Moving Beyond the Classroom: Integrating Requirements Engineering Research & Education to Improve Practice

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Abstract

Requirements continue to be a major source of problems during development and maintenance of software-intensive systems. Requirements engineering researchers, educators, and practitioners seek to create, identify, and transfer solutions to these problems into practice. However, the lack of mechanisms to integrate these efforts negatively impacts their effectiveness in improving the state-of-the- practice. This paper is the first in a series of papers that proposes an intensive program of integrated research and education, embedded in practice, which has the likely outcome of making major progress towards the assimilation of the best new requirements engineering ideas into practice. The focus of this paper is on the educational aspects of this novel approach, which are designed to facilitate life-long learning and stimulate continuous improvement of requirements engineering practice.

1.0. Introduction

Too many of the problems industry encounters when trying to develop and maintain software-intensive systems can be directly attributed to problems with requirements. A continuing stream of studies (e.g., [1, 2, 3]) since the 1970's has shown that a large number of software-intensive projects result in product failures, and that many of these failures can be traced to poor requirements planning, poor requirements management, and poor handling of requirements change. As a result, Requirements Engineering (RE) researchers, educators, and practitioners continue to seek ways to solve these problems and improve the state-of-the-practice in RE. RE researchers create new theories, methodologies, methods, processes, guidelines, techniques, and tools to solve these problems; and then disseminate these new RE practices primarily through academic journals and conferences. RE educators develop courses based on requirements textbooks, as well as academic and/or trade publications; and then deliver those courses to students primarily in traditional classroom environments as part of Software Engineering (SE), Computer Science (CS) or Information Systems (IS) degree programs. RE practitioners seek solutions to their RE problems from the courses they took in college, through selected reading of primarily trade publications, or possibly by hiring consultants.

However, as evidenced by the problems that continue to be experienced in practice, this current approach to RE research and education is not as effective as desired in improving RE practice. This can partially be explained by the following potential disconnects between the efforts of RE researchers, educators, and practitioners:

- RE researchers are actively creating new practices to solve RE problems. In fact, the numbers of RE publications during the past 20 years is growing exponentially [4]. Yet, reports from the field indicate that little is changing in industry practice that is related to such research results. This disconnect between research and practice may occur if researchers do not understand the problems practitioners continue to encounter and are therefore solving the wrong problem [5]. Or, researchers may be disseminating results in a manner (e.g., outlet, content, or style) that is not accessible (or of interest) to practitioners or even educators. Or, they may not be validating their results and providing the evidence of effectiveness necessary to convince practitioners to adopt their research.
- RE educators have increased the depth and breadth of RE coverage in SE, CS and IS degree programs. However, improved RE education has not sufficiently penetrated the current practitioner population to achieve wide-spread improvements to the state-of-the-practice. This may simply take more time. Or, it may indicate a disconnect between education and practice caused by educators' focus on traditional delivery of courses to degree-seeking students that does not adequately address the needs of current practitioners for flexible, life-long learning opportunities. Some educators may find it

difficult to balance RE theory and practice and present RE to practitioners so that they can become agents of change and improve the state of practice in their organizations. There may also be a disconnect between research and education where educators are unable to identify those best practices from the myriad of RE research results which should be incorporated into their courses, so they are not providing practitioners with state-of-the-art RE practices.

- Many RE practitioners actively seek new RE practices to solve their requirements problems and improve their current practices, but often face significant constraints on the time available to do so. These time constraints only exacerbate the accessibility disconnects with research and education discussed previously. Furthermore, there are some practitioners who do not see the need for improved RE practices. This problem may indicate additional disconnects with research and education if they can not clearly demonstrate the value of the RE best practices to those practitioners.

Another complicating factor is that many RE practitioners (and even some RE researchers and educators) seek the "silver bullet" that will solve all requirements problems. There simply is no one so called "best practice" that will apply optimally to every system in every situation. Figure 1 shows the situational "best practice" approach to RE that provides a framework for our work and the ideal practice of RE.

