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## **AC 2009-541: INTRODUCING AND STIMULATING SUSTAINABLE ENGINEERING IN FIRST-YEAR CIVIL ENGINEERING STUDENTS**

### **Tom Bramald, Newcastle University**

Tom Bramald is the Development Officer for Newcastle University's School of Civil Engineering and Geosciences. He is module leader for the first year module, Sustainable Solutions in Civil Engineering.

The Development Officer role has a wide variety of responsibilities including schools and industrial outreach and engagement, teaching, and significant in-reach activity. Internally, it involves developing and maintaining a large number of relationships with academics, researchers, support staff, university services and students. Externally, he works with schools (students and teachers), professional & trade bodies and small, medium and large companies.

A former Marine Construction Surveyor, he has been with the university for five years.

### **Sean Wilkinson, Newcastle University**

Dr Sean Wilkinson is a Senior Lecturer in Structural Engineering at Newcastle University's School of Civil Engineering and Geosciences. He is the degree programme director for the school's suite of MEng and BEng degree programmes in Civil and Civil & Structural Engineering.

His main interests lie in structural design, particularly in the context of Earthquake Engineering and Extreme Loadings.

## **Introducing and stimulating sustainable engineering in first year Civil Engineering students**

### **Abstract**

To support a sustainable engineering agenda, three years ago Newcastle University (UK) introduced a new first year study module titled *Sustainable Solutions in Civil Engineering*. There were several original aims for the module: introduce sustainability in the context of civil engineering; act as a catalyst for sustainable thinking in studies beyond first year; and present an enthusiastic, “big picture” of civil engineering that would complement the technically intense first year modules.

While the original aims of the module have remained, the mechanism of delivery and assessment has been refined each year and the module’s content has been extended to adopt various sustainability literature including papers from professional bodies and learned societies. In the module’s current form, engineering, academic and transferable skills are all introduced, practiced and assessed, four different forms of assessment are used, three different teaching environments attended, and the module leader is supported by a variety of staff including academics, guest lecturers from industry and construction site managers and operatives.

Senior Academic staff have shown considerable support for the module and it was complimented by a professional accreditation visit that took place in the year of the module’s first outing. The students have found the module interesting, enjoyable and well delivered although they have also found its workload light compared to other first year study modules.

This paper presents the module as an example of how to engage first year Civil Engineering students in thinking sustainably. It will describe the successes and deficiencies of the module, how the module is being incorporated into the students’ education within and beyond the first year of study and, finally, what the future of first year sustainable engineering is following a rebuilding of Newcastle’s Civil Engineering programmes.

## **Background**

Newcastle University offers undergraduate degree programs in Civil and Civil and Structural Engineering (C&CSE). As one would expect, the programmes find themselves in a permanent state of evolution as industrial, academic and professional developments and requirements are adopted in to the students' curricular. It is inevitable that the rise to prominence of sustainability in engineering has had a role to play in the programs' evolution and in 2005, the C&CSE Board of Studies commissioned the inclusion of a new first year module titled *CIV1002 - Sustainable Solutions in Civil Engineering*, hereinafter CIV1002.

From its first outing in the academic year 2006-2007, the module has been subjected to iterative review and improvement. The overall aims of the module have, however, remained the same:

- introduce sustainability in the context of civil engineering;
- present an enthusiastic, “big picture” of civil engineering that would complement the technically intense first year modules; and
- act as a catalyst for sustainable thinking in studies beyond first year.

The module is a compulsory, 10 credit module - a 10 credit module is expected to require 100 hours of student's time, that being made up of a combination of lectures, seminars, site visits, laboratory sessions and individual review and work on assessed pieces. It has been taken each year by an average of 85 full time students and it is a compulsory component of the following full time undergraduate degree programs:

- MEng Civil Engineering (4 years)
- MEng Civil and Structural Engineering (4 years)
- BEng Civil Engineering (3 years)
- BEng Civil and Structural Engineering (3 years)

Each of the degree courses listed above are accredited by the Joint Board of Moderators that works to ensure that the degree programme graduates can meet the requirement to register as a professional engineer with the Engineering Council UK<sup>1</sup>.

This paper aims to describe the evolution and content of CIV1002, identifying its successes and areas that have been identified as less successful. The future of the module, and its adaption into a complete rebuild of Newcastle C&CSE programmes, is also presented.

