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Using Online Roleplay Simulations for Teaching Sustainability Principles to Engineering Students*

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Developing in students a deep understanding of the concept of sustainability, and how it applies to engineering, is a difficult task. Here we introduce a novel framework for developing online roleplay simulations for teaching sustainability principles to engineering students, based on a systems model of sustainability. Application of the framework is illustrated with a case study, the Mekong e-Sim, which is an online roleplay simulation set around proposed development issues in the Mekong region of South-East Asia. In 2005, the e-Sim was centred on public inquiries into two proposed development issues, including the Nam Theun II hydropower dam in Laos and the proposed Lancang project in China. The latter includes the blasting of rapids to improve river navigation and the construction of a large hydropower dam. The recommendations in relation to the proposed developments were to proceed with the Nam Theun II dam, but that approval of the Lancang project was unlikely. An evaluation of the 2005 Mekong e-Sim revealed that there was a high degree of interaction between roles about the social, environmental and economic issues surrounding the two proposed hydropower projects, and that the e-Sim was able to develop (i) awareness of the complexity of, and need for, sustainable development, (ii) the ability to see engineering issues from multiple perspectives, (iii) an understanding of the political, social, economic and scientific dimensions of engineering decision-making and (iv) a better understanding of the meaning of sustainable development.

Keywords: online roleplay simulation (e-sim); generic skills; sustainable development; Mekong e-Sim; environmental engineering

INTRODUCTION

MAINTAINING LIVING STANDARDS in developed countries, and increasing the quality of life in developing countries, requires sustainability to be at the core of all engineering activities. Consequently, the goal of engineering should be to ensure that we can provide adequate infrastructure and natural resources for current generations, without compromising the ability of future generations to do the same. Therefore, it is vital that sustainability is a major focus in engineering education.

In recent years, this need has been recognised by professional bodies responsible for the accreditation of engineering degree programs [e.g. 1]. However, ensuring engineering students obtain a good understanding of the concept of sustainability, and how it applies to engineering, is not an easy task in a traditional classroom setting. In response, a number of active learning methods (i.e. 'learning by doing') have been proposed as alternatives, including collaborative learning, problem-based learning, case methods, enquiry-based learning and roleplay simulations [2].

Roleplay simulations have already been used successfully in a number of disciplines, including engineering [3, 4, 5], and are ideally suited to helping students see multiple perspectives surrounding an issue, such as proposed engineering projects. Traditionally, roleplay simulations have been conducted in a face-to-face setting. However, with the increased usage of computers in university environments, online roleplay simulations have gained popularity, as they are generally more cost effective, provide the option of adopting an extended timeframe, thus offering more opportunities for reflection and analysis, and are able to cater for geographically spread participants [6].

DEVELOPING ONLINE ROLEPLAY SIMULATIONS

Background

Online roleplay simulations include multiple learners, who adopt the roles of stakeholders with varying points of view and interact about complex issues that do not have a single correct

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outcome.They generally consist of three main stages: briefing, interaction and debriefing. In the briefing stage, students become familiar with the requirements and setting of the roleplay simulation, as well as the online learning environment. In addition, they adopt their particular role, which requires a good understanding of what the responsibilities and views of their character are, and how their character would act in a variety of situations. The interaction stage commences with a trigger event, which requires the roles to interact with each other in order to solve the problem that forms the basis of the enacted scenario.

In many instances, the expected learning outcomes of online roleplay simulations go beyond the specific issues that are a feature of the particular scenario being considered. Generally, a scenario is an instance of a larger class of problem, and the lessons learnt from the scenario being played out have wider applicability. For students to be able to generalize beyond their experience of a particular scenario, it is vital for them to have the opportunity to step back and reflect on the general processes that occurred as part of the interaction phase of the roleplay simulation. This is achieved during the debriefing stage.

PROPOSED APPROACH

Sustainability is commonly defined as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs [7]'. Here we propose that the sustainability model developed by Foley *et al.* [8] (Fig. 1) can be used to guide the design of online roleplay simulations to ensure deep learning outcomes are achieved in relation to sustainability principles. The model is based on the premise that sustainability is a characteristic of a system [9, 10]. In relation to engineering education, the systems of interest are engineered systems, such as those associated with urban developments, transport, sewerage, water supply and energy. Consequently, infrastructure needs to be considered in addition to the three commonly used aspects of sustainability (i.e. environmental, economic, social) in order to achieve sustainable systems [8, 11, 12] (Fig. 1).

