the challenges of the linear materials economy

In the first part, teachers and students were shown two pictures of Black Friday events. One takes place in USA and the other in Greece. They were then asked to add a title to each picture and think about where it takes place. Most of the teachers replied that both take place in USA, Japan or Mexico with just a few of them correctly identifying Greece as well. Most of the students were able to infer the place. The title in most of the cases has been Black Friday, but consumption frenzy was often mentioned as well.

In the second part, teachers and students had to complete a questionnaire on their first (Figure 1) and daily use of mobile phones and refer to its functions (Figure 2). They were also asked and had to provide reasons for: frequency of replacement (Figure 3), criteria for buying a new device and end of use decisions (Figure 4). The results showed differences between the two groups as most of the students started using them below 10 years of age, but most teachers above 18 years of age. Most of the students reported that they use them more than 8hrs/day to browse the internet, while teachers less 3 hours to make phone calls, both buy new devices every 1-2 years or more in case their phone is damaged or malfunctions. When they buy new device, most students look at the technical features, whereas most teachers at the price. Finally, end of use actions included recycling, giving it to other people or keeping them in a drawer.

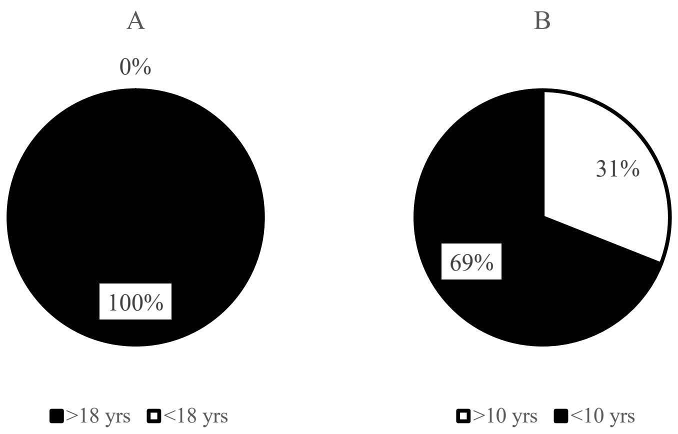

Figure 1. Percentage of A. teachers (below or above 18 years old) and B. students (below or above 10 years old) age when first mobile phone was used.

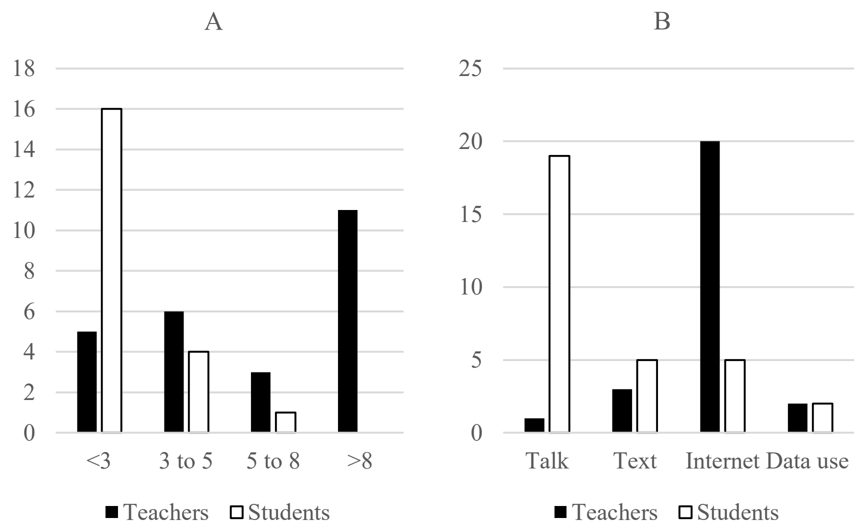

Figure 2. A. Daily use of mobile phones (hrs) and B. functions used by teachers and students.