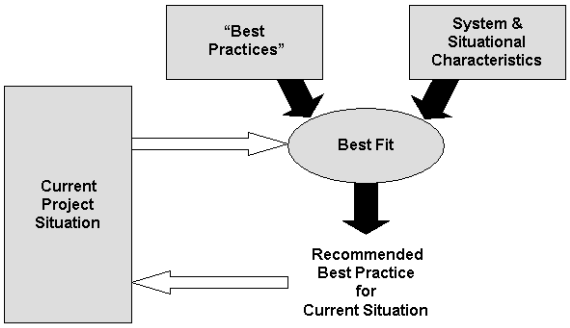

Figure 1. Requirements Engineering Framework

In the upper left center of this figure, we see a collection of existing requirements practices, i.e., methodologies, methods, processes, guidelines, techniques, and tools. Only those practices that have been validated as effective on real-world development projects will be considered as "Best Practices." Each of these practices is catalogued along with information concerning when it is most appropriate, how effective it has been in those situations, when it should not be used (i.e., its contraindications), and so on. These factors are shown in Figure 1 in the upper right box labeled "System and Situational Characteristics." When a project necessitates the use of RE, the current situation (rectangle on the left in the figure) is compared to the catalogued system and situational characteristics using a best-fit algorithm (oval in center of the figure). From this, the most appropriate practices are selected [6, 7, 8]. Once selected, these practices are then applied [9].

This paper is the first in a series of papers that proposes an intensive program of integrated research and education, firmly embedded in practice, to reduce the afore-mentioned disconnects between RE research, education, and practice and identify RE best practices along with their effectiveness and appropriate situations, as shown in the RE Framework (Figure 1). The ultimate objective of this program is to make major progress towards the assimilation of the best new requirements engineering ideas into practice.

The focus of this paper is on the educational components of our proposed integrated approach to RE research and education. These components are designed to facilitate life-long learning and stimulate continuous improvement of requirements engineering practice. The next section of the paper begins this focus on education by providing some basic background on software and requirements engineering education and defining our educational objectives as well as our long-term practice objective. Our integrated research and education approach is introduced in Section 3 with details provided in Section 4. Section 5 describes how we plan to implement and assess this approach. The paper concludes with Section 6 which briefly summarizes the potential contributions of the proposed project and the integrated research and education approach.

2. Background and Objectives

Software engineering education covers a wide range of topics, including requirements engineering. A number of conferences and colloquia have been focused on software engineering education, including the Conference on Software Engineering Education & Training (CSEE&T), the International Conference on Software Engineering: Education and Practice, the Conference on Software Engineering Education, and the IEE Colloquium on Software Engineering Education. In addition, a software engineering education track has been included in the International Conference on Software Engineering (ICSE). The IEEE International Conference on Requirements Engineering (RE) is adding a workshop on Requirements Engineering Education and Training (REET) this year. This level of interest indicates the importance the academic and industrial communities place on software and requirements engineering education.

One of the key challenges facing all software engineering educators is to balance theoretical aspects of software engineering concepts with practical application of those concepts; in other words, ensuring that the academic material has industrial relevance [10, 11] and takes into account new advances in the practice [12]. Striking an appropriate balance is a challenge that is facilitated by our approach. Because the educational methodology described below integrates module delivery with evaluation of current and improved RE practices within industrial environments, students will receive the benefit of both academic and industrial points of view. This leads us to our first educational objective:

- **Objective 1**. Ensure that the academic material in our RE education approach exhibits appropriate industrial relevance.

Others have pointed out the value of explicit interactions between industry and academia. Beckman, et al. [13] suggest that industry and academia can work together in the pursuit of educational goals, yielding both industry and academic benefits. The cited benefits include industry influence on academic programs, industry access to university research to improve competitiveness, and academic insights into corporate issues; our approach yields all three of these benefits. In our approach, students are also industrial practitioners. Because our educational component includes evaluation of current practices and improvement activities, students' organizations are expected to reap direct benefits from our approach, yielding our second educational objective:

- **Objective 2**. Ensure that organizations whose employees participate in the proposed RE education benefit from that participation.

To take advantage of the potential benefits, the number of industry and university collaborations focusing on software engineering education and training has increased over time [14]. We believe that the interactions between the researchers, educators, and industry representatives and other characteristics of our approach will constitute a significant and critical collaborative relationship.