## **The Curriculum for CIV1002 – Sustainable solutions in Civil Engineering**

### **Defining sustainability**

The module presents an explicit opportunity to teach sustainability to first year undergraduate students as opposed to its being embedded in the teaching of different aspects of civil engineering. In considering sustainability explicitly, however, the module must start by defining what sustainability means.

Following an introduction to the module that focuses on logistics and operational matters, i.e. no actual teaching or introduction of sustainability, the first task in each of the three years has been

a “live brainstorm” by the students to define sustainability. The live brainstorm takes the form of a blank PowerPoint slide that the module leader completes with words or phrases as they are volunteered from the student body in the lecture theatre in response to the question, “What does ‘sustainability’ mean?” The following shows the results from each cohort’s live brainstorm.

*Academic year 2006-2007*

Will it last?	Consideration of future generations	Maintenance
Best use of resources	Fit for purpose	Supply and scarcity of raw materials
User friendly	Integrity of a structure	Financial stability

*Academic year 2007-2008*

Recycling Jobs Cost effectiveness Fulfil Human Needs	Longevity Maintain Complementary to environs	Environmental Protection Safety Future Proof
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*Academic Year 2008 – 2009*

Making things last Minimal environmental damage	Cost effectiveness Consider the future	Renewable resources
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The module leader takes the approach of a “devil’s advocate” during the brainstorm, challenging each student to expand on their one-word and phrased contributions to articulate why their response relates to sustainability. This often draws others in the room in to the discussion as students’ peers volunteer their own articulations.

From there, Lecture 1 presents some basic background and definitions of sustainability from a variety of sources that are related to civil engineering. This runs as follows:

- Presentation of the Bruntland Commission Report definition of sustainability<sup>2</sup>
- Timeline of sustainability debate starting with the 1968 Club of Rome through to 2002’s Rio to Johannesburg conference
- Presentation of UK Government Principles of Sustainable Development (see Figure 1)
- Triple Bottom Line Methodology presented as:
  - Venn diagram
  - Russian Doll Model<sup>3</sup>
- Presentation of the Royal Institution of Chartered Surveyors property life cycle<sup>4</sup>
- Mapping the life cycle against the three pillars of social
- Defining virtuous links
- Complex feedback loops

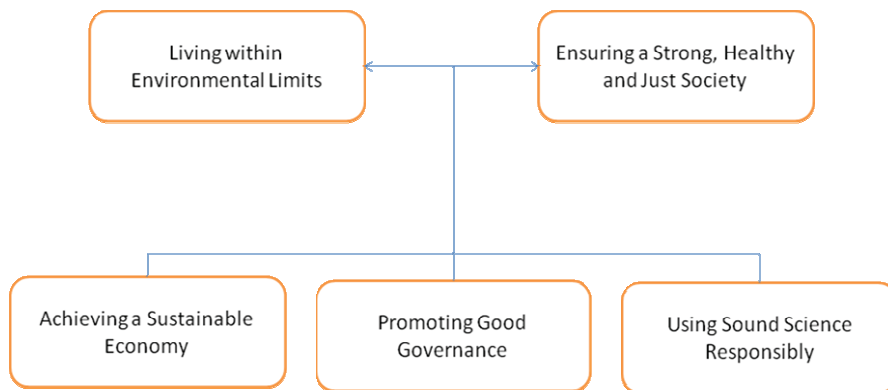


Figure 1: From Securing the Future<sup>5</sup>

The second lecture of the module is built upon the Royal Academy of Engineering's (RAE) document, *Engineering for Sustainable Development: Guiding Principles*<sup>6</sup>. Following the introduction of the three pillars in Lecture 1, five forms of capital defined in the RAE's guide are presented to the students as an alternative approach to thinking about sustainability. The five capitals are:

- Human (the peoples of the world)
- Environmental
- Social
- Financial
- Manufactured

The remainder of the lecture identifies and explains the RAE's 12 guiding principles as they are presented and explained in the document. The authors would encourage anybody interested in teaching sustainability in any engineering discipline to review the document. Its 12 guiding principles are given below:

- Look beyond your own locality and local future
- Innovate and be creative
- Seek a balanced solution
- Seek engagement from all stakeholders
- Make sure you know the needs and wants
- Plan and manage effectively
- Give sustainability the benefit of any doubt
- If polluters must pollute ... then they must pay as well
- Adopt a holistic "cradle to grave" approach
- Do things right, having decided the right thing to do
- Beware cost reduction masquerading as value engineering
- Practice what you preach

The third lecture builds on *Egan Review Skills for Sustainable Communities*<sup>7</sup>. This is included to stimulate student thinking about their skills development, the other professions who they may be working with in the future and to support their year-long first year design project which is looking at conceptual design of an eco-town for 20 000 people.

