ALL-RE: A MODEL FOR TEACHING AND LEARNING REQUIREMENTS ENGINEERING

Rafia Naz Memon*, Irfana Memon**, Shah Zaman Nizamani*, Fiza Siyal*, Pardeep Kumar**

ABSTRACT

Requirements Engineering (RE) is an uncertain discipline and requires comprehensive understanding from the organizational, human and technical aspects. Therefore a suitable and adaptive approach is needed to teach RE. This paper aims to analyze the student's and lecturer's perceptions and understanding of RE and propose a learning model that can be adopted and employed to teach RE course. Through literature review and surveys, the student's and lecturer's perceptions and understanding of RE were analyzed that lead us to the need of a collaborative and sustainable learning model for teaching RE course. A learning model based on activity-Led learning (a pedagogical approach that uses activity as a main point of learning experience) was proposed for teaching RE. The proposed model was named as ALL-RE to depict that the model is based on activity-Led learning (ALL) and intended to be used for teaching and learning requirements engineering (ALL-RE). The main ideas of ALL-RE model is the inclusion of teaching and learning material (in the form of RE course material, knowledge repository and case studies) and various teaching, learning and assessment methods. ALL-RE was then evaluated through expert reviews by the RE experts and showed positive results.

Keywords: *Requirements Engineering, Requirements Engineering Education, Activity-Led learning, didactic triangle.*

1 INTRODUCTION

Requirements Engineering (RE) is considered as one of the most complex discipline of software engineering. [1] Due to its complex and uncertain nature, it requires comprehensive understanding of organizational, human and technical aspects of users and systems. The future software/requirements engineers will get in depth knowledge of RE only when they are taught RE as a core course in universities using rigorous teaching methods. However as evident by RE literature, the RE course offering in universities have several deficiencies. The problems that students and lecturers face in studying and teaching RE course are reported in several studies such as [2-6] etc. Due to the deficiency of RE course offerings in universities, software developers have to learn to perform RE while doing their jobs [7]. This makes most software developers lacking in RE skills and knowledge. Therefore it is suggested that a suitable and adoptive approach is needed to teach RE course that can provide students sufficient RE skills and prepare them for working on industrial projects.

This study therefore aims to analyze the student's and lecturer's perceptions and understanding of RE and to propose a learning model that can be adopted and employed to teach RE course to software engineering students in a traditional academic environment in universities. The proposed model can also be used to teach RE in industry led and open delivery courses and certifications. Through literature review and surveys, the student's and lecturer's perceptions and understanding of RE are analyzed using edges of didactic triangle proposed by [8]. This analysis results lead us to the need of a collaborative and sustainable learning model for teaching RE course. A learning model based on activity-led learning (a pedagogical approach which uses activity as a focal point of learning experience) is then proposed. The proposed model was named as ALL-RE to depict that the model is based on activity-Led learning (ALL) and intended to be used for teaching and learning requirements engineering (ALL-RE). The main ideas of ALL-RE 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. ALL-RE was then evaluated through expert reviews by RE experts (the lecturers who have experience of teaching and researchers who are doing research on RE).

The rest of paper is organized as follows. Section 2 presents the student's and teacher's perceptions and understanding of RE course through edges of didactic triangle, section 3 elaborates the need of a learning model for teaching RE course, section 4 presents the proposed learning model (ALL-RE) and explains its components, section 5 presents the evaluation of ALL-RE model and section 6 summarizes and concludes the paper.

* Department of Information Technology, QUEST, Pakistan
{rafia@quest.edu.pk}

** Department of Computer Systems Engineering, QUEST, Pakistan

2 THE DIDACTIC TRIANGLE

An effective way to analyze and describe the teaching situation of the subject is through three main elements: the student, the teacher and the content [9]. The didactic triangle by Kansanen [8] effectively illustrates these elements and their interaction. The triangle is used as an analytical tool for analyzing and improving awareness of the current status of the subject (RE in our case) [9]. Kansanen's didactic triangle is presented in Fig. 1 below.