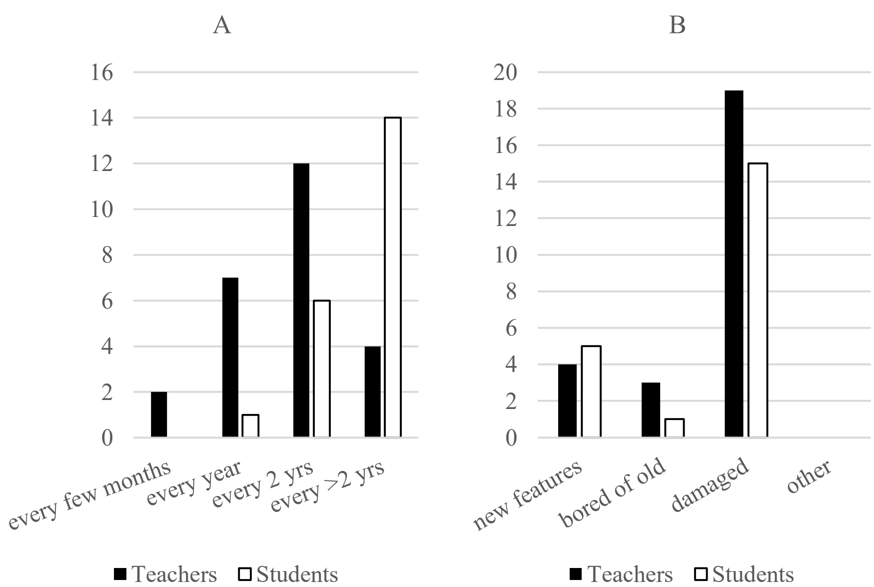

Figure 3. A. Frequency of mobile phone device replacement (months/years) and B. reasons for replacement by teachers and students.

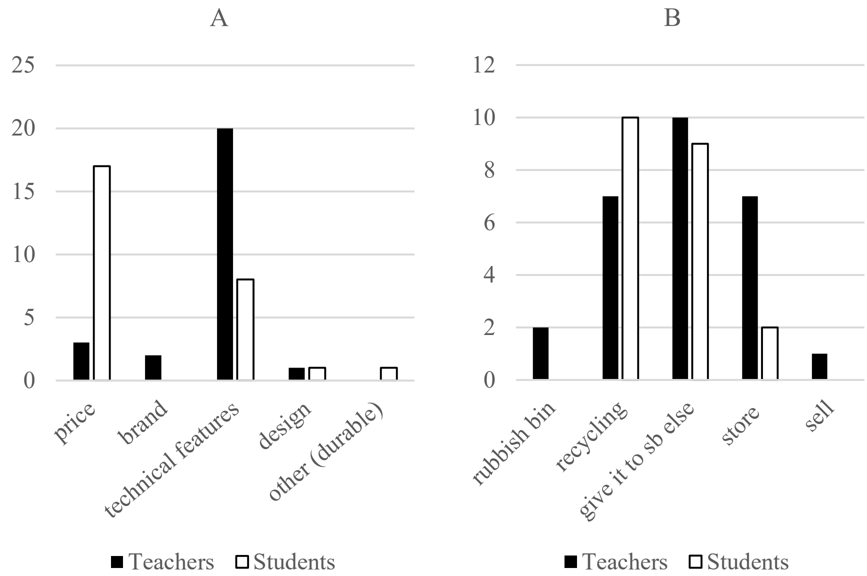

Figure 4. A. Criteria for mobile phone purchase (hrs) and B. end of use actions by teachers and students.

In the next part, the focus was on the materials of mobile phones to introduce complexity in the discussion. Rare earths elements (REE) is one category of elements crucial for their function as they have important magnetic properties. The IMOS video and lecture [11] were used to introduces these. An infographic about REE and socioeconomic issues related with their extraction, distribution and applications was also provided for discussion.

Life Cycle Analysis (LCA) was introduced as a tool to help address some of the challenges that were identified in the discussion. Teachers and students considering the history of any product in their ownership, realised the role their own decisions play in how linear is the economy (buy, consume, and dispose). They also realised that there are many environmental and social issues associated with production, consumption and disposal that are often neglected by the school curriculum.

After watching the video on the Story of Electronics [12] the students and teachers completed a worksheet reflecting on the various stages of the life cycle of electronics (extraction, production, distribution, consumption, and disposal) and their environmental, economic and social impact. Their findings are presented in Table II.

