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SDIMI2013
30 June - 3 July

Assessing the familiarity of engineering students with sustainability

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Aim of the study

- Comprehensive information about the status of sustainability education and practice in any nation **is missing** (Desha et al., 2009).

- Sustainability has been designated as a definite challenge of the twenty-first century and is a **fundamental goal** of society's economic and social progress (DIUS, 2007)

The specific study aims at providing initial information concerning the **familiarity of students** in engineering education **with sustainability related issues**.

+ discussion regarding ways to improve it.

Desha, C., Hagroves, K. and Smith,M., 2009. Addressing the time lag dilemma in curriculum renewal towards engineering education for sustainable development. *International Journal of Sustainability in Higher Education*, 10(2), 184–199.

DIUS, 2007. Department for innovation, universities and skills, world class skills – implementing the Leitch review of skills in England. London: Department for Innovation, Universities and Skills.

Sustainability and Engineering

The **"IPAT" master equation**:

Affluence: consumption/person

Technology: impact/unit of consumption

$$I = P \times A \times T$$

I → Total impact; P → Population; A → Affluence; T → Technology

- "*Engineering schools have been at the forefront of SD incorporation*" (Glavic et al., 2009)

- "*Sustainability cannot be understood, studied or even conceptualized without understanding technology*" (Allenby et al., 2009)

Glavic, P., Lukman, R. and Lozano, R., 2009. Engineering education: environmental and chemical engineering or technology curricula – a European perspective. European Journal of Engineering Education, 34 (1), 47–61.

Allenby, B., et al., 2009. Sustainable engineering education in the United States. Sustainability Science, 4, 7–15.

Sustainability in Greek schools of engineering

➢ A study was conducted in 2010 to examine the level of sustainability integration in Greek schools of engineering.

➢ The **study guides** and the available **websites** were comprehensively examined.

➢ **Established Criterion:** Presence of **specific keywords** in the title, aim or description of the course.

- Sustainability
- Sustainable development
- Earth 's carrying capacity
- Social responsibility
- Life cycle assessment
- Renewable energy
- Industrial ecology
- Waste minimization
- Zero waste production
- Social justice
- Depletion of natural resources
- Ecological footprint
- Material/substance flow analysis
- Design for environment
- Sustainable engineering
- Cleaner production
- Green process
- Green chemistry
- Design for sustainability
- Generational equity

➢ Identify and record **independent actions** that promote sustainability in every department.

Sustainability in Greek schools of engineering

- Overview of the data examined.

No.	Universities examined	Departments examined	
		No.	Name of the department
1	National Technical University of Athens (NTUA)	9	AE, AMPS, CE, ChE, ElCE, ME, MEM, NAME, RSE
2	Aristotle University of Thessaloniki (AUTH)	7	AE, CE, ChE, ElCE, ME, RSE, URPDE
3	Democritus University of Thrace (DUTH)	5	AE, CE, EE, ElCE, PEM
4	Technical University of Crete (TUC)	5	AE, ECE, EE, MRE, PEM
5	University of Ioannina (UOI)	1	MSE
6	University of Patras (UPATRAS)	6	AE, CE, CEI, ChE, ECE, MEA
7	University of the Aegean (AEGEAN)	3	FME, ICSE, PSDE
8	University of Thessaly (UTH)	5	AE, CCE, CE, ME, PRD
9	University of Western Macedonia (UOWM)	2	EIT, ME
	Total number of departments examined		43
	Total number of undergraduate courses examined		5001
	Total number of graduate programmes examined		73
	Total number of graduate courses examined		2204

Notes: AE, Architectural Engineering; AMPS, Applied Mathematical and Physical Science; CCE, Computer and Communications Engineering; CE, Civil Engineering; CEI, Computer Engineering and Informatics; ChE, Chemical Engineering; ECE, Electronic and Computer Engineering; EE, Environmental Engineering; EIT, Engineering Informatics and Telecommunications; ElCE, Electrical and Computer Engineering; FME, Financial and Management Engineering; ICSE, Information and Communication Systems Engineering; ME, Mechanical Engineering; MEA, Mechanical Engineering and Aeronautics; MEM, Mining Engineering and Metallurgy; MRE, Mineral Resources Engineering; MSE, Materials Science and Engineering; NAME, Naval Architecture and Marine Engineering; PEM, Production Engineering and Management; PRD, Planning and Regional Development; PSDE, Product and Systems Design Engineering; RSE, Rural and Surveying Engineering and URPDE, Urban-Regional Planning and Development Engineering.