The proposed framework for developing online roleplay simulations is shown in Fig. 2. As can be seen, it is suggested that to develop a deeper understanding of sustainability principles, the issues or problems that are at the core of online roleplay simulations need to have infrastructure, economic, social and environmental dimensions. In the context of engineering education, these issues or problems are generally centred on proposed engineering projects, which are likely to have a strong infrastructure component and be resource intensive. Consequently, to teach students about sustainable engineering practice, the objective of the roleplay simulation would typically be the development of an understanding of the linkages between a proposed infrastructure project and the environmental, social and economic components of sustainable systems (Fig. 1).

To ensure that students actively engage with each other, it is vital that the issues or problems being investigated exploit areas of potential conflict, such as opposing emotions or motives, perpetual differences and/or clashes over scarce resources [13]. If the proposed development is set in an international context, the potential of transboundary and/or cross-cultural issues provides additional sources of conflict. This will assist students with seeing engineering developments from multiple perspectives, and highlight the

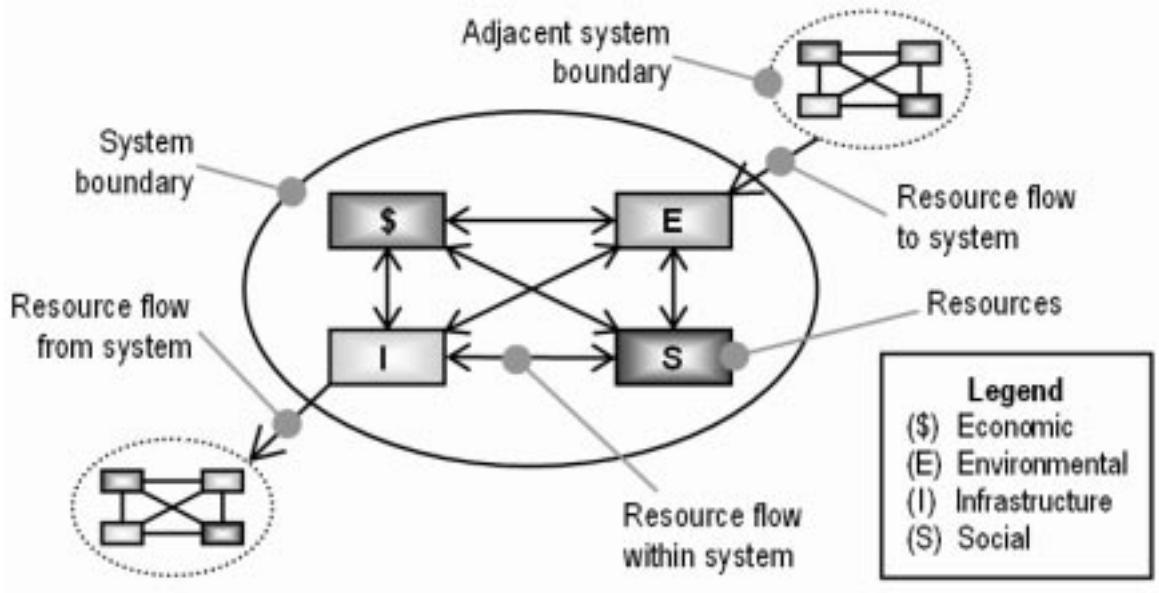

Fig. 1. Systems Model of Sustainability [8].

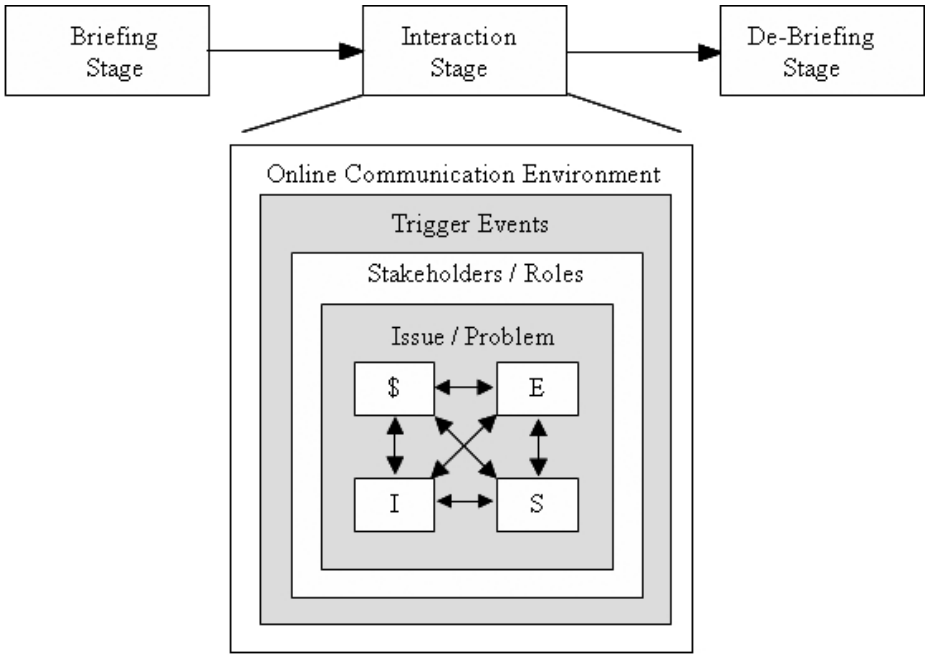

Fig. 2. Diagrammatic Representation of Proposed Framework.

social, cultural, global and environmental responsibilities of professional engineers.