Table II. Findings from the life cycle analysis activity

Extraction	Production	Distribution	Consumption	Disposal
Destroys ecosystems	Causes air, water and soil pollution	Pollution during transportation	Radiation emission	Air, soil, water pollution
Causes air, water and soil pollution	Exploitation of workers	Greenhouse gases emission	Toxic substances	Disassembly in 3rd world countries
Accelerates desertification	Boosts employment	Employment	Isolation	Poor working conditions
Contributes to resource depletion	Work accidents/poor working conditions	Consumerism/capitalism	Addiction	Toxic waste
Boosts employment	Produces toxic waste	Financial boost	Health problems	Child labour
Associated with conflict	Involves child labour	Fuel & energy consumption	Consumerism	Poor health
Work accidents/poor working conditions	Poor health/no insurance for workers	Low salaries/long working hours	Energy consumption	Recycling
Produces toxic waste	Demands high energy consumption	Unfair competition		Landfills/ Environmental degradation
Involves child labour		Packaging waste		Waste of materials/energy

To encourage the teachers and students reflect critically on the previous activities they participated, they were asked to produce tanglegrams in groups of 4-5. The theory of entanglement, which originates from the book of Ian Hodder [13], was also discussed. Examples of the tanglegrams that were used to showcase the interdependencies between electronics, rare earths and humans are shown in Figure 5.

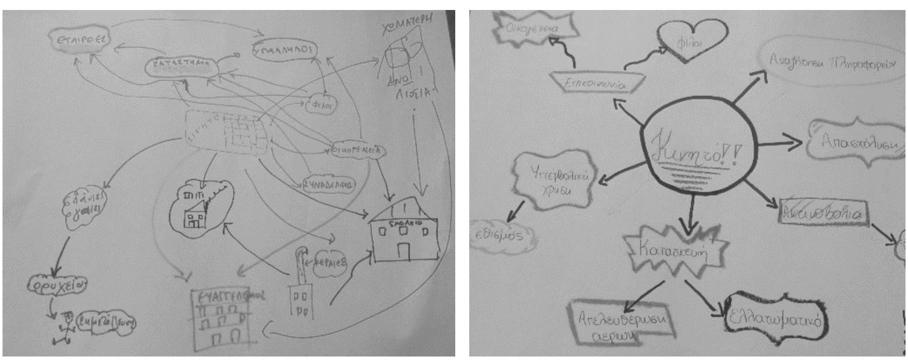

Figure 5. Teachers' and students' tanglegrams

Students' tanglegrams were shown to be more linear in nature. Although they thought of different connections stemming out from their core concept (i.e. electronic device), those had a cause and effect relationship with no connections between individual branches. This is a known obstacle to understanding sustainability suggested by other authors [14]. Teachers' tanglegrams on the other hand, were more complex, with many connections between individual branches, concepts and ideas. They focused on environmental (pollution, resource depletion), economic (employment, consumerism) and social issues (poor working conditions, health issues) but also on positive aspects of electronic devices' use, such as communication with other people and the ability to find information online. In general, every team of participants brought new ideas to the table so by combining all the tanglegrams together a more realistic view of the connections was inferred. This clearly demonstrated both that the participants were capable of systems thinking and the benefits of its use [15].

Planned obsolescence and circular economy

The film "The untold story of planned obsolescence" was chosen to encourage more profound explanations of the observed patterns of consumerism in our societies and to convey the concept of designing for the dump. After the discussions, teachers strongly expressed the view that our current take-make-dispose economy is jeopardising the future of humanity and the planet and they started discussions about the importance of the establishment of the circular economy model.

The participants understood the viewpoints of various stakeholders in the society as they were asked to role-play in the following story: "An engineer manufactures an everlasting thread and is very happy about this invention! How do the following stakeholders react to the news?" The stakeholders are: factory owner (designs old type fibres), factory workers, politician, consumers, representative of environmental organisation. The engineer also support their opinion with arguments. The outcome of this activity showed that all the participants actively reflected on the viewpoints and arguments of each role and were enabled to participate in a debate about the impact of this innovation on the environment, economy and society.

Using the slideshow "The electronic waste trail in Ghana" available at Greenpeace's website [16], the problem of e-waste was presented. The teachers and students were given cards containing excerpts and pictures of the e-waste trail and were asked to put them in the correct order to reconstruct the full story. This activity enabled the participants to explore the far-reaching social and environmental impact of end of use disposal choices.

Reflecting on the sustainability issues discussed in all the previous activities, the students and teachers were asked to design an innovative "green mobile phone" that would provide solutions to them. The participants came up with ideas for wearable devices made of biodegradable materials, ones that would be easy to dismantle and their materials could be used in other technological applications, that would be charged by renewable energy sources or used as sensors to facilitate Internet of Things applications to optimise processes in smart cities.