Sustainability in Greek schools of engineering

Summarized Results*:

- **2%** and **3.2%** of the examined undergraduate and graduate courses respectively found to be related with "sustainability" issues according to the established criteria.

- Great discrepancies were observed between different departments varying from **0% to 11.8%** for undergraduate level and **0% to 38.8%** for graduate level.

- Sustainability related courses identified were primarily **environmental related** whereas the economical and social aspects of sustainability were barely integrated into the courses examined.

- Communication and promotion of SD actions outside of the university environment is important. Sustainability should not only be an internal matter.

Results indicated that there **are worth to mention gaps** concerning the integration of sustainability notion, principles and tools in Greek engineering universities.

** Analytical findings: Gaidajis et al. (2011),* Sustainable development integration in Greek schools of engineering: current situation, experiences and actions, *International Journal of Sustainable Engineering, DOI: 10.1080/19397038.2011.574743*

Actions for improvement

Taking into account

- Gothenburg recommendations on education for sustainable development textbook.
- Analysis regarding successful examples of sustainability integration in top-performance universities.

Development of actions to enhance sustainability teaching through **Industrial Ecology** in an engineering department namely the ***Production Engineering and Management Department*** (PME) of Democritus University of Thrace.

Actions for improvement

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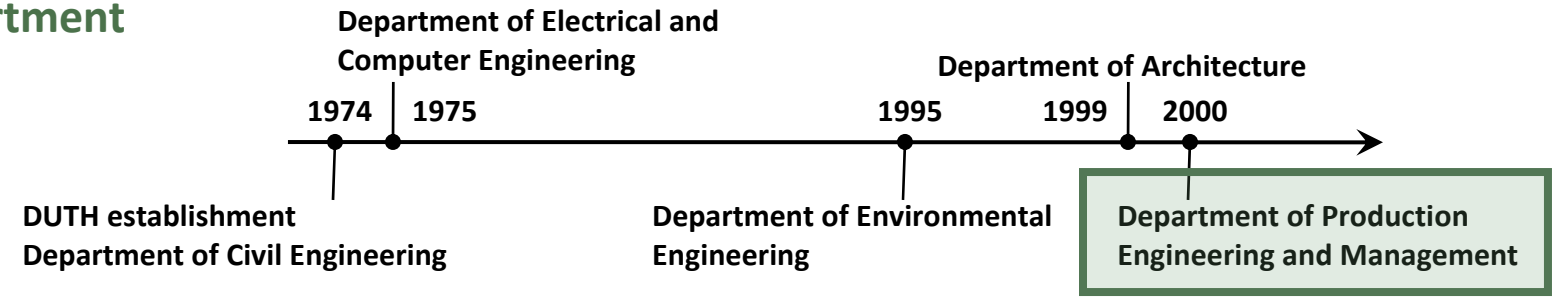
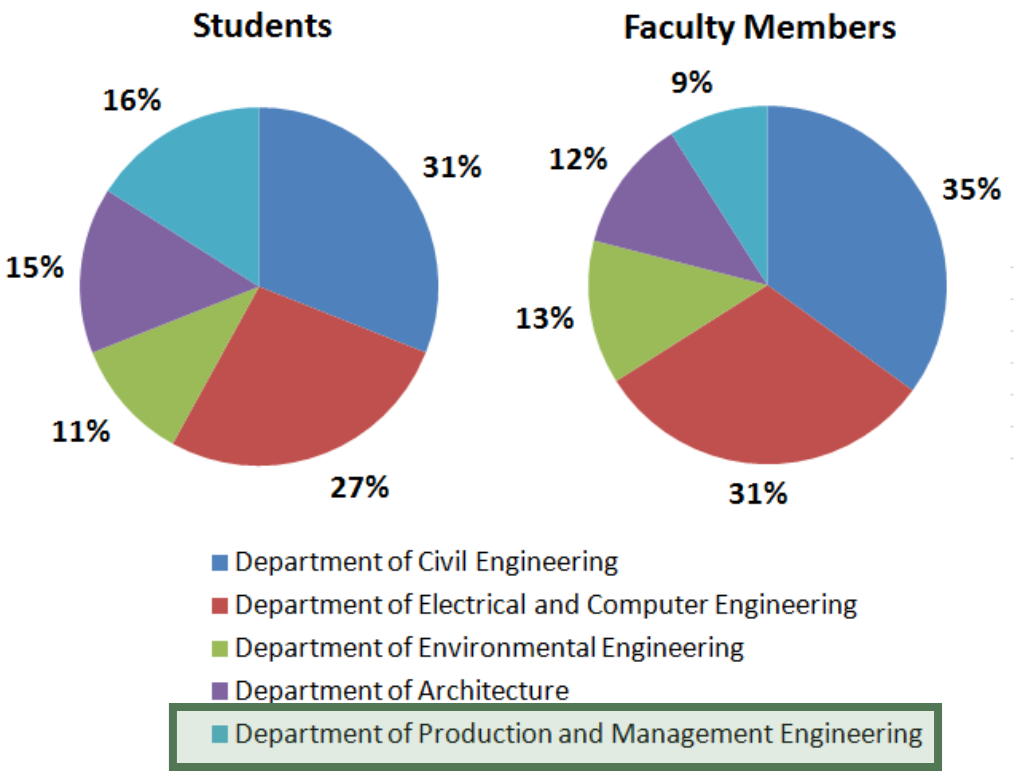
➢ Our department