As part of the proposed framework (Fig. 2), it is suggested that to explore/discuss the various perspectives (i.e. social, environmental, economic) that surround the proposed engineering project, all relevant stakeholder groups need to be represented to ensure all points of view are heard. Each stakeholder group is generally represented by one or more roles (e.g. characters, organizations).

To encourage interaction between roles, a number of trigger events should be used throughout the interaction stage of online roleplay simulations (Fig. 2). One trigger event usually occurs at the beginning of the interaction phase, and is generally related to the announcement of the proposed engineering project. Care needs to be taken to ensure that this initial trigger event requires all of the roles to respond. If this is the case, and the actual project meets one or more of the criteria for engaging students in roleplay simulations outlined above (e.g. opposing emotions or motives, scarce resources), a high degree of interaction should ensue. However, to maintain this degree of interaction, additional trigger events may be required throughout the interaction phase. These might be in the form of 'controversial' news releases that are aimed at roles belonging to particular stakeholder groups. In addition, queries or comments from other roles will provide the trigger for particular personae to respond, thus providing a continuous cycle of interaction. Given that the roles belong to stakeholder groups with differing interests, interactions between roles in an effort to come to a common solution to the issue or problem being investigated will bring to light the various perspectives and points of view (e.g. environmental, social, economic, cultural, political, technical) that surround the proposed engineering project.

To ensure that the roles are able to express their points of view in relation to the proposed engineering project, and that their voices can be heard by other roles, appropriate communication channels and avenues for sharing information need to be provided (Fig. 2). It is important to represent the available communication channels in a realistic manner, including appropriate communication hierarchies and provision for both private (e.g. e-mail) and public (e.g. discussion boards) communication. The provision of appropriate online 'meeting places' is particularly important in the context of online roleplay simulations. Some of these 'meeting places' might be accessible by all stakeholders (e.g. discussion boards that everybody can read and post to), whereas others might provide forums for 'private' discussion and/or sharing of information for some of the stakeholder groups (e.g. discussion boards that only selected groups can read and post to). Such private 'meeting places' are also useful in situations where individual roles are played by groups of students, rather than individuals.

CASE STUDY: MEKONG E-SIM

Introduction

The Mekong e-Sim involves 60–140 students with various technical backgrounds from a number of universities who adopt the roles of stakeholders and respond to proposed development issues in the Mekong River basin of South-East Asia. Through research and interaction with