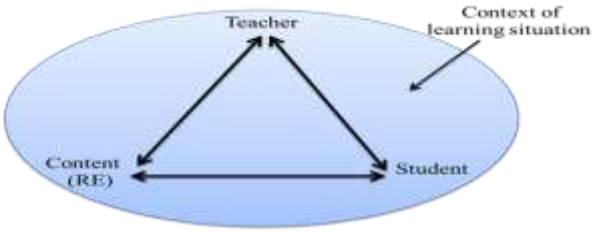

Figure-1 The didactic triangle

In this study, teaching and learning situation of RE course is analyzed using edges of didactic triangle that are: RE and teachers, RE and students, and student and teacher. The following sub sections discuss each of them.

2.1 RE and Teachers

In the relation between the teacher and the content, the teacher's competence in content is in focus [8]. The relationship between teachers and RE is analysed to find out the teacher's perception and understanding of RE. Most of the authors of studies related to Requirements Engineering Education (REE) are lecturers teaching RE course. They have shared their experiences of teaching RE and presented problems they encountered in teaching RE. Our analysis based on the related literature review and the survey results performed on lecturers [5] lead us to the following observations:

- The commonly used RE teaching methods are lectures, whereas a few other approaches used are labs, group discussions and presentations.
- Most of the basic RE concepts are taught in RE course, while RE challenges are not emphasized due to the lack of practical work. Lecturers feel that it is difficult for them to set practical exercises for students in class.
- Teachers have not given sufficient time period to cover RE (normally they have to complete the course in about 3-4 months), while the advanced RE topics are not covered by the syllabus provided to them by the course designers.
- Lecturers face difficulty in teaching students to deal with RE challenges such as changing requirements.
- According to lecturers, teaching students to communicate with original customers need a lot of resources not usually available at institutions.
- Lecturers feel it difficult to find the good case studies and proper RE tools to be used for teaching RE.
- Many researchers have provided solutions to resolve REE problems and improve REE, however REE community still report many problems.

Based on the above observations, it can be concluded that lecturers are ready to offer practical experience to students by giving them practical examples, and assigning and involving them in lab exercises, but they are unable to do so due to the lack of proper course materials, resources and advanced teaching methods.

2.2 RE and Students

The student's relationship to the RE is the key to didactic understanding [8]. The relationship between students and RE is analyzed to find out the student's perception and understanding of RE. Our analysis based on related literature review and results of surveys performed on students [2, 10] lead us to the following observations.

- The students are mostly learnt RE through lectures, presentations and group discussions. Only few have exposure of lab exercises.
- They find requirements modelling and analysis as the most difficult RE activity to perform.
- Mostly students taking RE course have no industrial experience neither they have provided any while teaching RE course but only been exposed to small and toy projects.
- The students have been taught basic RE concepts but dealing with RE challenges and RE process models are not emphasized in class.
- Students need group projects and independent exercises as assessment methods.
- Students found RE course hard to understand and boring due to strong emphasis on theoretical parts rather than practical side.
- Students have difficulty in applying knowledge of RE in the real world.

Based on above observations, it can be concluded that students need improved teaching approaches that can introduce exercises, real-life examples of industrial projects, more interesting ways to deliver lecturers, reduce theoretical parts and include tools to perform RE activities in practice. In addition, they need enhanced assessment methods such as group assessment.

2.3 Teachers and Students

The relationship between teachers and students is a neglected area of REE research. The teacher-student relationship is a two-way but REE literature does not write more on this relationship. In general, a few reporting from literature are presented here.

A focus group study was conducted with teachers by [11]. One focus group participant stated about the emotional connection with students as… If you want to be a good teacher, you really have to show the students … that you are passionate about the things you are teaching. The students can very quickly discover the fraud, so you must actually show your love of that material, if that comes across I think half the battle is won. [12] argued that the student-centered approach is more advanced and effective, in that it presupposes the teacher-centered approach. To focus on the student, a teacher must be capable of taking a step 'outside' herself and seeing her acts not as an aim in itself, but in relation to the student.