School of Engineering Profile

- 153 Faculty members
- 3,458 graduate students
- 339 post-graduate students
- Campus area: > 1,500,000 m^2



Actions for improvement

➢ ***What is Industrial Ecology (IE)?***

➢IE consists of various holistic and systemic concepts and tools that try to simulate the way that nature works by eliminating material and energy losses thus leading to sustainability (**closed loops system**).

➢ The notion popularized in 1989 in a Scientific American article by Robert Frosch and Nicholas E. Gallopoulos:

"why would not our industrial system behave like an ecosystem, where the wastes of a species may be resource to another species?"

The "well known" Kalundborg Eco Industrial Park (Source: Google Earth)

Actions for improvement

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- ***Why Industrial Ecology?***

  - "*Industrial Ecology (IE) was found to be especially useful for teaching sustainable development to engineers*" (*Allenby et al.. 2009*)

  - "*IE is increasingly becoming a key reference at universities throughout the world*" (*International Society of Industrial Ecology, 2010*)

  - Industrial Ecology textbook by T. E. Greadel and B. R. Allenby, **is the most common used teaching material regarding sustainable engineering education in USA**

International Society for Industrial Ecology

  - Highly recognized universities have included IE in their curriculum as a pre-graduate course or as an MSc Program

  - Due to the wide variety of specialities that IE tackle with, it can be featured in courses of different scientific fields

Allenby, B., et al., 2009. Sustainable engineering education in the United States. Sustainability Science, 4, 7–15.

ISIE, 2010. International society of industrial ecology [online]. Available from: http://www.is4ie.org/education

Actions for improvement

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➢ **Actions performed:**

1. Action	Focus Area	Aim
IE related theses	Undergraduate students	Give undergraduate students the opportunity to work in depth with Industrial Ecology related tools and principles.