Garlan, et al. [15] suggest that software engineering programs can help prepare students to be agents of change in their organizations. Practical application and analysis of the effectiveness of both current and improved practices are cornerstones of our approach, and by planning for, implementing, and evaluating improvements to current practice, every student will gain real-world experience as an agent of change in their organization.

Agents of change are faced with obstacles that may keep organizations from benefiting from the incentives associated with adopting new methods [16]. One of the strongest such incentives from a business standpoint is the potential for improved quality and productivity, but first practitioners must overcome the inertia resisting use of new methods. Because each improvement effort in our approach will be on a relatively small scale, we believe that these efforts will more effectively overcome such inertia. To ensure the validity of this belief we establish our final educational objective:

- **Objective 3**. Ensure that participants in our RE education approach can effectively act as agents of change.

Upon initial examination, it may seem that achieving Objectives 1 and 3 will automatically provide the answer to Objective 2. If the RE material presented has industrial relevance and the participants are effective RE agents of change, we would expect participating organizations to reap benefits from the improvement activities initiated by their participating employees. We choose, however, to retain Objective 2 as a separate objective to focus attention on this valuable component of our approach and to explicitly capture and evaluate information about these organizational benefits.

Finally, the primary goal of the proposed project is to conduct an innovative combination of research and education to identify RE best practices and improve the state of RE practice. However, what good are the RE best practices if they are not widely used by a broad spectrum of practitioners? And what good is this project if it doesn't have some long-term effect on how we build software-intensive systems? Thus, our long-term goal is to raise the level of requirements engineering practice for software-intensive system development, which results in a final, long-term objective relating to practice:

- **Long-Term Objective**: Ensure that the software-intensive system development industry benefits from the use of RE best practices introduced into practice by the proposed RE education approach.

3. Overall Approach

Our proposed approach is to analyze current RE research to populate the RE framework defined in Figure 1 with selected initial best practices, incorporate those best practices into the content of the RE educational modules, promulgate those practices to industry through those educational modules, and continuously update the best practices via metrics gathered during the promulgation process. The essential concept is to conduct research into RE best practices at the same time that we educate practitioners and improve the state-of-the-practice. Details of this integrated research and education approach embedded in real-world practice are shown in Figure 2. The ovals represent the specific research and education tasks we propose. The numbered arrows show the relationship of those tasks to practice. Detailed descriptions of the tasks and their relationships to practice are provided in Section 4.