Based on this analysis, it can be concluded that the attitude of teachers is an important factor. RE course should be taught using student-centered approach in which teachers should not only teach students through the usual role of informer, but also collaborate with students by using various teaching methods and by playing different roles.

3 THE NEED OF A LEARNING MODEL

The information about existing REE literature and state-of-art concepts is presented in our previous work. Such as complete analysis of all REE problems reported in literature is presented in a conceptual integrated model [6], verification of REE problems through empirical studies from lecturers is presented in [5] and from students is presented in [10], recommendations for improving REE are presented through a direction framework in [10], and critical issues in REE are presented in [13].

It is observed that RE process as presented in the books and literature and as it is being taught in institutions are not according to the needs of industry [14]. Students and teachers are facing number of problems in learning and teaching RE course. This is due to the fact that students are still taught RE through traditional methods. It is therefore recommended that software engineering education should introduce alternative teaching approaches. [15] Thus, there is a need of improved teaching and learning approach to include learner-centered design while developing curriculum and teaching methods, to exploit new technologies for on-campus learning [16].

Based on the analysis of didactic relationships, an approach for teaching RE is needed that can:

- Incorporate practical experience
- Use real projects
- Assign lab exercises
- Include real-life examples of industrial projects
- Include tools to perform RE activities
- Reduce theoretical parts
- Use student-centered approach
- Include enhanced assessment methods
- Actively involve students in a learning process.

The student-centered teaching approach can be developed in the form of a learning model. McCowan and Knapper point out: "Learning is a passive system has a much greater tendency to be both superficial and quickly forgotten. Active involvement in learning helps the student to develop the skills of self-learning while at the same time contributing to a deeper, longer lasting knowledge of the theoretical material...[and]...it is almost the only effective way to develop professional skills and to realize the integration of material from different sources" [17]

A learning model based on Activity-Led Learning (ALL) was therefore proposed in order to actively involve students in a learning process. ALL was selected because it is a learning approach that emphasizes on promoting student retention, engagement and achievement, and hence can serve the aim of this study. The proposed learning model is described in the following section.

4 A PROPOSED LEARNING MODEL

This section first introduces ALL approach and then presents the proposed learning model in detail.

4.1 Activity Led Learning (ALL)

The ALL approach was proposed by Conventry University, UK to improve the learning experience of students and address the problem of student satisfaction and retention rates. ALL is a pedagogic approach in which the activity is the focal point of the learning experience and the tutor acts as a facilitator. An activity is a problem, project, scenario, case-study, research question or similar in a class room, work-based, laboratory-based or other appropriate setting and for which a range of solutions or responses are appropriate [18]. ALL needs an independent process in which the individual learner, or team of learners, get and apply the information, practices, personal and physical resources related to the task or activity being performed [19].

4.2 ALL-RE: A learning model based on ALL

A learning model was proposed that applies ALL to RE course (and therefore named as ALL-RE). Through ALL approach, the students acquire technical skills as well as some business knowledge and practice some of their soft skills on real-life situations [20]. The ALL-RE model also includes the material to help lecturers and students in teaching and learning RE. The proposed ALL-RE learning model is presented in Fig. 2. The components of the ALL-RE model are explained in detail below.

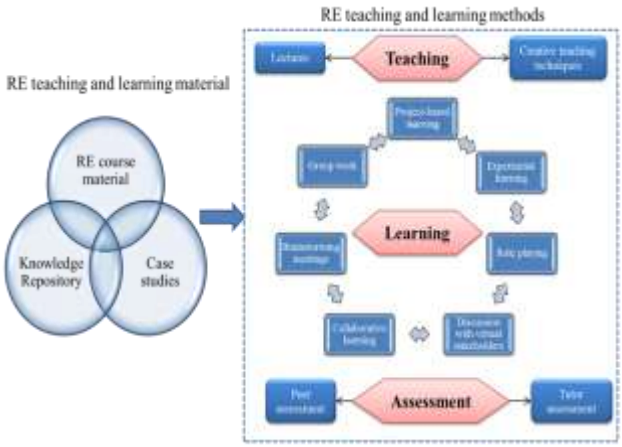

Figure-2 The ALL-RE learning model

RE teaching and learning material. The suitable and appropriate material plays an important role in the learning process. It is suggested that during RE course, the lecturers should strive to provide students with the following items.