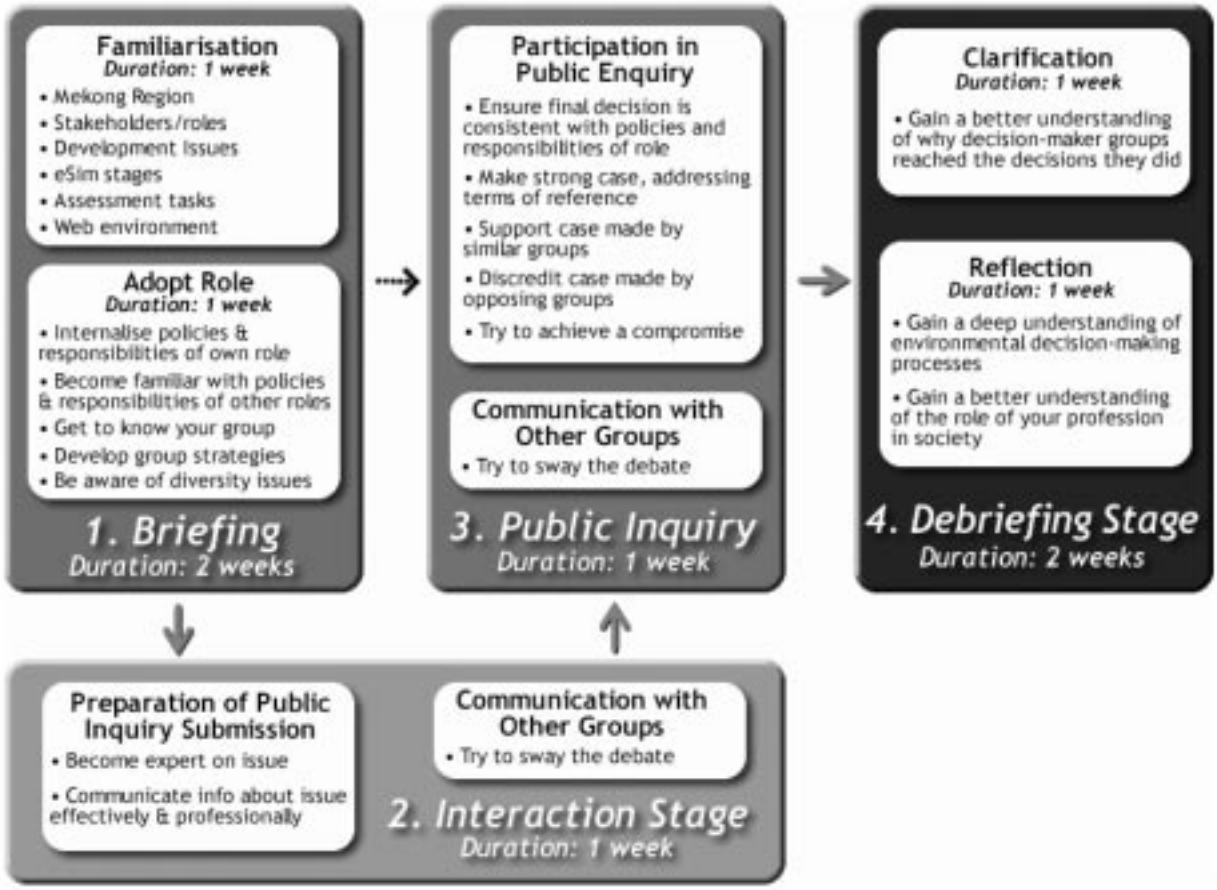

Fig. 3. Stages of the Mekong e-Sim (2005).

other roles, participants build a case whether the proposed development should proceed or not, which they present and defend during an online public inquiry. The learning objectives of the e-Sim include:

1. To learn to see engineering projects from multiple perspectives;
2. To gain an improved understanding of the role of engineering in society;
3. To gain a better understanding of the complexity of engineering decision-making;
4. To develop an understanding of the need for, and the meaning of, sustainable development;
5. To prepare students for working in multidisciplinary and international environments;
6. To develop communication, groupwork, research, and critical thinking skills.

The Mekong e-Sim was developed in 2001; a detailed description of the prototype is given in [14] and [2]. Over the last three years, a number of significant changes have been made to the Mekong e-Sim as a result of student feedback and a Community of Inquiry evaluation [15].

Details of the 2005 version of the Mekong e-Sim are given in Fig. 3. It can be seen that the duration of the e-Sim is six weeks, with two weeks for briefing, two weeks for interaction (interaction and public inquiry stages) and two weeks for debriefing. The Briefing stage enables participants to become familiar with the e-Sim structure, geographical context, requirements and technology. It also requires them to obtain information from a range of sources to develop an understanding of the responsibilities, views and strategies of their adopted role. During the first week, participants are asked to complete two online quizzes (Table 1); one on the Mekong region and one on the various roles. Participants can attempt the quizzes as many times as they like. Each time a quiz is attempted, questions are drawn at random from a pool of questions. During the second week, groups of participants sharing a role have to produce a document discussing what strategies their role might adopt during the interaction phase, as well as issues surrounding group diversity and their ability to represent their role.

During the interaction stage, different roles correspond with each other in response to simulated events, including the announcement of a public inquiry into a proposed infrastructure development. Participants are therefore required to operationalize their understanding of the policies and responsibilities of their role gained during the briefing stage (i.e. participants have to act in their role in response to simulated events). This understanding is reshaped as participants experience consequences that follow from their actions.

Table 1. Summary of Mekong e-Sim Assessment

Assessment Item	Submission Type	e-Sim Stage	% of e-Sim Mark
Quiz: Roles	Individual	Briefing	5
Quiz: Mekong	Individual	Briefing	5
Role Profile: Strategy	Group	Briefing	10
Participation	Group	Interaction / Public Inquiry	20
Public Inquiry Submission	Group	Interaction / Public Inquiry	20
Debriefing Report	Individual	Debriefing	40

During the Public Inquiry stage, each role makes a submission to the public inquiry and responds to submissions made by other roles. At the conclusion of the public inquiry, the roles whose responsibility it is to chair the public inquiries announce their decision, including a detailed justification of why this decision was made. Assessment during the interaction and public inquiry stages includes a mark for participation, as well as a mark for the submission to the public inquiry (Table 1).