The Egan Review presents seven components that are core to realising a sustainable community. They are:

- Social and cultural
- Governance
- Services
- Economy
- Environmental
- Housing and Built environment
- Transport and connectivity

Each of the components is presented to the student body before they are tasked with considering the following questions in “buzz groups” (informal, small groups encouraged to form and discuss a point whilst sat in a large group teaching environment):

1. What is the common sub-component of all of the components described above?
2. Rank these 7 themes from the point of view of a Civil Engineer.
3. Rank these 7 themes from the point of view of the community itself.

### **Putting it into context**

Lectures 1-3 form the backbone of defining sustainability. The remaining lectures in the module, typically numbering ten, are used to showcase different disciplines of civil engineering i.e. water resources, structures, geotechnical *et cetera* and are delivered by different staff from across the School. After the 2006-2007 outing of CIV1002, it was felt that this approach was a little too loose and that the students were struggling to bind pieces of information together from each lecture. For 2007-2008 and again in 2008-2009, academics and students were afforded a brainstorm created by the module leader that identified civil engineering factors in and around the city of Newcastle upon Tyne (home of Newcastle University). This approach was not meant to limit the students’ thinking to Newcastle but rather be a tangible example of the web of civil engineering that surrounds us every day.

The aims of this aspect of the module were to expose the students to other academic staff that, prior to the development of CIV1002 they may not have seen until latter years of study and to also give a holistic view of civil engineering, its disciplines and components

The lectures included in each of the academic years have been:

2006-2007	2007-2008	2008-2009
1. Overviews of	1. Overviews of	1. Overviews of
2. The Civil Engineering Community	2. The Civil Engineering Community	2. Environmental Engineering
3. Environmental Engineering	3. Environmental Engineering	3. Water Resources Engineering
4. Water Resources Engineering	4. Water Resources Engineering	4. Geotechnical Engineering
5. Earth Systems Engineering	5. Earth Systems Engineering	5. Geomatics
6. Geotechnical Engineering	6. Geotechnical Engineering	6. Structural Engineering
7. Geomatics	7. Geomatics	7. Transport Engineering
8. Structural Engineering	8. Structural Engineering	8. Guest lecture
9. Transport Engineering	9. Transport Engineering	
10. Guest lecture	10. Guest lecture	

The guest lectures have changed each year and have been delivered as follows:

2006 – 2007	Faber Maunsell and Laing O’Rourke. A consulting and contracting engineer respectively, these companies presented their joint work on the UK’s Building Schools for the Future programme. For more information see <a href="http://www.number10.gov.uk/Page5801">http://www.number10.gov.uk/Page5801</a> .
2007 – 2008	Sir Robert McAlpine. A large contracting engineering firm, Sir Robert McAlpine provided two staff from their environmental team to discuss why and how the company works sustainably. For more information, see <a href="http://www.sir-robert-mcalpine.com/">http://www.sir-robert-mcalpine.com/</a>
2008 -2009	Centre for the Protection of National Infrastructure. The UK government’s authority which provides protective security advice to businesses and organisations across the national infrastructure presented an overview of their work. For more information see <a href="http://www.cpni.gov.uk/">http://www.cpni.gov.uk/</a>

In addition to the lectures, the module used site visits to give the students the opportunity to see civil engineering projects first hand and try to take note of sustainability issues. To do this, they were encouraged to use a matrix with the three pillars of sustainability as column headings and the RICS property life cycle as the row leaders. Owing to the cost of transporting students and limited time being available in their timetable, the projects selected for site visits have all been within 15 miles of Newcastle upon Tyne. The downside of this is that students have been limited to only seeing projects that are local to the university but each site is presented as an “engineering project” rather than a “local project” The site visits have been:



2006 – 2007 All students	The Royal Victoria Infirmary. Redevelopment of a large hospital site including concrete frame building works.
Half students	Pegswood Bypass. Construction of a 2.5 mile long road scheme around a village. Included a bridge structure across the main East coast railway line.
Half students	Blyth Coal Import Terminal. Construction of a new quayside to afford to import of coal and subsequent loading on to train.
2007 – 2008 All students	The Royal Victoria Infirmary. Redevelopment of a large hospital site including concrete frame building works.
Half students	Smith's Dock. A 850 000m <sup>3</sup> contaminated land remediation project.
Half students	Blue House Bridge. Replacement of a dual carriageway bridge on ne of Newcastle's major east-west road corridors.
2008-2009 Half students	Student Administrative Services Building. A new concrete frame building with significant foundation difficulties being built on the Newcastle University campus.
Half students	Biomedical Science Building. A new steel frame building being built in a confined space on the Newcastle University campus.

In academic years 2006-2007 and 2007-2008, seminars were used to follow up the site visits. Based on the groupings used for the site visits, the seminars comprised teams of up to six students presenting their site visit experiences to a group who would have one site in common with them and one site different. This was not possible in 2008-2009 owing to timetabling constraints, a fear of over-assessment and that the students hadn't been able to take in a site visit that they all saw thus removing the common-ground for comparing and contrasting with the opposing seminar team.

### **Assessment**

Assessment for the module has varied in each of the three years and is summarised below.

2006 – 2007  
Essay (50%)

Students were asked to provide a 2000 word commentary on a civil engineering project of their choice. The piece was to include reference to the role of different disciplines of civil engineering in the project and to comment on sustainability issues.

Seminar (15%)

Assessment of the seminar by the module leader.

Seminar (10%)

Assessment of an individual's contribution to their own group by their group members.

Site Visit (12.5%)

Attendance at the site visit to the Royal Victoria Infirmary.

Guest Lecture (12.5%)

Attendance at the guest lecture by Faber Maunsell and Laing O'Rourke.

2006 – 2007  
Essay (60%)

Students were asked to provide a 2000 word commentary on a civil engineering project of their choice. The piece was to include reference to the role of different disciplines of civil engineering in the project and to comment on sustainability issues.

Seminar (20%)

Assessment of the seminar by the module leader.

Seminar (10%)

Assessment of an individual's contribution to their own group by their group members.

Site Visit 1 (3%)

Attendance at the site visit to the Royal Victoria Infirmary.

Site Visit 2 (3.5%)

Attendance at the site visit to either Smith's Dock or Blue House Bridge.

Guest Lecture (3.5%)

Attendance at the Sir Robert McAlpine guest lecture.

2008 – 2009  
Essay (90%)

Students were asked to provide a 2000 word commentary on a civil engineering project of their choice. The piece was to include reference to the role of different disciplines of civil engineering in the project and to comment on sustainability issues.

Site Visit (5%)

Attendance at the site visit to either the Student Administrative Services Building or the Medical Science Building.

Guest Lecture (5%)

Attendance at the CPNI guest lecture.

## Impact evaluation

Towards the end of the module each year, the students were presented with a module feedback form that asks them to rate various aspects of the module on a five point scale from Poor to Excellent. While this afforded the authors useful data for looking at immediate efficacy of the module, it was felt that an attempt to evaluate the longer term impact should be made.

A survey was carried out with third and second year students who completed the module in 2006-2007 and 2007-2008 respectively. The survey was conducted anonymously, by paper, with students in a large group teaching environment. The surveys were taken either 12 months following their completing CIV1002 (46 students completed a return) or 24 months following their completing CIV1002 (44 students).

The students were asked to identify the three pillars of sustainability that were introduced to them in CIV1002 from six possible answers. The possible answers were designed by the authors. The correct response – Social; Economic; Environmental – was included alongside five other answers that the authors felt were plausible but that the students should be able to identify as incorrect. The responses are shown below. Students were encouraged not to guess and if they did not know, to select the “do not know” option. The question and results are shown below:

Q: What were the three pillars of sustainability introduced in CIV1002?			
Possible Answer	Students who completed the module 24 months ago	Students who completed the module 12 months ago	Total
Infrastructure; Finance; Political	0	0	0
Social Infrastructure; Political	1	0	1
Social; Economic; Political	2	1	3
Social; Economic; Environmental	28	37	65
Political; Financial; Natural	0	0	0
I can't remember	6	6	12
No answer	7	2	9
<b>TOTAL</b>	<b>44</b>	<b>46</b>	<b>90</b>

Table 1: Student Responses when asked to identify the three pillars of sustainability taught in CIV1002

Table 1 suggests that, of the students surveyed, 12 and 24 months after completing CIV1002, the majority can recall the three pillars of sustainability as they were presented i.e. Social, Economic and Environmental.