RE course material. RE course should be designed according to guidelines provided by software engineering community in "Guide to Software Engineering body of knowledge" [21]. In addition, a report entitled "Software Engineering 2004 – Curriculum Guidelines for Undergraduate Degree Programs in Software Engineering" [15] by ACM and IEEE education board recommended software engineering core curriculum and a section entitled "Software Modelling and Analysis" includes the complete core RE curriculum. The course designers should consider this core curriculum as a basis to design RE courses for their universities. They can also enhance and include advance topics depending on their program structure and available resources. During RE course delivery, the lecturers should provide complete RE course contents along with the reference material to students to help them in their learning process.

Knowledge Repository. Because of its theoretical nature, the students take less interest in RE and easily forget the important concepts. Therefore it becomes very difficult for them to deploy those concepts for performing RE activities. To address this problem, the idea of creating RE knowledge repository is proposed. The knowledge repository should keep all RE concepts with example projects from industry, past examples solved by students, solved case studies, sample software requirements specifications (i.e. the final output of RE process) and any other information that can help students in their learning process. The students should be able to retrieve any required information from the knowledge repository. The lecturers should create the knowledge repository and provide it to students during RE course.

Case studies. The students should be provided with the list of unsolved case studies. Lecturer should make the groups of 4-5 students and assign each group a case study to solve. The students can take help from knowledge repository by retrieving solved case studies and example projects, and can make use of various learning methods to solve the case studies.

RE teaching and learning methods. The teaching and learning methods are based on ALL's teaching, learning and assessment methodology. To enhance students' understanding and to provide them guidance in their learning process, the following teaching and learning methods should be used.

Teaching. The lecturer plays the role of tutor as well as facilitator. In a traditional role of tutor, the lecturers deliver their lectures according to predefined schedule. While as a facilitator, the lecturer plays multiple roles. Such as provide RE teaching and learning material (including RE course material, knowledge repository and case studies), facilitate students in the various learning methods (e.g. play the role of virtual stakeholder) etc. The teaching includes:

- ***Lectures***

The lecturers deliver lecturers in a typical class room environment to provide students the background knowledge and basic RE concepts.

- ***Creative teaching techniques***

The lecturer should always strive for using innovative and creative teaching technique along with lectures to make it easier for students to understand the complex and theoretical subject like RE. In order to make class experience of students interesting, creative teaching applies flexible and appropriate techniques. Creative teaching emphasized that the lecturers should be sharers of knowledge as well as inspirers and navigators [22].

Lecturer should adopt various creative teaching techniques based on subject matter, teaching resources, their teaching style and personality influence. Few examples of creative teaching techniques are: picture prompt (showing students an image without any explanation and ask them to explain it and justify their answers, instructor storytelling (Instructor illustrates a concept, idea, or principle with real-life application, model, or case-study), empty outlines (distribute a partially completed outline of today's lecture and ask students to fill it in at the start or at the end of class) [23].

Learning. As proposed by our model, learning RE is achieved through the iterative process of learning various methods. These methods are successfully adopted by various researchers. The various learning methods are presented below.

- ***Project-based learning***

Project-based learning engages students as active learners by assigning them RE projects. Students experience and learn to perform RE activities by applying them on their projects. This method of learning has been emphasized and adopted by [24]. Through project-based learning they tend to provide in depth knowledge of RE to students and improve the collaboration.

- ***Group work***

Group work is a valuable experience for students that provide them a better opportunity for learning many RE topics as well as practicing the theoretical issues [25]. By forming the groups of students and assigning them RE tasks, students are encouraged to held group discussions and performing group exercises. Learning through group work is successfully adopted by [25-27].

- ***Brainstorming meetings***

Brainstorming is the process of systematic and liberal generation of a large volume of creative ideas from a number of participants [28]. Typical brainstorming meetings in RE course can bring students together into a creative process through which the students can effectively learn RE concepts. Learning through brainstorming is successfully adopted by [3].