2. Action	Focus Area	Aim
IE related graduate dissertations	Postgraduate students	Give postgraduate students the opportunity to work in depth with Industrial Ecology related tools and principles and promote IE.

3. Action	Focus Area	Aim
IE related lectures during ET course*	Undergraduate students	Give undergraduate students the opportunity to learn the basics about sustainability and IE and how these two notions are related.

ET course*: Environmental Technology course, taught to the 4th year students

Actions for improvement

- **Actions performed:**

4. Action	Focus Area	Aim
IE Work Project	Undergraduate students	Give undergraduate students the opportunity to further expand their knowledge about IE.

5. Action	Focus Area	Aim
Visit to Industrial Facilities	Undergraduate students	Give undergraduate students the opportunity to discuss with experienced engineers and visit real time working environments.

6. Action	Focus Area	Aim
IE related research	Postgraduate students, industry	Further expand the knowledge about IE, publish prototype works and create synergies with industries.

Assessment methodology

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7. Action	Focus Area	Aim
Survey	Undergraduate students	1) Assess the familiarity of the students with SD-related issues, 2) Examine the feasibility of introducing an autonomous IE course and 3) Find whether the IE-related activities that took place during the fourth-year course of ET had exerted any quantifiable results on the student's attitude towards IE.

➢ The survey was conducted **in 2012** using a **questionnaire** adopted from a similar study (Azapagic et al., 2005)

➢ Questions regarding various environmental issues, legislation, policy and standards, environmental tools and technologies.

➢ Students could choose between "**Not heard of**", "**Heard of but could not explain**", "**Have some knowledge**" and "**Know a lot**", quantified through a scoring **scale of 1-4** respectively.

Azapagic, A., Perdan, S. and Shallcross, D., 2005. How much do engineering students know about sustainable development? The findings of an international survey and possible implications for the engineering curriculum. *European Journal of Engineering Education*, 30 (1), 1–19.

Assessment methodology

- The questionnaire was developed and distributed to the students of every study year **electronically**.

- A total number of **162 questionnaires** were answered anonymously (112 and 50 male and female students, respectively).

- **A similar survey was carried in 2010**, in order to assess the familiarity of students with SD-related issues in Greek higher education.

- The results of the current survey are **compared** with those of the previous survey.

Έρευνα με Θέμα:
Περιβάλλον και Βιώσιμη Ανάπτυξη
Τμήμα Μηχανικών Παραγωγής και Διοίκησης
(1ο, 2ο και 3ο Έτος)

∗ 6. Πώς θα αξιολογούσατε την γνώσης σας σχετικά με τα επόμενα θέματα:
Κατηγορία: Βιώσιμη - Αειφόρος Ανάπτυξη

	Δεν το έχω ακούσει	Το έχω ακούσει αλλά δεν μπορώ να εξηγήσω	Γνωρίζω κάποια πράγματα	Γνωρίζω λεπτομερώς το θέμα
Βιώσιμη – Αειφόρος Ανάπτυξη – ορισμός / αρχές	✓			
Βιώσιμη – Αειφόρος Ανάπτυξη – Στοιχεία		✓		
Αρχή της πρόληψης			✓	
Αύξηση του πληθυσμού			✓	
Δια- και ενδο-γενεακή ισότητα (Inter- and intra-generational equity)				✓
Κοινωνικοί εταίροι (Stakeholders)		✓		
Σύνδεση μεταξύ φτώχειας, πληθυσμού, κατανάλωσης και υποβάθμισης του περιβάλλοντος		✓		
Φέρουσα ικανότητα της Γης (Earth's carrying capacity)		✓		
Κοινωνική υπευθυνότητα (social responsibility)			✓	
Ο ρόλος των Μηχανικών στη Βιώσιμη ανάπτυξη			✓	

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Assessment results

- The overall level of knowledge for all categories and topics related to sustainability issues was **not satisfactory :**
  average score **2.2/4 in 2012** and **2.3/4 in 2010**.