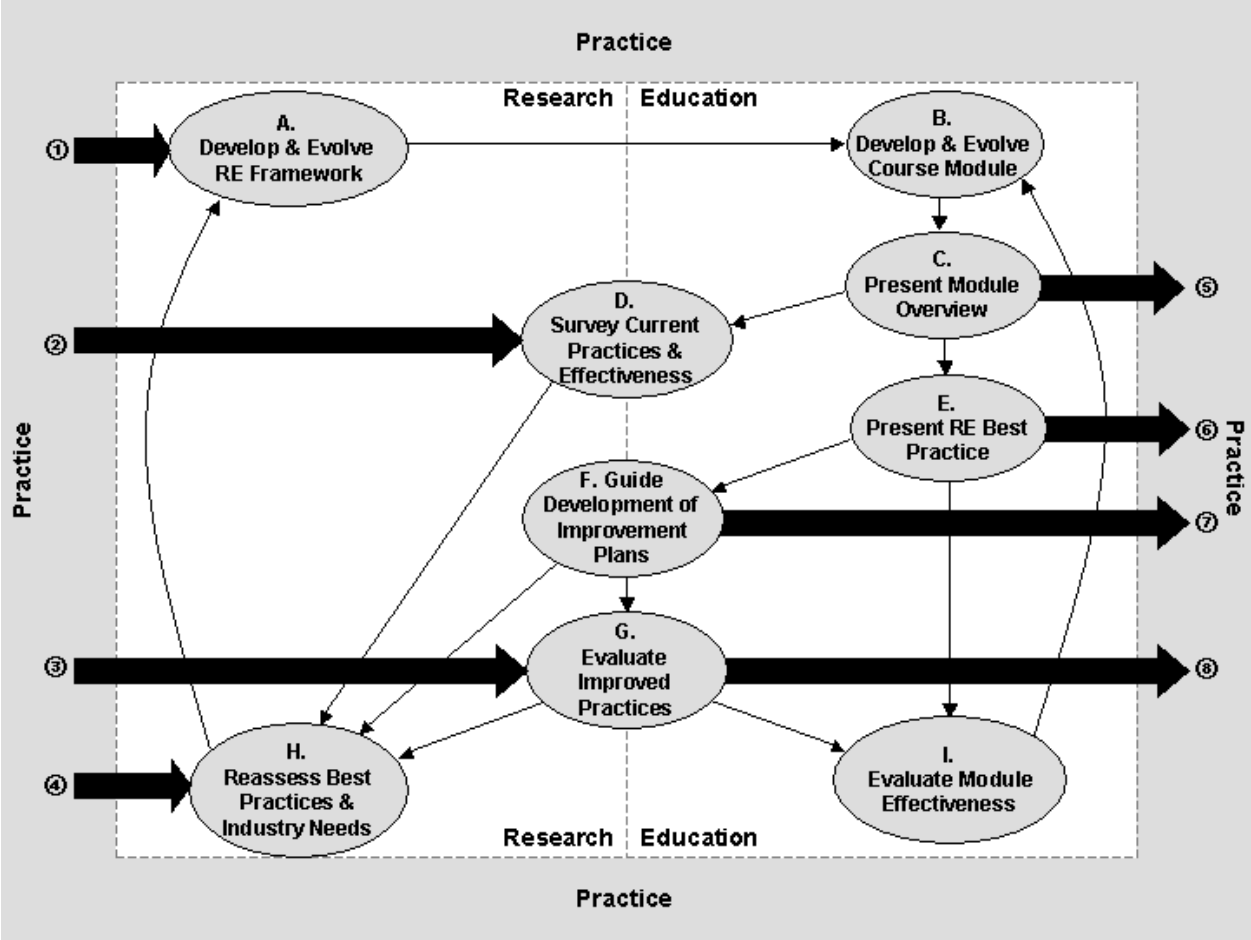

Figure 2. Integrated Research and Education Approach

This section of the paper provides an overview of our proposed approach from the perspectives of the participating practitioner, a single RE best practice, and RE researchers and educators. It also describes the key characteristics of our educational methodology.

3.1. Participating Practitioner Perspective

The primary emphasis of this approach is to provide a mechanism for life-long learning beyond the traditional classroom and degree program. Therefore, the targeted course participants will be current requirements practitioners. These practitioners will have the background and experience necessary to fully appreciate the situational nature of requirements engineering. They will also have direct access to their own organizations to implement and assess the RE practices under study. If non-practitioners are allowed to participate, they must be evaluated to ensure adequate background to successfully complete each course module. Arrangements will also need to be made to identify organizations willing to allow these students to implement and assess new RE practices. However, even if such arrangements can be made, these students will still be at a disadvantage because they will not have the prior project experience with that organization required for in-depth understanding of the situational context nor the long-term continuing relationship required to effectively evaluate the impact of proposed improvements over time. Therefore, we will continue to focus on our target audience, current requirements practitioners, and simply empower educators to tailor our approach for non-practitioners as their specific situations warrant.

From the perspective of a single practitioner, that individual will enroll in a course module corresponding to some RE practice. After being introduced to the practice by the module, the participant will assess the current state-of-the-practice within his/her organization, following guidelines provided by the research team. After completion of the course module, the participant will develop a “get well” plan that will define how he/she will implement the practice in the organization, what kind of

evidence the participant will produce, and how he/she will measure success. This plan will also detail the characteristics of the project, organization, and team that drove the participant to selection of this particular approach. Over the next few months, the participant will implement the plan, will prepare the requisite evidence, and report the experimental outcomes. Once completed, the participant will be given a certificate of course completion.

3.2. Single Practice Perspective

Initially, RE best practices will be identified and documented by the RE researchers and educators based on current literature and the research already conducted by the authors [17, 18, 19] and others (e.g., [20, 21, 22, 23, 24]). The RE practice will then be studied further to determine the situations and conditions under which the practice is most suitable and/or needs to be adapted. This will then be packaged as a course module to be used to promulgate the practice (and thus raise the state-of-the-practice). Meanwhile, feedback from participants concerning current state-of-the-practice and effectiveness (under specific conditions) of the practice in their organization will be used to evolve (a) the description of the RE practice, and (b) the course for future participants. As time continues, both the practice and the module will become validated by the data.