In the first week of debriefing, participants remain in their roles and have the opportunity to seek clarification from the decision-maker groups about why they arrived at their decision (i.e. why certain points were not taken into account or why certain factors were weighted more heavily than others). Participants are required to form alliances (consortia) with other, like-minded, groups and each consortium has to develop one or more questions. These are put to the decision-maker groups during face-to-face sessions, followed by a response from the decision-maker groups and general discussion.

In the second week of debriefing, participants step out of their role and identify what they have learned as a consequence of participating in the e-Sim. This is done during face-to-face sessions that use a structured process of guided recall, reflection and analysis based on student experiences. It is here that participants have time to reflect on the occurrences of the previous five weeks and draw their own conclusions. These are discussed in a debriefing report (Table 1).

DESIGN BASED ON PROPOSED APPROACH

Issues/problems

In 2005, public inquiries were held into two proposed infrastructure developments, including the Nam Theun II hydropower dam in Laos and the Lancang development project in China. The latter includes the construction of a large hydropower dam and the blasting of rapids to improve river navigation. Details of the terms of reference for the two public inquiries are given in [15].

The proposals at the centre of the public inquiries have multiple dimensions (e.g. social, cultural, economic, technical, environmental), are highly controversial and are likely to polarize stakeholder groups. In addition, the potential impacts of the projects are diverse and far reaching. Environmental impacts include reduced fish passage, sedimentation and a loss of biodiversity. Social impacts are related to the dislocation of villagers and the loss of traditional ways of life. There are also a number of positive effects, such as economic development, potential increases in living standards, increased opportunities for employment and the generation of renewable electricity. Impacts also span a number of countries, providing additional sources of conflict. Consequently, the proposed developments provide ample opportunity for the presentation of different perspectives, hence the development of the desired linkages between the infrastructure, environmental, social and economic components of sustainable systems (Fig. 1).

Stakeholders/roles

The stakeholder groups considered come from a variety of countries and disciplines and have a range of views. They include government, non-government, development, academic and research, engineering and media organizations, as well as village groups. Each of these stakeholder groups is represented by a number of specific characters / organizations, including a decision-maker group for each public inquiry, which chairs the inquiry, weighs up the evidence presented and comes to a final decision in relation to whether the proposed development should proceed or not.

Details of the individual roles associated with the Nam Theun II and Lancang public inquiries are given in Table 2. The roles represent an appropriate balance between stakeholder groups, as well as organizations from different countries. Care was taken to ensure that each role has to respond to the announcement of the public inquiries into the proposed developments, given their policies and responsibilities.

Trigger events

The initial trigger event is the release of the terms of reference for the two public inquiries by the e-Sim facilitators via news bulletins. In response, students have to explore the issues surrounding the terms of the reference of the public inquiries by conducting research and corresponding with other roles. Apart from the initial trigger, there are numerous other trigger events throughout the interaction stage of the e-Sim. For example, the initial submissions to the public inquiries provide the trigger for other groups to

Table 2. Details of Roles (2005)

TYPE OF ROLE	NAME OF PERSONA	AREA
GOVERNMENT ORGANISATIONS	Cambodia National Mekong Committee (CNMC)	Cambodia
	Ministry of Agriculture, Fisheries and Forestry (MAFF)	Cambodia
	Ministry of Agriculture and Forestry (MAF)	Lao PDR
	Ministry of Industry and Handicraft (MIH)	Lao PDR
	Science, Technology, and Environmental Agency (STEA)	Lao PDR
	Leading Group For Water Resources And Water And Soil Conservation (LGWRC)	China
	National Planning Committee of the Peoples Republic of China (NPC)	China
	Electricity Generating Authority of Thailand (EGAT)	Thailand
	Ministry of Agriculture and Rural Development (MARD)	Vietnam
DEVELOPMENT ORGANISATIONS	China Development Bank (CDB)	China
	The World Bank International Advisory Group (WB_IAG)	Based in USA
	United Nations Development Program (UNDP)	UN
	Transport, Communications, Tourism and Infrastructure Development division of the UN Economic and Social Commission for Asia and the Pacific (TCTID)	UN
	Mekong River Commission (MRC)	Cambodia, Lao, Thailand, Viet Nam
NON-GOVERNMENT ORGANISATIONS	Towards Ecological Recovery and Regional Alliance (TERRA)	Thailand
	Oxfam International (OXFAM)	Mixed
	International Rivers Network (IRN)	USA
ACADEMIC AND RESEARCH INSTITUTIONS	Probe International (PROBE)	Based in Canada
MEDIA	Vientiane Times (VTIMES)	Lao PDR
	Watershed: The People's Forum on Ecology (WATERSHED)	Thailand
	Cable News Network (CNN)	World
VILLAGE GROUPS	Nam Theun Villagers (NTV)	Lao PDR
	TonLe Sap Fishers (TLSF)	Cambodia
ENGINEERING ORGANISATIONS	Scott Wilson International Consultancy (SWI)	Australia

respond. Other trigger events include the regular release of news bulletins, both from the e-Sim facilitators and the media groups played by some of the students, and the receipt of e-mails from other roles.