The survey then identified that three different learning environments had been used during the students' studies on CIV1002, namely Lectures, Seminars and Site Visits. The students were asked three questions relating to those learning environments as follows:

	Site Visits			Lectures			Seminars		
	*24	12	Total	24	12	Total	24	12	Total
Which environment did you find the most enjoyable?	39	42	81	1	2	3	3	1	4
Which of the three environments was most useful to developing your sustainability knowledge?	16	5	21	24	34	58	1	5	6
Which of the three environments was most useful to developing your wider civil engineering knowledge?	29	24	53	14	16	30	0	3	3

\*24: Students who completed 24 months ago. 12: Students who completed 12 months ago.

Table 2: Student reactions to the different learning environments used in CIV1002

The results in Table 2 suggest that site visits can be a useful tool to make a subject enjoyable, and to develop wider civil engineering knowledge. Lectures, however, seem to be the most useful tool for developing knowledge of sustainability.

The survey also presented three major themes of the module to the students as follows: introduce and stimulate sustainable thinking, introduce the “big picture” of civil engineering and give experience of civil engineering sites. Students were asked to what extent the module had succeeded in each of these themes:

	Not successful at all			Not successful			Successful			Very successful		
	*24	12	T	24	12	T	24	12	T	24	12	T
Sustainable thinking	0	0	0	2	3	5	41	37	78	1	5	6
Big Picture	1	1	2	8	10	18	30	31	61	4	3	7
Site Experience	1	0	1	8	4	12	20	23	43	13	18	31

\*24: Students who completed 24 months ago. 12: Students who completed 12 months ago.

Table 3: Student opinion as to the success of CIV1002 against three themes

Table 3 shows that the vast majority of those students felt the module was successful or very successful in terms of introducing and stimulating sustainable thinking.

The students were then asked to use a four point Likert scale to comment on different statements designed by the authors. The statements were presented in a random order but are presented here, grouped by themes namely civil engineering as a whole (CIV), a module issue (M) or a program issue (P). See table .

	Strongly Disagree		Disagree		Agree		Strongly Agree		Spoiled / Not answered			
	*24	12	24	12	24	12	24	12	24	12		T
Sustainability is a key component of Civil Engineering	0	1	0	0	20	24	21	45	0	0	0	CIV
With hindsight, CIV1002 has formed an appropriate part of my studies	5	2	18	12	17	30	0	0	4	2	6	M
CIV1002 was a well structured module	2	0	9	4	29	36	1	7	3	0	3	M
I have used some or all of what was taught in CIV1002 in my Civil or civil and structural engineering studies since	4	0	14	15	23	28	2	5	1	0	1	M P
Considering Sustainability has had an impact on my design work	2	0	9	5	19	32	5	17	1	4	5	P
If sustainability has impacted on my design work, I can attribute some or all of this to CIV1002	1	0	26	11	37	32	1	3	3	1	4	M
CIV1002 had a lighter workload than other modules I have taken	0	0	6	8	27	26	11	22	0	1	1	M
Apart from CIV1002, I haven't really had to look at sustainability in my studies	7	10	19	27	46	8	2	3	1	0	1	P
Sustainability has featured in experiences related to my studies	0	0	2	3	30	31	9	21	3	0	3	P
CIV1002 fitted well with my first year studies	1	0	7	4	31	36	5	10	0	1	1	P
Consideration of sustainability exists throughout my program	0	0	6	3	31	30	6	12	1	1	2	P
A sustainability thread is building throughout my program	0	0	9	3	31	35	3	11	1	0	1	P
Stage 1 was a technically intensive year	6	0	13	23	36	22	41	4	3	0	3	P

\* 24: Students who completed 24 months ago. 12: Students who completed 12 months ago.