3.3. RE Researchers and Educators

Other RE researchers and educators will be able to develop their own course modules to promulgate their new research ideas and other RE best practices, after the initial modules have been developed, the integrated research and education approach is validated, and quality standards established for the educational modules. The resultant data collection can be used by the researchers to validate, refine, and/or perfect their ideas.

3.4. Education Methodology

The distinguishing features of our proposed educational approach include:

- Builds a strong connection between the module content and delivery and the evolutionary state of the practice in RE.
- Implements a unique, iterative approach to module delivery involving phases of topic coverage, practical application, and analysis of results.
- Integrates use of measurement and analysis templates for students to learn how to measure and evaluate changes in their state of the practice
- Facilitates continuous use of feedback for module improvement.

The 3 key characteristics of the methodology used in the educational component of our approach are: phased, on-line delivery of module material; integration of research and practice activities over the course of each module; and continuous refinement of module content and delivery approach. Each of these characteristics is discussed below.

Phased, On-line Delivery of Course Modules. In our approach, course content for each module will be delivered in two phases. Both phases will be delivered through on-line mechanisms such as MIT's recently announced free distance education software called Caddie.Net [25], rather than in a traditional classroom environment. Use of this approach has two main advantages. First, it will let the participants complete each module asynchronously at their own pace. Participants are no longer constrained by geography to near-by colleges or by job restrictions to courses that fit their travel schedules. On-line modules will allow participants to complete their course work where and when it is convenient – as essential feature when educating working professionals. Secondly, the distance education software will provide the tools needed to facilitate on-line chats, threaded discussions, and other interaction between faculty and students and among the students – which is essential to effective learning and is the key differentiator between this approach and simple correspondence courses.

Integration of Research and Practice Activities. The phased delivery of module material is interleaved with participant activities that combine research and practice aspects. In essence, the community of practitioners will be using the teaching platform to actively learn new RE practices. However, simultaneously, these same practitioners will be actively involved in creating the RE framework and defining RE best practices:

- After learning the basic contents of the course module, participants will survey the current practices in their organizational environments and evaluate the effectiveness of those practices.
- To successfully complete the course module, students will develop and implement plans to improve current practice in their own organizations and evaluate the effectiveness of those improvements.
- After participants implement those improvements and measure their effectiveness in their organizational environment, they will report the results of their improvement and measurement activities.

Continuous Refinement of Module Content and Delivery. Participants will also complete a formal module evaluation upon completion of the module. Informal feedback may also be solicited at key points during

module delivery. The third key characteristic of our methodology is the continuous refinement of module content and delivery based on these surveys. Initial development of each module will be based on a combination of our current understanding of the state of the practice in RE and the academic literature addressing techniques that could effectively be incorporated into the state of the practice. As described above, the integrated delivery of module material interleaved with student activities in their organizational environments yields real-world industrial measurement results. These results will be used to continuously refine the contents of each module to more accurately reflect both the current state of the practice and promising areas for improvement to those practices. In addition, we may also discover more effective means of delivering the module material based on student feedback and instructor evaluation.

The next section describes our integrated education and research approach and the specific tasks necessary to implement our proposed educational methodology.

4. Integrated RE Education and Research

4.1. Education and Research Tasks

The major tasks associated with the education component of the approach are discussed in detail below with brief summaries provided for research tasks. The detailed descriptions of the education component of combined Tasks D, F, and G are supplemented with a brief summary of the research aspect of the task.

Research Task A: Develop and Evolve RE Framework. The primary purpose of this task is to analyze available information from academia and industry to identify RE best practices, and the situational guidance needed to employ them effectively for incorporation into course modules. As mentioned earlier, evidence of effectiveness on real-world projects will be the primary criteria for identifying best practices. Our own research (and the research we built upon) also provides a strong foundation for identifying system, domain, and other situational characteristics that impact the appropriateness of a RE practice [7, 8, 9, 19].