Online communication environment

In the Mekong e-Sim, the online communication environment is provided by the Blackboard learning management system, which is used at the University of Adelaide. Students log into the system as their role, thereby maintaining student anonymity and assisting students with interacting in a professional manner. Groups with the actual name of the role are created, and individual students portraying that role are enrolled in this group. This enables e-mails to be sent to various roles, and the Group feature in Blackboard enables a number of students, who play a particular role, to share files and communicate via discussion boards in private.

Separate discussion boards are used for each media group to enable them to reach a mass audience. However, while the messages on the media discussion boards are accessible to every role, only the appropriate media group is able to post to their designated discussion board. Separate discussion boards are also used for the public inquiries. By reading the public inquiry submissions made by the various roles, students are exposed to a range of views on the proposed developments, have to challenge the views of other roles and defend their own viewpoint.

EVALUATION METHODOLOGY

Sustainability issues addressed

During 2005, 63 students from the University of Adelaide and the University of Technology, Sydney took part in the Mekong e-Sim. The students adopted the 24 roles shown in Table 2 in groups of two to four students.The Mekong e-Sim constituted approximately 40 per cent of the assessment of the third year course Technology Assessment at the University of Technology, Sydney and the second year course Environmental Engineering II at the University of Adelaide [2]. In order to determine which issues were the drivers in the decision-making process for the Nam Theun II and Lancang public inquiries, and which social, environmental, economic and infrastructure aspects they addressed, the content of the e-mails and discussion board postings were analysed.

Degree of interaction

In order to determine the degree of interaction between stakeholder groups, the number of e-mails sent between the various groups, and the number of postings to the discussion forums, were analysed. It should be noted that in order to determine student participation marks (Table 1), an anonymous online peer evaluation survey was used to assess the perceived quality and impact of student interactions, in addition to data on the quantity of interaction.

Student perception

To assess student perception of how well their awareness and understanding of sustainability principles were developed as part of the Mekong e-Sim, a survey was designed, which contained the questions shown in Table 3. Student responses were measured on a 7-point Likert scale, ranging from 'strongly agree', which corresponds to a rating of 7, via 'neutral', which corresponds to a rating of 4, to 'strongly disagree', which corresponds to a rating of 1. The survey was randomly administered to 33 of the 47 University of Adelaide students who participated in the Mekong e-Sim in 2005 and processed by the Centre for Learning and Professional Development at the University of Adelaide. In addition, written student responses to some of the topics discussed as part of the face-to-face debriefing sessions at the University of Adelaide and the debriefing reports were included in the evaluation.

RESULTS AND DISCUSSION

Sustainability the main concern

Much of the discussion surrounding the two proposed developments was centred on aspects of sustainability, as discussed below. The impact of the various points of view presented by the different stakeholder groups was reflected in the final decisions of the two decision-making groups—The World Bank (Nam Theun II) and The China Development Bank (Lancang). Interestingly the final decisions of the two Banks differed. Whereas the Nam Theun II development received the 'go ahead', the China Development Bank decided that the proposed Lancang development should not proceed. However, it should be noted that the outcomes of the public inquiries vary from year to year, depending on the strength of the arguments put forward by various roles.

Nam Theun II development

The World Bank's final decision clearly concentrated on infrastructure, environment, social and economic factors. They approved the project, stating that ' . . . on balance it was decided that the social and economic advantages outweighed the environmental drawbacks'. The World Bank considered that the project met all the safeguard policies and the main aim of alleviating poverty. They further stipulated that every effort will be made to 'ensure that the 4500 relocated villagers are as close as possible to their former locations . . .' and that they will be provided with electricity, running water, schools and health clinics, 'all of which the villagers previously did without'. Overall, this would result in improved infrastructure for locals, as well as the region as a whole.

The decision-makers clearly indicated that they had considered the input of other groups (stakeholders) including EGAT, PROBE, MAF and MIH. EGAT and MAF (see Table 2 for details of organizations) and put forward arguments in relation to the economic benefits of the project. The World Bank agreed with this over the claims made by PROBE that decentralised multigeneration plants would be the better option. Economic benefits would be at both government and local levels, including an increase in the standard of living of displaced villagers.

With regard to social considerations, MIH considered that relocation of villagers would improve their standard of living and that the relocation area would be as close as possible to their former locations. It was surmised by the decision-makers that the villagers would be properly compensated for the inconvenience of relocation by significant improvements to their living standards.

