

A Green Learning Model for Teaching Requirements Engineering Course

Rafia Naz Memon, Irfana Memon and Fiza Siyal

Abstract - Nowadays, severe environmental issues are faced by our planet mainly because of increase in consumption of energy, and waste from industry. The “Green IT” concept has been introduced in our society in order to increase the age of our planet and improving health of its inhabitants by reducing carbon emission. In order to effectively adopt green IT principles, it is suggested that it should be taught to undergraduate students as a part of several course in order to train them to use green IT concepts in their professional life. Requirements Engineering (RE) process is perceived as one of the most critical activities within software development projects and need to be effectively taught in universities. The main purpose of this work is to introduce the concept of Green IT while teaching RE course. The enhanced learning model (referred as Green learning model) highlights activities to teach students the green IT concepts and makes RE more environmental friendly. In our existing learning model, green IT concepts have been incorporated at several places especially “RE teaching and learning material” section introduces three new concepts in addition to adding green IT concepts in existing concepts of the model that are agile software development, risk analysis in terms of energy and environmental sustainability as a non-functional requirement. The green learning model was then evaluated through expert reviews by RE experts and showed positive results. It is expected that the proposed green learning model can increase awareness and understanding of environmental sustainability of IT in software engineering education and will help the production of quality requirements engineers that possess all required RE skills.

Index Terms- Requirements Engineering, Green IT, Learning model.

I. INTRODUCTION

Nowadays, severe environmental issues are faced by our planet mainly because of increase in consumption of energy, and waste from industry. The contribution of several forms of Information Technology (IT) in new business methodologies have been increased and it has also effected and increased the wealth of nations, societies, organizations and individuals. Especially in last two decades, increased use of IT have caused an increase in IT-related power consumption which resulted in higher carbon emission [1].

Rafia Naz Memon, Fiza Siyal Department of Information Technology, Quaid-e-Awam University of Engineering, Science & Technology, Pakistan. Irfana Memon, Department of Computer Systems Engineering, Quaid-e-Awam University of Engineering, Science & Technology, Pakistan. Email: rafia@quest.edu.pk.

The complex software applications need much increased power and resource consumption, resulting enormous negative impact on environment. Sustainable development refers to “taking into account the ecological, social and economic impacts on the use of resources for fulfilling the human needs”. IT industry, though, has been trying to find effective solutions to address environmental issues, it is still not clear whether resource and energy savings by IT will exceed its resource consumption or not. [2]

The “Green IT” concept has been introduced in our society in order to increase the age of our planet and improving health of its inhabitants by reducing carbon emission. Various IT organizations, while planning and managing IT infrastructure, are taking this phenomenon as a serious issue. Environmental footprint and its danger to our planet can be reduced by making businesses greener by incorporating the green IT principles in firm’s daily activities. The objective of adopting green IT principles are to result in big savings, as expanding carbon emissions, increase in energy bills and other environmental rules and restrictions cost businesses a lot of money. [1] In order to effectively adopt green IT principles, it is suggested that it should be taught to undergraduate students as a part of several course in order to train them to use green IT concepts in their professional life. Watson et al. [3] articulate the need of incorporating environmental sustainability as an underlying foundation in teaching, so that students can embrace environmental sustainability in their core principles and foster changes that reduce the environmental impact of our community.

Requirements Engineering (RE) process is perceived as one of the most critical activities within software development projects because many projects fail due to RE problems. Hence, ensuring effective RE process is a great challenge not only to the software industries but also to the academic world who is responsible for educating future requirements engineers. The main objective of RE course is to teach students the relevant concepts and skills that they need to perform RE, as well as enabling them to practice performing RE activities while working on software development projects. [4] In a previous study [5], a learning model based on activity-led learning (a pedagogical approach which uses activity as a focal point of learning experience) was proposed to teach RE course to software engineering students in universities.

The main purpose of this work is to introduce the concept of Green IT while teaching RE course. To serve this purpose, our previously proposed learning model [5] has been enhanced by incorporating green IT concepts in it.

The rest of this paper is organized as follows. Section II elaborates the concept of green IT and presents our previously proposed learning model that serve as a background for this study. Section III presents the focus of the study, section IV presents the proposed green learning model, section V presents preliminary evaluation of the model and section VI concludes the paper.