- ***Collaborative learning***

Learning through collaborative activities aims to provide students with RE skills by interacting with stakeholders who have different needs and requirements. Our aim of introducing collaborative activities in RE course is to emulate an experience that students are likely to be engaged in as practicing requirements engineers [29]. Learning through collaborative activities has successfully been adopted by [29, 30].

- ***Discussion with virtual stakeholder:***

Incorporating virtual stakeholder in RE course project and learning through discussing with virtual stakeholder can be an effective learning method to help students in learning RE concepts and can improve students' communication skills. The lecturers, supporting staff or non-software engineering students can play the role of virtual stakeholder. Learning through discussion with virtual stakeholder has successfully been adopted by [31].

- ***Role playing:***

Role playing is an effective and widely used technique for teaching RE course [32]. The students can actively participate in their learning by playing different roles such as client and developer. Learning RE through role playing has successfully been adopted by several researchers that are [26, 33-35].

- ***Experiential learning:***

The experiential learning method provides students organizational experience in RE course by giving them an opportunity to experience a simulated work environment. Using this method, the students can learn RE practices by playing the educational games that simulate a business case and then discuss the problems faced in the game. The experiential learning approach in teaching RE course has successfully been adopted by [4, 36].

A few other methods that can help students in learning RE are just-in-time learning (teaching fundamental material immediately before teaching the application of that material), learning by failure (Students are given a very difficult task and then taught methods that would enable them in future to do the tasks more easily and self-study materials (Students work through their own schedule, it include online and computer-based learning) [37].

Assessment. The assessment should be performed in a way that promote integration of assessment and instruction, seeing the student as an active person who shares responsibility, reflects, collaborates and conducts a continuous dialogue with the teacher [38]. 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.

- ***Peer assessment***

Peer assessment is the process through which groups of individuals rate their peers [39]. Peer assessment may be in the form of informal feedback from group members or it may involve the use of rating instruments designed by lecturers or group heads before the peer assessment exercise. The peer assessment method is suggested and adopted by [20, 35] in their studies.

- ***Tutor assessment***

This is the normal form of assessment carried out at universities. However the suggested way of carrying out this method of assessment is bit different. Tutor assessment is carried out by lecturer who examines the documentation developed by each group in response to the tasks and projects assigned to them. There should be an assessed seminar in which groups of students discuss their solutions and the lecturer observes the quality of their discussions. At the end of seminar, the lecturer highlights the strengths and weaknesses of their solutions and provides feedback on the performance of students.

5 EVALUATION OF ALL-RE

The proposed ALL-RE model was evaluated using expert reviews. This evaluation study aimed at evaluating the effectiveness of ALL-RE model for teaching and learning RE course in universities. This section presents the

evaluation study in terms of participants, questionnaire, procedure used and results.

5.1 PARTICIPANTS

The target participants of this study were the lecturers experienced in teaching RE and the researchers doing research in RE. They can be considered RE experts because of their experience and knowledge in RE and it was expected that they can better respond to questionnaire. A total of 7 experts participated voluntarily in the study in response to an invitation by email. A brief profile of participants in presented in Table 1.

Table 1- Profile of the participants of evaluation study

No.	Position	Institution	Experience in years
01	Associate professor	Quaid-e-Awam university of Engineering, Science & Technology, Pakistan	12
02	Researcher	University of Malaya, Malaysia	05
03	Senior lecturer	University of Malaya, Malaysia	10
04	Assistant professor	Isra University, Pakistan	10
05	Assistant professor	Quaid-e-Awam university of Engineering, Science & Technology, Pakistan	07
06	Researcher	Mehran university of Engineering & Technology, Pakistan	06+
07	Researcher	Hanyang University, ERICA Campus, South Korea	06

5.2 Questionnaire

The questionnaire consists of following parts.