With regard to environmental considerations, concerns by villagers about poor soil quality and low crop yields were countered with claims that modern farming techniques will boost yields, and further, that they will have a choice of alternative types of occupation. In addition, the villagers will receive rice supplements 'in the first few years until food and income sources stabilize'. A further environmental concern was that of fish migration. The World Bank cited various occurrences of

Table 3. Results of Student Evaluation of Learning and Teaching Surveys

Survey Question	Mean (Max 7)	Median (Max 7)
The Mekong e-Sim developed my ability to see engineering issues from multiple perspectives	6.1	6
The Mekong e-Sim developed my awareness of political, social, economic and scientific dimensions of engineering decision-making	5.9	6
The Mekong e-Sim increased my awareness of the complexity of sustainable development issues	6.4	7
The Mekong e-Sim increased my awareness of the need for sustainable development	6.2	7
The Mekong e-Sim increased my understanding of the meaning of sustainable development	5.8	6

successful fish migration, including strategies used in the United States, France and Russia, in order to address environmental concerns of disruption to fish migration as a result of the construction of the Nam Theun II dam. Another environmental concern was that of the ecosystem and biodiversity affecting soils and aquatic habitats. The World Bank recommended several strategies to address these concerns, including coordination of water releases with other dams to prevent sudden temperature changes and allowing the release of sediment and nutrients to replenish soils and aquatic habitats downstream. Also, logging practices would cease and planting of vegetation would be introduced to combat erosion possibilities. Controlling water releases would also provide the region with the necessary flooding for rice farming and irrigation to new settlements. Development of new fisheries and modern farming practices, as well as water bubblers to overcome anoxicity, were also identified.

Economically, the World Bank (WB_IAG) considered that poverty would be alleviated by the development of the Nam Theun II dam and revenue generated put towards healthcare, education and infrastructure.

Lancang development

The China Development Bank (CDB) was the decision maker for the Public Inquiry into the development of the Lancang. In its final decision, it noted that during the Inquiry, the key areas of concern were social, environmental and economic. Loss of culture was recognized as a major social impact to the villagers and would 'outweigh most advantages'. It was considered that relocation would not compensate the villagers (less agriculture and fishing production), and this would force them to look for work in cities resulting in difficulties in adjusting to new conditions.

Environmentally, the China Development Bank was concerned with the effect of the building of the dam on the biodiversity of the region. This included fish migration and spawning, as well as the effect on native birds who eat fish, who would either perish or migrate to other regions. Sedimentation concerns and the impact on downstream rice fields were also identified, as well as soil erosion, widening of the river and added danger to villagers.

The China Development Bank did not consider the economic impacts as important as the social or environmental impacts, but noted that the most common topic of discussion amongst the various groups was the negative impact on the economy through reduced fishing and agricultural productions. The China Development Bank observed that to counter this economic downturn, the proposed Lancang development and resulting power generation would not only increase China's desperately needed power, but would also result in increased revenue by selling its power to Thailand.

There was a high level of debate around environmental and social impacts within the online discussion boards during the public inquiry stage with regard to the proposed Lancang development. The China Development Bank was no doubt affected by the very good arguments both for and against the development. Its final stance was that, on balance, the proposed Lancang development should not proceed in its current form. However, the Bank suggested that a future public inquiry into the proposed development with expanded terms of reference (e.g. including the assessment of the impact of alternative forms of power generation, such as a number of smaller hydropower dams) should be considered.

Degree of interaction

During a one-week period (interaction stage), 303 emails were sent and received (Table 4). Only two groups did not send any emails and all groups received emails. The majority of email interaction was between non-government groups (all concerned with sustainability issues), the media and the two village groups. Individually, most email activity occurred with WATERSHED, who sent 11% of the total emails to the majority of the groups, and received 13% of the total emails. This is a media group concerned with sustainability issues and ensuring that the people's views on ecology are represented. WATERSHED's brief was to focus on reporting environmental concerns, democratic participation, poverty alleviation and political activity within the Mekong River Basin. When comparing numbers of groups represented within each category, there was considerably less email interaction with government, development and engineering organizations.

As illustrated in Table 5, in a period of just over one week (the interaction stage, including the final decision-making), there were a total of 378 postings and 16,982 readings within the online discussion board forums. This was an average of 270 readings per student. This high level of interaction within each of the two public inquiries (Lancang and Nam Theun II), along with the various Media groups, was very heavily focused on sustainability issues, as discussed previously.

Across both public inquiries, the majority of discussion board postings were by government, non-government and development groups, as well

Table 4. Degree of E-Mail Interaction

Category	No. of Email Sent	No. of Emails Received
Government Organisations (n:9)	55	58
Development Organisations (n:5)	49	40
Non-Government Organisations (n:3)	89	63
Academic and Research Institutions (n:1)	11	14
Media (n:3)	46	77
Village groups (n:2)	44	39
Engineering Organisations (n:1)	9	12
TOTAL	303	303

Table 5. Degree of Discussion Board Interaction.