II. BACKGROUND STUDIES

This section first introduces and elaborates the green IT concept (in section II-A) and then presents our previously proposed learning model for teaching and learning RE course (in section II-B).

A. The concept of Green IT

The Green IT is also termed as Green IT/IS, sustainable IT, Green ICT etc [6]. According to Jenkin et al. [7], Green IT and systems refer to initiatives and programs that directly or indirectly address environmental sustainability in organizations. According to Molla et al. [8] Green IT is emerging as an increasingly important issue as organizations come under pressure to address environmental sustainability concerns. Green IT depicts for us the use of IT procedures, products, and services in an environmentally safe and responsible manner. [1]

Many researchers have already done their research in the field of green IT, but their focus mainly lies on environmental sustainability in terms of computer hardware. The research on energy consumption in software still need to be done in order to achieve green computing. [2]

An art of developing and managing green and sustainable software engineering process is referred to as green and Sustainable Software Engineering. Therefore, it can be interpreted as an art of definition and development of software products in such a way that assessment and documentation of the negative and positive impacts on sustainable development that result and/or are expected to result from the software product over its whole life cycle can be performed and used for a further optimization of the software product. Green and Sustainable Software is the software that has minimal direct and indirect negative impacts on economy, society, human beings, and environment that can result from development, deployment, and usage of the software and/or which has a positive effect on sustainable development. [2]

This work focuses on the sustainable development of software mainly in terms of RE process.

B. Learning model for teaching Requirements Engineering

In order to facilitate the need of improved teaching and learning, a learning model [5] based on Activity-Led Learning (ALL) was proposed that emphasizes on actively involving students in a learning process. The model includes RE teaching and learning methods that are based on ALL's teaching, learning and assessment methodology. The model also includes the material to help lecturers and students in teaching and learning RE. The main ideas of proposed learning model is the inclusion of iterative process of learning, the knowledge repository that keep past examples, the ability to retrieve related example projects, and the ability to share and get feedback from others in the class. [5] The proposed learning model is presented in fig. 1 and its complete description can be found in [5].

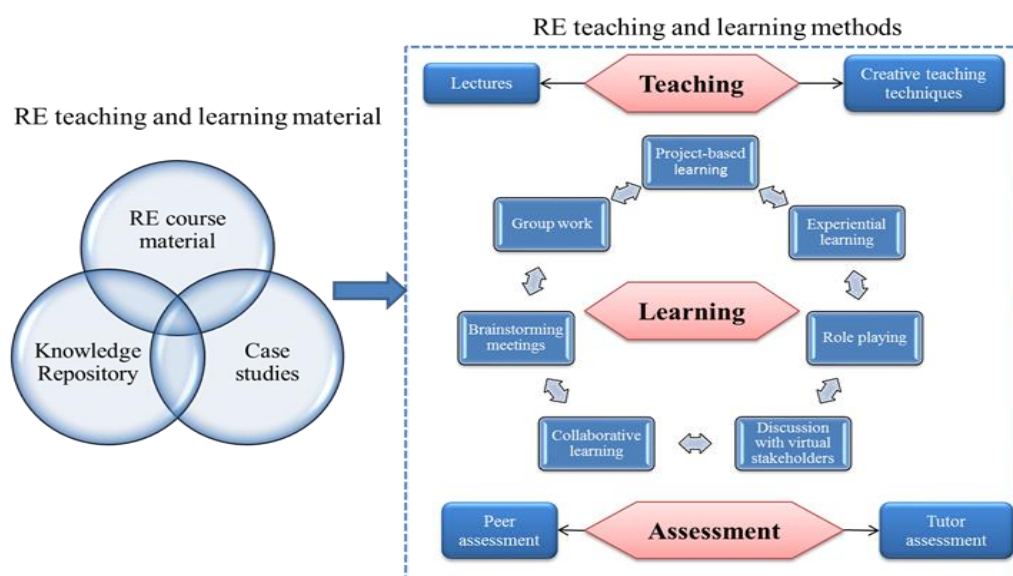


Fig. 1. The learning model [5]

III. FOCUS OF THE STUDY

Sustainability has three major pillars: environment, society and economy. Traditional RE targets economy, while in this research work, environmental sustainability in terms of incorporating green IT concepts in RE has been focused as sustainability is not supported by traditional software engineering methods.