- The student group up to 7th semester showed **similar results in both surveys (≈2.2/4)**. This finding raises questions regarding inadequate integration of sustainability issues in secondary education.

- On the other hand, **the score of the group with students above the 8th semester is relatively increased (2.4/4)**. Those results indicate that IE-related activities may play a positive role in the improved performance of the latter group.

Assessment Category	Avg. Score	Best-known topics for every category	Avg. Score	Least-known topics for every category	Avg. Score
Environmental Issues	2.79 (-)				
		Global warming	3.47 (↑)	Salinity	1.79 (-)
		Water pollution	3.32	Particular matter	1.90 (↓)
		Climate change	3.28 (↑)	Photochemical smog	1.97 (↓)
Sustainable development	2.28 (↑)				
		Social Responsibility	2.78 (↑)	Inter- and Intra- generational equity	1.47 (↓)
		Population Growth	2.71 (↓)	Earth's Carrying Capacity	1.85
		Connection between poverty, population, consumption and the degradation of the environment	2.62 (↑)	Principle of prevention	2.08
Environmental tools, technologies and approaches	2.12 (↓)				
		Renewable Energy technologies	3.00 (↑)	Tradable permits	1.62 (↓)
		Waste minimization	2.69 (↑)	Fuel cells	1.88 (↑)
		Life Cycle Assessment	2.23 (-)	Clean-up technology & DfE	1.92
Environmental legislation, policy and standards	1.57 (↓)				
		Kyoto Protocol	2.00 (↓)	EMAS	1.20
		ISO 14001	1.79	IPCC	1.34
		Copenhagen summit, 2009	1.70 (↓)	Johannesburg summit	1.47
All categories	2.19 (↓)				

Note: ↑,↓, - indicate the positive, negative or stable difference comparatively to past survey's results, respectively.

- The most well-known topics were those related to **'environmental issues' (average 2.8/4)**, whereas the least-known topics were those related to **'Legislation, Policy and Standards' (average 1.6/4)**. These results were similar with the results from 2010 survey.

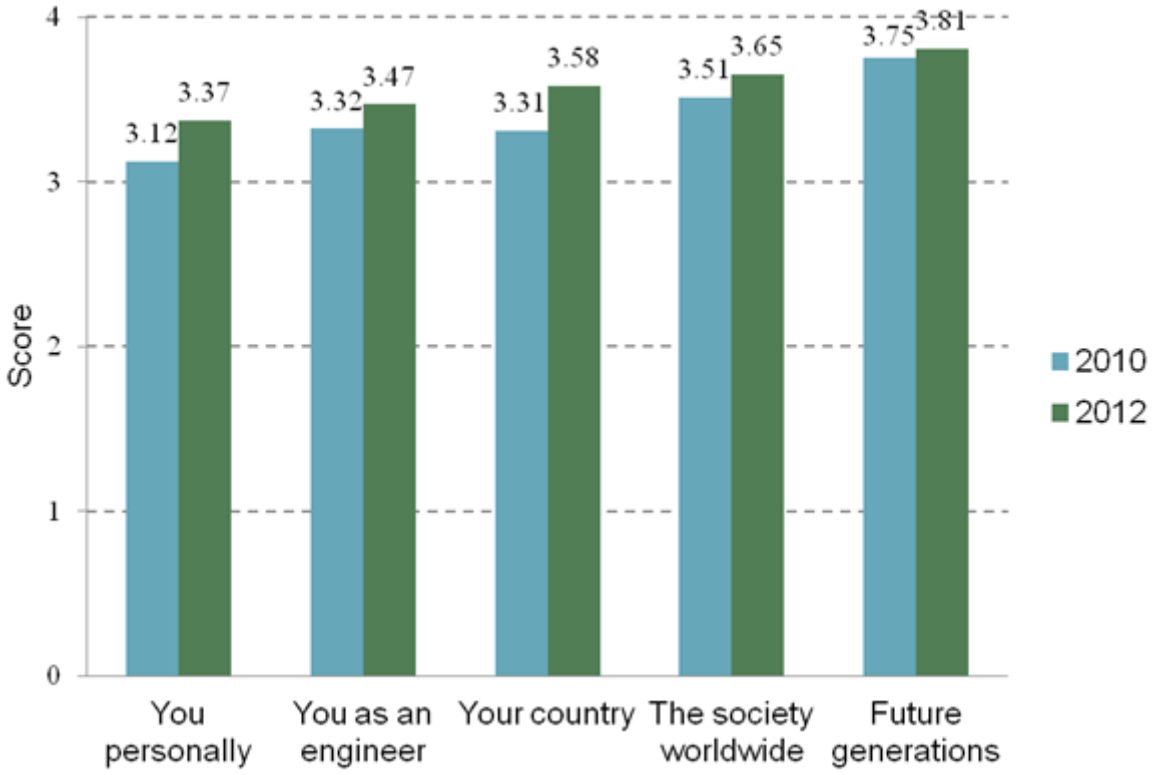
- **The results were identical** with a worldwide survey that gave an **average score of 2.2**, a score of **2.8 for 'environmental issues'** and a score of **1.5 for 'environmental legislation'.**