- In the first part of questionnaire, participants were asked their opinion about the importance of the elements related to RE teaching and learning material used in the model with the scale 5 (Most important) - 1 (Least important).
- In the second part of questionnaire, participants were asked their opinion about the importance of the elements related to RE teaching and learning methods used in the model with the scale 5 (Most important) - 1 (Least important).
- In the third part of questionnaire, the participant were asked their opinion about the possibility to provide the material and use the methods proposed in the model within the limited time and resources available at universities for teaching RE course. The scale used was 3 (Possible) - 1 (Not possible).
- In the fourth part of questionnaire, the participants were asked to rate the following in order to assess the effectiveness of the model with the scale 1 (Strongly agree) – 5 (Strongly disagree).
- The concepts used in the model are relevant to RE.
- The teaching and learning material and methods (if used in teaching) can help in addressing RE problems.
- The students will be able to understand RE well if proposed model is implemented.
- Overall the model (if implemented) is effective to address RE problems and teach RE course.
- Your suggestions for improving the framework (if any).

5.3 Procedure

The background material and details of the model along with the questionnaire were sent to participants through email and they were requested to go through the material and fill in the questionnaires.

5.4 Results

The results of each part of questionnaire is presented and discussed below.

5.4.1 Results from part 1 of questionnaire

The results obtained from the rating of the importance of the RE teaching and learning material elements used in the model are presented in the Fig. 3.

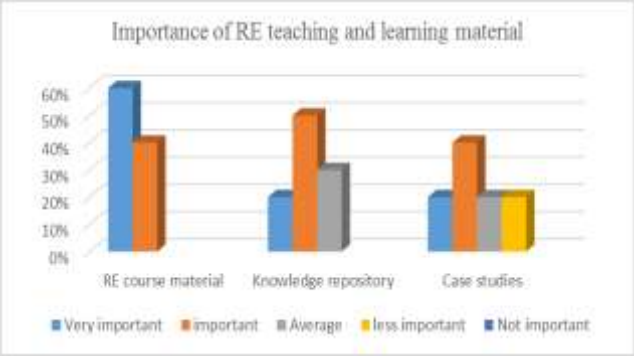

Figure-3 The ratings on importance of RE teaching and learning material

The results show that most of the experts feel the material used in the model as most important and important. Only few think the knowledge repository and case studies as average or less important. Hence, based on expert's opinions, the material used in the model can be considered acceptable.

5.4.2 Results from part 2 of questionnaire

The results obtained from the rating of the importance of the RE teaching and learning method elements used in the model are presented in Fig. 4.

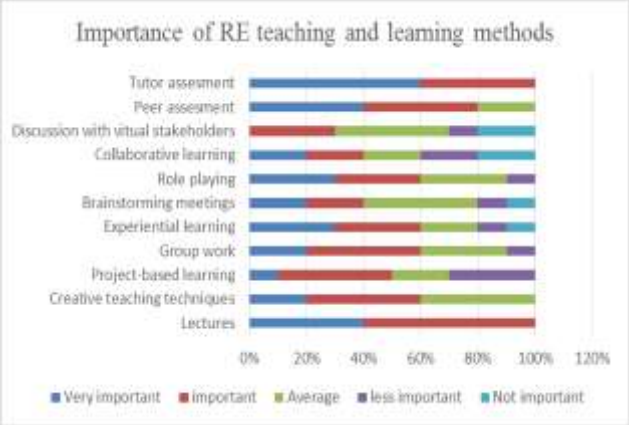

Figure- 4 The ratings on importance of RE teaching and learning material

The results show that according to experts, RE teaching and learning methods used in model are mostly important to be used in class rooms for teaching RE. Only few such as, discussion with virtual stakeholders, collaborative learning and experiential learning can be considered either less important or not important.

5.4.3 Results from part 3 of questionnaire

The results obtained from the rating of the possibility to provide the material and use the methods proposed in the model within the limited time and resources available at universities for teaching RE course are presented in Fig. 5.