It is claimed that while taking software life cycle into account, in software engineering process RE stage is considered very important in organizing how green a software product can be. Therefore RE is very critical and should be added to the life cycle of a software product. All the later stages are affected by this stage as if few requirements of the system to be built are missing and misinterpreted by requirement engineer then the design and implementation stages also need to be changed. [2]

Mahaux and Canon [9] also argue that RE is critical to the whole software life cycle primarily in the usage phase where customers are delivered the system and expect it to conform to their requirements. They claim that correct RE

can help software last longer thus reducing the energy consumption.

This study therefore focuses on teaching students the concepts of green IT in RE course in order to get them familiar with environmental sustainability.

IV. PROPOSED GREEN LEARNING MODEL

The enhanced learning model is referred to Green learning model as it incorporates the concepts of green IT in teaching/learning RE process. The Green learning model highlights activities to teach students the green IT concepts and makes RE more environmental friendly. In existing learning model, green IT concepts have been incorporated at several places (and are marked green) especially “RE teaching and learning material” section introduces three new concepts in addition to adding green IT concepts in existing concepts of the model. Green learning model is shown in fig. 2 and only those sections where Green IT concepts are incorporated have been discussed in sections IV-A and IV-B.

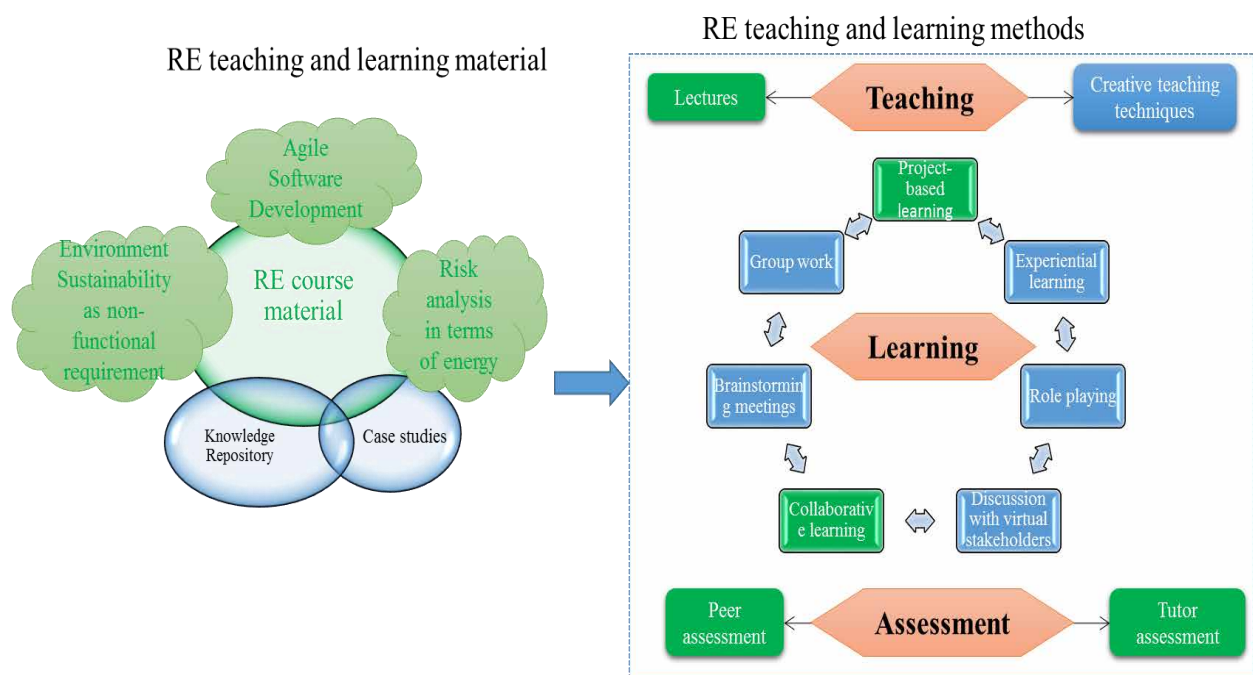


Fig. 2. Green learning model

A. RE course material

As it was recommended in our previous study [5] that RE course designers should consider the guidelines and core curriculum provided by software engineering community provided in “Guide to Software Engineering body of knowledge” [10] and ACM and IEEE education board in report entitled “Software Engineering 2004 –