Assessment results

- The majority of the students answered that **sustainability is important** for them, both personally and as engineers, for their country and the society worldwide but most importantly **for the future generations**.

- The scores of 2012 **have been increased** compared to those in 2010.

- Actions for the promotion of sustainability in the department will be probably supported by students.



Importance of SD according to the students' opinion (1: Not important, 2: Possibly important, 3: Important, 4: Very important).

Assessment results

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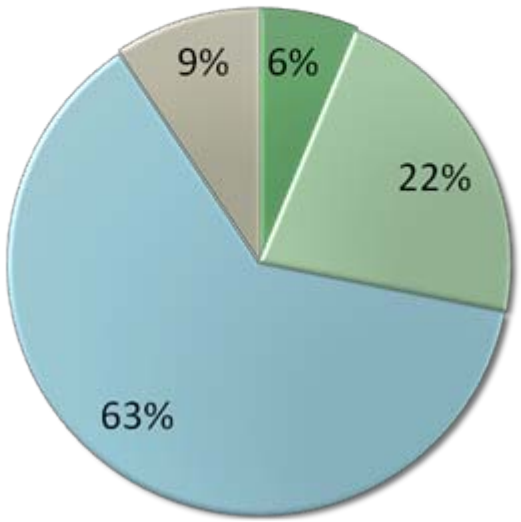
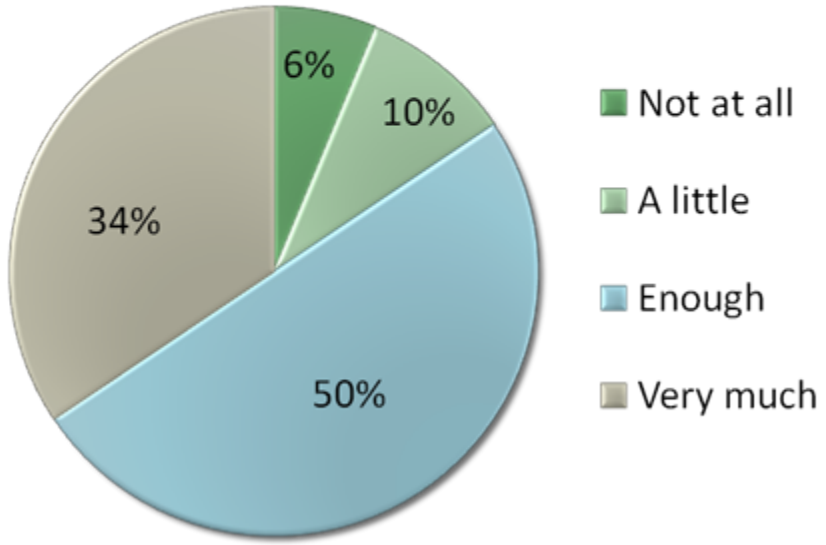
How much did the course "Environmental Technology" contributed to the sensitisation of the examined topics?