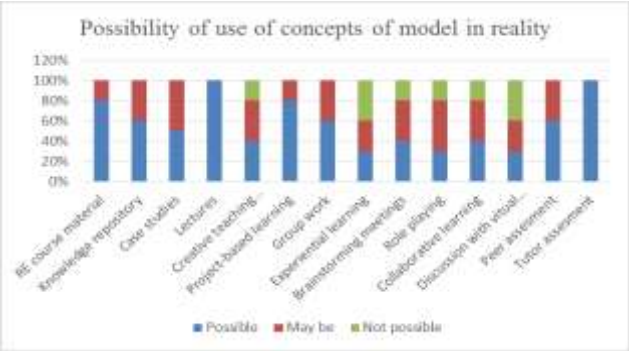

Figure-5 The possibility to use the material and methods proposed in model in RE course

The results show that according to experts, few teaching methods may not be possible to use in real class rooms such as creative teaching techniques, experiential learning, role playing, collaborative learning, discussion with virtual stakeholders etc. The possible reason can be the need of more time and resources in implementing such techniques. While the other well-known methods are possible to implement in class rooms.

5.4.4 Results from part 4 of questionnaire

The results obtained from the assessment of the effectiveness of the model is presented in Fig. 6.

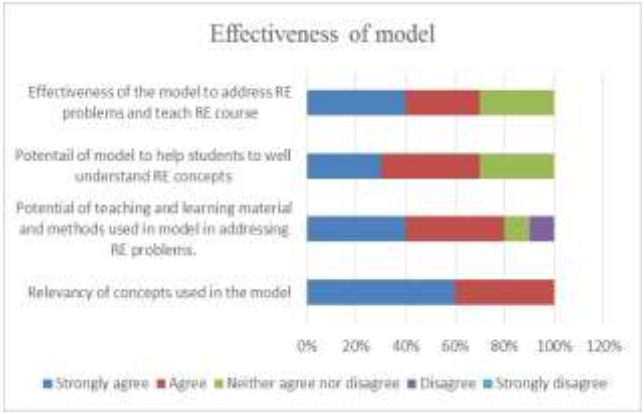

Figure-6 The ratings on effectiveness of model

The results show that the model can be considered effective based to 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.

5.4 Threats to validity

To ensure representative coverage, our subjects included lecturers and researchers of various levels of experiences, qualifications and backgrounds.

Clearly, an important limitation of the evaluation study involves the small sample size (only 7) and the relatively homogenous population (lecturers and researchers from three Asian countries). This severely limits the external validity of this study.

Fortunately, the goal of this study is to evaluate the learning model proposed for teaching RE. Because of the factors that the RE course is being taught using standard topics and due to the nature of RE, students and lecturers usually face similar problems in learning RE concepts. Therefore, it is expected that a replication of this study in a different site and/or with different size teams shall generate the same results. However, all the lecturers and researchers participated in the study are either involved in teaching RE course or in doing research in RE in different countries. Therefore the results can be generalized.

6 SUMMARY AND CONCLUSION

The paper analyses the status of teaching and learning RE course through the relationships depicted by edges of didactic triangle. The literature review of REE and the surveys performed on lecturers and students acted as the background of the analysis. The analyses results lead us to the need of a learning model for teaching RE that can improve the lacking in current teaching and assessment methods. A learning model named ALL-RE based on Activity-Led Learning (ALL) was then proposed to involve students as active learners by performing various activities and to involve lecturers as a facilitator by playing different roles. The proposed learning model includes teaching and learning materials as well as teaching and learning methods. It is suggested to include RE course material, knowledge repository and case studies in the teaching and learning material. While teaching and learning methods follow ALL's approach by including its three main elements that are teaching, learning and assessment. Teaching includes two methods that are lectures and creative teaching techniques. Learning includes an iterative cycle of various methods to emphasize more on learning at every stage of the course. While assessment include two methods that are peer assessment and tutor assessment. Therefore it can be said that the proposed model describes the way of improving teaching methods for learning RE course. The preliminary evaluation of ALL-RE 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.

It is supposed that proposed model will help the production of quality requirements engineers that possess RE skills. It can provide great support towards developing the right system with the right requirements for users. Also the proposed model, with some refinements, can be applied to any course relevant to software engineering discipline.

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