Curriculum Guidelines for Undergraduate Degree Programs in Software Engineering” [11] as a basis to design RE courses for their universities. According to this core curriculum, RE course should be comprised of four units that are, Requirements fundamentals, eliciting requirements, requirements specification and documentation, and requirements validation. Along with the traditional RE course material, the green concepts

should also be added in each unit of the course. The suggested green concepts for each units are described below.

Requirements fundamentals: In traditional RE curriculum, this unit introduces RE and includes topic such as requirements process, requirements characteristics, layers/levels of requirements etc. We propose that in addition to these topics, this unit should also include green IT topics such as:

- Identification of project's potential power conception.
- Estimation of project's carbon emission quantity.
- Energy regulatory requirements
- Business directives keeping in mind carbon emission and energy consumption.

Eliciting requirements: In traditional RE curriculum, this unit includes topics such as elicitation sources, elicitation techniques etc. We propose that this unit should also include green IT concepts such as:

- Methods and tools to elicit and model greenness requirements
- Methods and tools to identify and analyze the trade-offs among the functional requirements, greenness requirements themselves and other quality attributes
- Discussion about alternate energy sources such as solar energy or wind along with eliciting requirements from users and stakeholders.
- Analysis of the possibility of least use of energy resources in executing the project.
- Discussion on more significant activities from Green IT perspective with customers such as incorporating power capping in the project, managing power in the computing environment and analyzing the possibility of relocating the computing center for the project where wind, solar or hydro power is widely available.
- Discussing with stakeholders about computing center cooling and airflow, introducing paperless environment, optimizing resource utilization, and minimizing e-waste.
- Allocation of software and hardware which use less energy resources and eco-friendly.
- Improving operational efficiency.
- Discussing computer hardware recycling of the project.

Requirements specification and documentation: In traditional RE curriculum, this unit includes topics related to writing requirements specification document with the help of different specification languages. We propose that the curriculum should also include potential areas with highlighted requirements related to Green IT along with documentation of other requirements.

Requirements validation: In traditional RE, this unit includes topics such as reviews and inspections, acceptance test design, validating product quality attributes etc. We propose that the curriculum should also techniques to ensure the appropriate inclusion of requirements related to

green IT. In addition to these units, three concepts should be emphasized while teaching sustainable RE course. These concepts are discussed below.

Agile software development: Traditionally, RE curriculum is comprised of RE process that is the part of traditional software development approach. On the contrary, the agile approach to software development is different from old and traditional ones in that it does not rely on heavy written requirement documents that do not accept any requirement changes. Also it does not prevent business people and customers to work hand in hand with the software developers. [2] Therefore, it is suggested that using agile approach for teaching RE process can promotes sustainable development by believing that developers, users, and sponsors should maintain working in a constant pace.

Risk analysis in terms of energy: Risk analysis is a process that identifies any possible negative external and internal condition, event or situation that may occur during project development. It is suggested that in RE course, students should be taught to analyze energy risks in addition to other types of risks and ways of alteration of requirements based on this risk analysis. It will show students the importance of taking energy consumption into account.

Environmental sustainability as a non-functional requirement: Traditional RE curriculum teach students to generate functional as well as non-functional requirements. It is suggested that more emphasis can be put on green IT concepts if they are taught as one of system's soft goal. So if main soft goal (non-functional requirement) of a system is environmental sustainability, then the following set of general low level soft goals for satisfying environmental sustainability can be taught in RE course.

- Using products that are environmentally approved for development
- Using internet as a communication source instead of usual transportation means
- Using service oriented software
- Sacrificing performance above a limit for energy efficiency
- Running the system on computers with power profiles
- Reducing unnecessary activities in the system
- Using reusable system to save energy.