Education Task B: Develop & Evolve Course Module. The initial development of each course module will be based on a combination of our current understanding of the state of the practice in RE and the academic literature addressing techniques that could effectively be incorporated into the state of the practice. After each module is completed, we will use our continuous feedback loop to identify improvements to the module content and delivery. Each of the modules will generally be relatively short. We will allocate to each module a subset of a hierarchy of requirements objectives so that the role of the module relative to the full RE world becomes clear to every participant. We expect the authors will serve as the primary course module developers for the first few modules. This will enable them to more easily perform quality control and to establish a common look-and-feel. After the first year, other academics as well as industry leaders could be solicited to develop further modules.

Education Task C: Present Module Overview. As described above, modules will be presented in two phases. In this first phase, participants are introduced to the RE concepts addressed by the module and the real and perceived problems associated with those concepts in practice. This phase will therefore serve to provide participants with a context for the module material, answering questions like “What issue(s) are we trying to address with this module?”, “Why is this important?”, and so on. After covering the concepts, we will work with participants to develop effective ways to survey current practices related to the module concepts and to measure the effectiveness of those practices. We expect this effort to be most time-consuming in the early implementation stages of our approach; over time, we expect to generate robust survey and measurement techniques to support these activities. We would therefore expect that later modules in our approach would include discussions of the advantages and disadvantages of the developed survey and measurement techniques rather than development of those techniques from scratch.

Education/Research Task D: Survey Current Practices & Effectiveness. From an educational perspective, the key components of this task are related to the survey instrument and evaluation of collected information. During this task, students will adapt and apply the survey instrument to effectively capture information about a project or projects in their organization using RE practices applicable to the current module. This adaptation will require both a good understanding of the kind of information captured by each survey question and analysis to decide which information is applicable for the current module. Evaluation of survey information collected will also require a strong understanding of these issues; because participants will provide an analysis of these survey results. From a research perspective, results of the survey will improve our understanding of current RE practice, the effectiveness of those practices, and the RE problems/challenges facing practitioners.

Education Task E: Present RE Practice. In the second phase of module delivery, current practice and proposed new practices are presented and discussed. We will then work with the participants to devise reasonable plans to improve the state of the practice at their organizations and to measure the effectiveness of those improvements. Initial efforts in this area will consist of building templates for the steps required for reasonable

improvement efforts and valid measurement approaches to evaluate the effectiveness of the implemented improvements. As in the case of the previous activity, we expect the effort in the early implementation stages to be focused on the development of these templates; later modules in our approach would include discussions of the advantages and disadvantages of the developed templates.

Education/Research Task F: Guide Development of Improvement Plans. For this task, participants will develop a plan to improve their requirements practices. Successfully planning for improvements will require that participants understand the issues associated with process improvement in general and the specific environmental factors likely to affect improvement efforts in their organizations. Participants must learn the importance of basing improvement efforts on real data; for that reason, they will need to identify appropriate metrics and plan their data collection approach to accurately assess their improvement efforts. Our intent is to provide participants with the required information and the skills needed to accomplish an effective improvement effort prior to this task. Module instructors will be available to guide the participants. From a research perspective, analysis of the improvement plans developed by students will provide additional empirical evidence on the problems they are facing and insight into which RE practices are applicable to their situations.

Education/Research Task G: Evaluate Improved Practices. The evaluation of the effectiveness of improvement efforts will educate participants in a number of ways. Careful consideration of collected data and metrics will help develop analytical skills that can be used whenever participants are making decisions. Reflection on effective and ineffective components of the improvement effort will help participants learn about specific factors affecting the success of improvement efforts, Finally, participants will learn through evaluation of the improved practices whether or not their specific practice change actually leads to an improvement. It is certainly the case that some ideas for improvement will not turn out to be as effective as expected; but we note that even failed improvement efforts yield important information. From a research perspective, analysis of the results of these evaluations will provide additional insight into the effectiveness of RE practices in specific project situations.

Research Task H: Reassess RE Practices and Needs. This task is an analytical and integration activity completed by researchers. The researchers will integrate the empirical results of tasks D, F and G to refine the RE framework defining best practices and appropriate situational guidance.

Education Task I: Evaluate Module Effectiveness. This is the continuous improvement feedback loop for the module itself. Module effectiveness will be evaluated through participant surveys, applicable metrics, and improvement results. Based on the evaluation of the module effectiveness, we will identify potential changes to improve the module. Modules will be modified based on evolving information about the state of the practice that is provided both through the participant surveys of current practices and their exploration of improved practices.