Table 4: Students responding to statements relating to their CIV1002 studies and resulting experiences 12 and 24 months after completing the module.

Table 4 shows a majority of students feel that while CIV1002 is a well structured module, it has not formed an appropriate part of their studies. This sits awkwardly with the results shown in Table 3 and suggests that the module needs to make more effort to explain the importance of sustainability in a civil engineering curriculum. A small majority of students agree that they have used material taught in CIV1002 in their C&CSE studies after completing CIV1002 (Table 4). Similarly, a small majority identify CIV1002 has having an impact on their design work since completing the module. While these are positive outcomes, it would be desirable to see a greater impact of the module on students' future work.

Finally, the students were asked which of the three components of CIV1002, sustainable thinking, big picture or site experience, was most important in their opinion.

	*24	12	T
Sustainable thinking	8	16	24
Big Picture	16	10	36
Site Experience	19	16	35

\*24: Students who completed 24 months ago. 12: Students who completed 12 months ago.

Table 5: Student responses to identifying which of three components of CIV1002 is the most important in their opinion.

That only 24 of the surveyed students thought sustainable thinking was the most important component of the module again suggests that the aim of the module needs to be clearer and more explicit in the module content. The "big picture" role of the module is the most important to students. While site visits are known anecdotally to be popular amongst the C&CSE students, the level of their success in CIV1002 (Tables 2, 3 & 5), and the suggestion of their value to teaching sustainability and conveying a big picture, is a great positive outcome for the module.

Students were given the opportunity to add commentary to their survey returns. There were a variety of responses and their range is demonstrated by the examples given below:

- "Module drummed in to me the idea of thinking about sustainability in projects. During planning, sustainability is now a key consideration for me and is also a major thing to think about when learning about other projects." (12 months after completing the module)
- "Lectures were pointless i.e. No need to turn up to pass. An easy module. Well organized module, lecturer keen for us to do well although I don't know whether he knew his lectures were unimportant" (12 months)
- "The essay was a good way of getting me to look at sustainability within a real life project." (12 months)
- "Really enjoyed the site visits and believe they put the course in to more context than a lot of other items we do, even some of the practicals." (12 months)
- "The site visits were good as industry engineers explained sustainability and related it to projects." (24 months)
- "This module is a valuable module however still requires some development." (24 months)

The mixed nature of the commentary offered by students and presented above would again suggest that the role and importance of sustainability needs to be conveyed more clearly to the students.

The role of the module being a catalyst to future sustainable thinking is giving a significant boost by the student comment “[The] module drummed in to me the idea of thinking about sustainability in projects. During planning, sustainability is now a key consideration for me and is also a major thing to think about when learning about other projects.”

## **Future Developments**

The 2007 accreditation visit by the Joint Board of Moderators, acknowledged the inclusion of the module as an important aspect of including sustainability in the programs. However, it was felt that a more widespread and embedded approach was needed. In 2008, the School of Civil Engineering and Geosciences Professors, whose roles related to the undergraduate C&CSE programs, embarked on a rebuild of the program. With sustainability at its core, a new program has been designed and will roll out in the 2009-2010 academic year. Within the new program, CIV1002 has been removed but its content remains and, indeed, has been expanded. The definition and discussion surrounding the term sustainability will move in to a first year design module along with the “big picture” role of the module. The big picture role will now be taught in the context of sustainable urban design rather than the generic background to each civil engineering discipline approach used in CIV1002. A new module titled Human Systems, Demands and Impacts has been created where the relationship of Civil Engineers and their work to wider society can be explored. This has been done to try and address the problem of conveying the importance of sustainability to civil engineers.

## **Summary**

This paper has described the introduction and delivery of a first year civil engineering module that has been designed to:

- introduce sustainability in the context of civil engineering;
- present an enthusiastic, “big picture” of civil engineering that would complement the technically intense first year modules; and
- act as a catalyst for sustainable thinking in studies beyond first year.

The module seems to have met its overarching aims but it is clear that its impact could have been greater and that a clearer message about the role of sustainability in civil engineering needed to be presented and then maintained in the students’ studies afterwards.

The use of the module as a catalyst for two new modules should afford the staff and students the opportunity to further explore sustainability in the context of civil engineering and the authors hope to continue the study of sustainability in first year education in the future.

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