How much did the course "Environmental Technology" contributed to the apprehension of the examined topics?



More than 3 out of 4 students answered that the course contributed to both the apprehension and sensitization of the examined topics.

Assessment results

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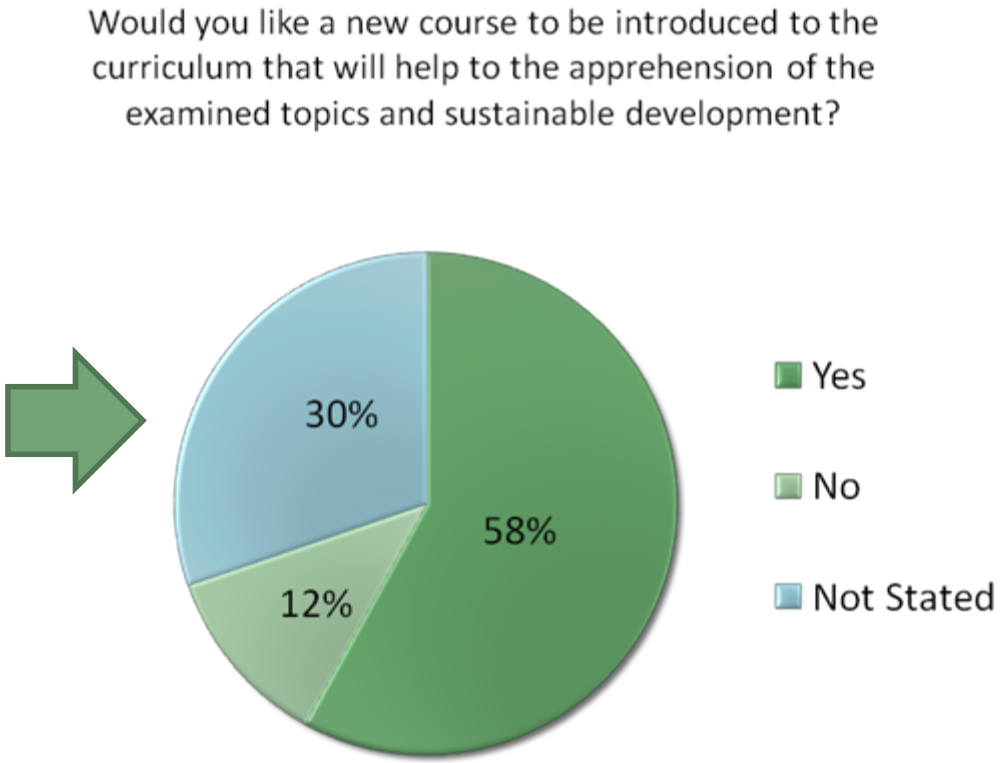
83% of the students who answered the relative question, are positive for an extra SD-related course (with extra work load).

Reasons why students answered "no" to this question:

1) It would be a too theoretical course.
2) Those to follow a core mechanical or managerial career do not really identify the connection between SD and their field.



Shortcomings

- No filtering procedure was applied for the answered questionnaires.
- Attendance of courses is not obligatory, it is therefore possible that several students might not attended the IE lectures or activities.
- The actions described in the methodology were performed through individual and personal efforts and not under a general sustainability strategy of the department.

Conclusions

- The overall level of knowledge for all categories and topics related to SD issues **was not satisfactory**.

- The survey indicated that IE-related activities **positively influenced** the understanding of sustainability principles of the undergraduate students, but not in a satisfactory level.

- Four out of five students would welcome an **extra sustainability-related course** (and **extra work load**) , in condition that it should be oriented towards case studies.

- The majority of students believe that **sustainability is important** both as a personal-individual value and for the world-humanity as well.

Assessing the familiarity of engineering students with sustainability

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Thank you for your attention

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