B. RE teaching and learning methods:

This part of learning model is intended to help to enhance student's understanding of RE course material and to provide them guidance in their learning process. Here, the methods that can adopt green IT concepts are discussed only. The complete information of all RE teaching and learning methods is available in [5].

Lectures: This is the traditional and most widely used teaching method. In RE course, the instructors provide background knowledge and basic concepts of RE. It is suggested that the instructor should first teach specific RE contents to the class with real life examples. After students learn to apply concepts in class assignments, the instructor should provide an overview of green IT and environmental issues.

Collaborative learning: Learning through collaborative activities aims to provide students with RE skills by interacting with stakeholders who have different needs and requirements [12]. As green IT is relatively new concepts and students may have difficulty in understanding it. Therefore along with applying collaborative activities for teaching RE concepts, they can also be applied for teaching students main issues related to the environment.

Project-based learning: Project-based learning engages students as active learners by assigning them RE projects [5]. It is suggested that RE projects should emphasize on capturing green IT requirements in addition to providing students the opportunities to explore areas and aspects of the software requirements engineering.

Assessment: In RE course, two assessment methods are suggested to be included in order to help students in their learning process that are peer assessment and tutor assessment [5]. Peer assessment is the process through which groups of individuals rate their peers [13]. While tutor assessment is the normal form of course assessment. It is suggested that the assessment should also cover the knowledge transfer of green IT as a part of RE course. In each assessment, at least one question related to green IT concepts and their use in RE should be included.

V. EVALUATION OF MODEL

The preliminary evaluation of proposed green learning model was conducted using expert reviews. The evaluation of existing learning model (presented in Fig. 1) have already been carried out and showed positive results. This evaluation study was aimed at evaluating the effectiveness of incorporating green RE concepts in RE course. This section presents the evaluation study in terms of participants, questionnaire, procedure used and results.

A. Participants

The target participants of this study were the lecturers having experience of teaching RE. Total of six experts from different universities of Pakistan, Malaysia and South Korea participated in this study in response to our email request.

B. Questionnaire

A short questionnaire consisting of six questions were designed to perform this study. Participants were asked to rate the following statements in order to assess the effectiveness of model with the scale 1 (Strongly Agree) – 5 (Strongly disagree).

- The green RE concepts are important to be taught in RE course.
- It is appropriate to provide the suggested material proposed in the model within limited resources available in universities.
- It is appropriate to use the teaching and learning methods proposed in the model for teaching RE.
- The green concepts used in the model are relevant to RE.
- The students will be able to understand the green RE concepts well if proposed model is implemented.
- Overall the model is considered as an effective step in achieving sustainable software engineering process.

C. Procedure

The details of model along with the questionnaire were sent to the participants (who agree to respond) through email. They were requested to go through the model and then fill the questionnaire. All the responses were received in one week time.

D. Results

The results obtained from the rating questionnaire responses are presented in Fig. 3.

The results show that the proposed green learning model can be considered effective based on experts' opinions. However, while giving suggestions, experts mentioned that the actual applicability and effectiveness of the model can be measured by implementing it in universities for teaching RE course.

VI. CONCLUSION

Green IT is getting more attention nowadays due its impact on decreasing degradation of our planet due to environmental disasters such as carbon footprint. In this study, the green IT concepts have been incorporated in an existing learning model proposed to teach a significantly important undergraduate software engineering course that is Requirements Engineering. The existing learning model is based on Activity-Led Learning (ALL), which involve students as active learners by performing various activities and involve lecturers as facilitator by playing different roles. The existing model is enhanced to green learning model by incorporating green IT concepts in it. It is expected that the proposed green learning model can increase awareness and understanding of environmental sustainability of IT in software engineering education and