Feedback from teachers' questionnaires and students' discussions.

Data analysis of the questionnaires revealed that the 100% of teachers were satisfied with the content and activities of the educational material in terms of quality. Eighty three percent of teachers thought that the material addresses middle school educational needs, while 17% suggest it is appropriate for high school delivery. Forty three percent of teachers stated that the educational material is suitable for ESD projects, 33% suggested “Natural Resources Management” and the remaining 24% was equally distributed between biology, chemistry and physics. This shows the potential application of the concept and the toolkit to various subjects. Ninety two percent of the teachers felt confident to use the educational material in their classroom. Fifty eight percent of teachers used some of the activities of the educational material in their teaching after their participation in the seminars.

In general, engagement with the activities of the educational material during seminars and classroom implementation was high, as was inferred by team observations. Students reported that this was the first time they had actively participated in discussions about socio-economic and environmental issues and their views about everyday consumer choices had been challenged.

CONCLUSIONS

These findings demonstrate the potential of systems thinking in supporting ESD. A significant part of the problem of sustainability is individuals’ inability to understand the complex interconnections between the causes and effects of our actions and interactions. The activities described here were designed to enable teachers and students to understand how and why social (society and economy) and ecological systems (environment) are linked and realise the importance of seeing component parts (or sub-systems) in the context of relationships with each other and with other systems, rather than in isolation. Systems thinking focuses on cyclical rather than linear cause and effect, and is applicable at any scale of human activities and contexts. The educational approach presented, offers an opportunity for teachers and students to learn to see things differently, coming to sustainability through independent thinking rather than instructional teaching. Consequently, its potential should be further investigated.

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REFERENCES

1. Hellenic Ministry of Education, Act 1892/1990, article 111, par. 13, 1990 (in Greek).
2. E. Tsaliki, in Environmental education in the 21st century: Theory, practice, progress and promise, edited by J. Palmer (Routledge, New York, 1998) pp. 188-190.
3. Irresistible: nanoscience and applications (2017). Available at: http://irresistible-greece.edc.uoc.gr/index.php/el/ (accessed 06/12/2017)
4. A. Spyrtou, E. Dagre, L. Manou and E. Konstantinidou, presented at the 10th Conference on Natural Sciences Didactics and New Technologies in Education, Rethymno, Crete, 2017 (unpublished).
5. STIMULATE: materials for a sustainable future (2014). Available at: http://www.materialsfuture.eu/ (accessed 06/12/2017).
6. A. H. King, when agendas align: Critical materials and green electronics, Electronics Goes Green 2016+ (EGG), Berlin, Germany, 1-6, (2016).
7. C. Kyriacou and S. Marshall, The Nature of Active Learning in Secondary Schools, Evaluation & Research in Education 3 (1), 1-5 (1989).
8. UNESCO, Education for Sustainable Development Goals: Learning Objectives, (UNESCO publications, France, 2017), p.67.
9. K. Jones and S. Accord, presented at the 2017 MRS Fall Meeting and Exhibit, Boston, MA, 2017 (unpublished).
10. V. Kioupi: The educational material (2017). Available at: https://sway.com/CYxQwyH5AwGj9Kv2 (accessed 06/12/2017).
11. MRS: IMOS Course (2011). Available at: http://www.mrs.org/imos-course (accessed 06/12/2017).
12. The Story of Stuff: Story of Electronics (2010). Available at: https://www.youtube.com/watch?v=sW_7i6T_H78 (accessed 06/12/2017).
13. I. Hodder, Entangled: An Archaeology of the Relationships between Humans and Things, (Wiley-Blackwell, 2012), p.264.
14. J. Segalàs, K. Mulder and D. Ferrer-Balas, What do EESD "experts" think sustainability is? Which pedagogy is suitable to learn it?, International Journal of Sustainability in Higher Education, 13(3), 293–304 (2012).
15. F. Betts, How systems thinking applies to education, Educational Leadership 50 (3), 38-41 (1992).
16. Greenpeace: Where does e-waste end up? (2009). Available at: http://www.greenpeace.org/international/en/campaigns/detox/electronics/the-e-waste-problem/where-does-e-waste-end-up/ (accessed 06/12/2017).