Discussion Board Forum	Postings	Readings	Average Readings/ Student
Lancang Public Inquiry	202	7671	
Lancang Final Decision	7	495	
Lancang Total	209	8166	
Nam Theun II Public Inquiry	116	5074	
Nam Theun II Final Decision	7	503	
Nam Theun II Total	123	5577	
Media Groups			
Watershed	16	1049	
Vientiane Times	9	496	
CNN News	15	997	
Mekong TV News	6	697	
Media Total	46	3239	
TOTALS	378	16,982	270

as the villager groups. The decision-makers also had the role of discussion board moderators and were effective in this role, creating new threads around specific issues identified, as well as reminding groups about adhering to the discussion board guidelines. One of the decision-maker groups locked some of the forums, as it considered that the conversations were 'off track and simply sniping at each other'. Within the Lancang public inquiry, the International River Commission (IRN), a US non-government organisation concerned with sustainability, posted the largest number of messages, closely followed by UNDP, a UN development organisation. Within Nam Theun II, MIH, a government organisation concerned with economic development, recorded the most discussion board interaction, followed by STEA, another government organisation concerned with the environment, and TERRA, a non-government organisation concerned with sustainability issues.

Student perception

The results of the student survey are summarised in Table 3. It can be seen that student perception was that the Mekong e-Sim strongly developed their awareness of the complexity of sustainable development issues (mean 6.4). It further increased their awareness of the need for sustainable development (mean 6.2) and developed their ability to see engineering issues from multiple perspectives (mean 6.1). The Mekong e-Sim also developed student awareness of the political, social, economic and scientific dimensions of engineering decision-making (mean 5.9) and increased their understanding of the meaning of sustainable development (mean 5.8). This highlights the success of the Mekong e-Sim, and the potential of online roleplay simulations in general, for teaching engineering students sustainability principles.

The success of the Mekong e-Sim in teaching sustainability principles to students is highlighted further by the following student comments:

'The need for sustainable development was introduced in lectures, but highlighted in the discussion board. Sustainable systems were explored by providing solutions to environmental and social and economic problems. Sustainability means something different to different people, and this was emphasized by the variety of problems and solutions brought up in the discussion forum. The e-sim materialized the concept of sustainability, so that we could see the process of creating and researching sustainable systems.'

'As a whole the e-Sim was a simulation that reflected the complexity of natural resource management issues very well. The wide range of stakeholders highlighted the broad scope of issues involved with development, particularly those surrounding sustainability. By having anonymous roles, and interacting on a virtual level, it was easier to slip into our persona, and really act as if we were members of the organizations.'

SUMMARY AND CONCLUSIONS

In this paper, a novel framework for developing online roleplay simulations for teaching sustainability principles to engineering students has been introduced. The framework is based on the systems model of sustainability of Foley *et al.* [8], which suggests that sustainable systems consist of four interacting components, namely infrastructure, economic, environmental and social. In the context of developing roleplay simulations, this means that the problems or issues that are at the centre of the roleplay (e.g. proposed engineering projects) need to have infrastructure, social, environmental and economic dimensions. To ensure that the differing points of view about the problem or issue are presented during the roleplay, a range of stakeholder groups need to be represented by specific roles. In order to achieve a high degree of interaction between roles, and hence the development of linkages between the infrastructure, environmental, social and economic dimensions of the problem, various trigger events are required. Finally, the roles have to be able to share their points of view, which requires an appropriate online communication environment.

Application of the framework was demonstrated with a case study, the Mekong e-Sim, which is an online roleplay simulation set around proposed development issues in the Mekong region of South-East Asia. An evaluation of the 2005 Mekong e-Sim revealed that there was a high degree of interaction between roles about the social, environmental and economic issues surrounding the proposed construction of the Nam Theun II hydropower dam in Laos and the proposed Lancang project in China, which includes the blasting of rapids to improve river navigation and the construction of a large hydropower dam. The recommendations in relation to the proposed developments were to proceed with the Nam Theun II dam, but that approval of the Lancang project was not advisable.

A survey of students participating in the 2005 e-Sim indicated that the e-Sim was able to develop:

1. awareness of the complexity of, and need for, sustainable development;
2. the ability to see engineering issues from multiple perspectives;
3. an understanding of the political, social, economic and scientific dimensions of engineering decision-making;
4. a better understanding of the meaning of sustainable development.

These results suggest that the proposed framework shows promise for developing roleplay simulations that are successful in teaching sustainability principles to engineering students.

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