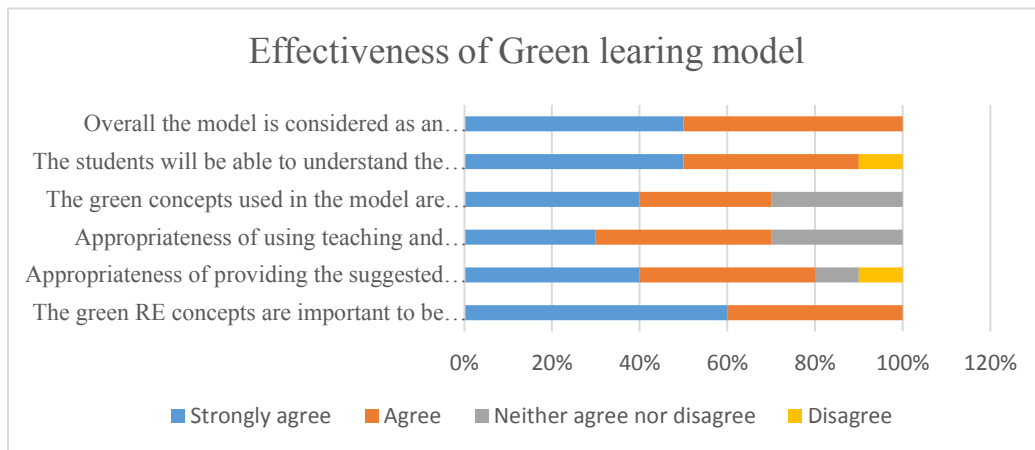


Fig. 3. The ratings on effectiveness of the model

will help the production of quality requirements engineers that possess all required RE skills. This work also highlight the opportunities for academia to incorporate these kind of concepts in various other courses in undergraduate education so that next generation of graduates better understand the environmental issues. The preliminary evaluation of green learning was performed through expert's reviews which showed positive results; however it is desired to validate the model by implementing it in universities for teaching RE course.

REFERENCES

- [1] F. Ahmed and K. Shuaib, "Incorporating Green IT concepts in undergraduate software requirements engineering course: An experience report," in *Information Systems and Technologies (CISTI), 2012 7th Iberian Conference on*, 2012, pp. 1-4.
- [2] S. S. Mahmoud and I. Ahmad, "A Green Model for Sustainable Software Engineering," *International Journal of Software Engineering and Its Applications*, vol. 7, 2013.
- [3] R. T. Watson, M.-C. Boudreau, and A. J. Chen, "Information systems and environmentally sustainable development: energy informatics and new directions for the IS community," *Management Information Systems Quarterly*, vol. 34, p. 4, 2010.
- [4] R. N. Memon, R. Ahmad, and S. S. Salim, "Requirements Engineering Education (REE): Problems and Recommendations for RE course implementations," *Malaysian Journal of Computer Science*, vol. 26, pp. 294-311, 2013.
- [5] R. N. Memon, R. Ahmad, and F. Siyal, "A learning model based on Activity-Led Learning for teaching Requirements Engineering course," presented at the *International Conference on Modern Communication & Computing Technologies (MCCT'14)*, Pakistan, 2014.
- [6] M. T. Ijab, A. Molla, A. E. Kassahun, and S. Y. Teoh, "Seeking the "Green" in "Green IS": A spirit, practice and impact perspective," 2010.
- [7] T. A. Jenkin, J. Webster, and L. McShane, "An agenda for 'Green'information technology and systems research," *Information and Organization*, vol. 21, pp. 17-40, 2011.
- [8] A. Molla, V. A. Cooper, and S. Pittayachawan, "IT and eco-sustainability: Developing and validating a green IT readiness model," 2009.
- [9] M. Mahaux and C. Canon, "Integrating the complexity of sustainability in requirements engineering," in *First international workshop on Requirements for Sustainable Systems*, 2012.
- [10] A. Abran, J. W. Moore, P. Bourque, R. Dupuis, and L. L. Tripp, *Guide to the software engineering body of knowledge: 2004 version*: IEEE Computer Society, Los Alamitos, CA; Tokyo, 2004.
- [11] R. LeBlanc, A. Sobel, J. Diaz-Herrera, and T. Hilburn, "Software engineering 2004: curriculum guidelines for undergraduate degree programs in software engineering," *IEEE Computer Society 0769523501*, 2006.
- [12] P. Thomas and S. Minocha, "Using a wiki to facilitate learning on a Requirements Engineering course," presented at the *Higher Education Academy's eighth Annual Conference*, 28-30 August 2007, University of Southampton, 2007.
- [13] N. Falchikov, "Peer feedback marking: developing peer assessment," *Programmed Learning*, vol. 32, pp. 175-187, 1995.