4.2. Relationship to Practice

The education and research tasks shown in Figure 2 are clearly embedded in practice. As shown by the bold arrows in Figure 2, research tasks depend on input from practice while education tasks produce output (improvements) to practice. The association of these tasks to practice are (bold **NUMBERS** in discussion below refer to the circled numbers on the bold arrows in Figure 2):

- Practice will influence research tasks through: analysis of the existing practitioner literature (**1**) which will complement the academic literature and aid in initial development of the RE framework (Task A); assessment of the effectiveness of RE practices by course participants (**2, 3**) during the survey of current (Task D) and improved (Task G) practices; and comparison of assessments and improvements plans by from course participants (**4**), to reassess the RE Framework (Task H).
- Education will improve the state of the practice (continually) (**5, 6**) by teaching RE practices to the course participants (Tasks C and E).
- Education will improve the state of the practice (continually) (**7, 8**) by empowering all course participants to solicit organizational support and apply what they learned in the modules to their workplace (Tasks F and G).

It is through such a close interplay between researchers and practitioners (as proposed by Potts [26]) that we expect to overcome the most common barriers to requirements technology transfer [16, 17, 18, 27].

5. Implementation and Assessment

5.1. Implementation Plan

Initially, we envision a three-year implementation plan During those first three years, the RE educational modules grow in two directions: toward more coverage of material (i.e., creation of more modules) and toward more impact (i.e., taught to more people), as shown in Figure 3.

Assessment of the effectiveness of the educational approach, as described in the following section, will begin on a small scale in Year 1, and be implemented fully by Year 2. Section 5.2 describes the longer-term approach

required for assessing the impacts on practice. Starting in Year 3, we anticipate that our integrated approach and the platform can be used by other RE researchers and educators to develop new course modules based on module guidelines and quality standards developed during in the first two years of the project.

Table 1 shows a small subset of the topics to be covered by the modules that could possibly be developed during the first 3 years. Modules will be developed to allow practitioners to focus on topics applicable to their specific situation and projects, which can span the spectrum from RE for development of custom software to commercial software to the RE needed for acquisition, implementation, and/or integration of that software. It is envisioned that while there may be a few introductory modules which must be taken first by all practitioners, the selection and completion sequence of the majority of the modules will be tailorable to the highly variable needs of the individual practitioners.

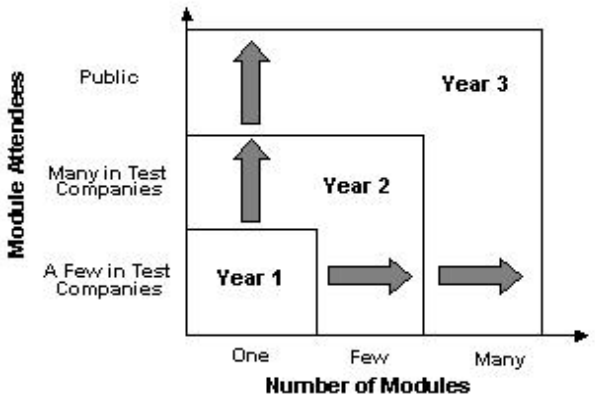

Figure 3. Growth of Educational Modules

5.2. Assessment of Educational Objectives

An integral part of our approach is to simultaneously assess achievement of the educational objectives we defined in Section 2. Planned assessment activities for each objective are as follows:

- ***Objective 1.*** *Ensure that the academic material in our RE education approach exhibits appropriate industrial relevance.* We will use a variety of surveys to evaluate the industrial relevance of our modules. The surveys that participants complete at the end of each module will include questions designed to evaluate the industrial relevance of material presented in the module. We will also regularly solicit survey feedback from the participating organizations. The questions on these surveys will be of necessity at a higher level than those on the participant surveys, but should still provide valuable information about the industrial relevance of the material presented through our modules.
- ***Objective 2.*** *Ensure that organizations whose employees participate in the proposed RE education benefit from that participation.* We will measure the extent of organizational benefits through organizational survey questions and through the reports of improvement results provided by each participant. The organizational surveys discussed above will also include questions designed to quantify the benefits the participant's organization has received as a result of participating in our approach. These responses will primarily be subjective. We will also access the objective measurements included in each participant's report on their improvement results. These reports will contain specific, quantitative information about the effectiveness of the implemented improved practices, thereby providing an objective measure of the benefits received by the organization as a direct result of participants' improvement efforts.
- ***Objective 3****. Ensure that participants in our RE education approach can effectively act as agents of change.* We will assess achievement of this objective using the same mechanisms discussed above: organizational surveys and participant reports. Questions on the organizational surveys will be designed to assess the effectiveness as an agent of change for each of that organization's participants. The participant reports will be used to assess effectiveness as an agent of change through both the reported improvement results and the more subjective participant description of the issues that supported or hindered the improvement efforts and how the participant addressed those issues.

5.3. Assessment of Long-Term Practice Objective

The long-term outcome of the successful execution of the proposed research is an increase in the effectiveness of software-system development efforts through an enriched understanding and application of proven RE principles. Although this outcome is not expected to be significant during the first three years, certain activities during this period can facilitate the subsequent collection and analysis of data. Over a period of five to ten years, we should see significant changes in the quality of *incoming* participants. For example, we should witness an increase in the use of RE best practices within organizations. During the first three years, we will collect sufficient data so that we have a clear *baseline* on the practices of industry. This baseline can then be used later for comparison to later timeframes.

Table 1. Representative Sample of Potential RE Course Modules

General RE Topics	Tailoring RE for Specific Environments
• Introduction to Requirements Management • Making the Business Case for Requirements • Measuring and Improving Requirements Quality and Productivity	• Analyzing System & Situational Characteristics • RE in a Systems Engineering Environment • RE for Life and Safety-Critical Systems • RE for Business Applications
RE practices For General Use	**Specific RE Practices to Support Individual Requirements Activities or Specific Environments**
• RE Practices for Elicitation and Analysis • Modeling in RE • RE Practices for Triage • RE Practices for Specification and V&V • RE Practices for Transition to Design; Testing • RE Practices for Non-Functional Requirements • RE Practices for Interacting with Stakeholders • RE Practices for Managing Change	• Facilitating Collaborative Requirements Workshops • Resolving Requirements Conflicts • Structured Analysis; Object-Oriented Analysis • Modeling with UML • Modeling with Statecharts; Petri Nets; …. • Balancing Requirements, Schedule & Budget

In addition, we will be collecting demographic data that should also show a trend toward increasing market penetration. For example, we could collect data on:

- What percentage of known RE best practices have had course modules developed and delivered?
- What percentage of existing course modules have been taken by each participant?
- What percentage of companies building software-intensive systems have enrolled at least one employee in at least one course module?

6. Conclusions

Identifying and using the best practices in RE is essential to the successful development of software-intensive systems, for without a solid understanding of user needs and desired external system behaviors, it is impossible to intelligently proceed with development. Without effective RE practices, developers may create systems that perform remarkably well, but perform the wrong functions. The proposed project is designed to develop and disseminate RE best practices through a novel, integrated research and education methodology, embedded in real-world practice. The integrated approach has been designed to deliver the following educational contributions, which will guide the actual implementation of this approach:

- Create an integrated research and education test bed for educating practitioners, collecting empirical evidence of the effectiveness of RE best practices, and empowering practitioners to implement those practices in their organizations.
- Define and evaluate a phased, on-line delivery mechanism for course content that interleaves education, research, and practice activities to enhance learning and facilitate implementation of RE best practices.
- Provide a standardized process for assessing the effectiveness of current and proposed RE best practices for use by researchers, educators and practitioners to assess and improve requirements practices and, as a result, the state-of-the-practice.
- Extend RE education beyond the traditional classroom and degree-seeking student to practitioners, enabling the life-long learning so critical to rapidly changing disciplines like RE.
- Educate practitioners on the use of effective requirements practices, and as a result, improved the state-of-the-practice.
- Educate practitioners on the use of assessments to improve requirements practices and, as a result, the state-of-the-practice.
- Define a new, balanced curriculum for requirements engineers based on RE best practices.
- Develop and evaluate the first set of course modules of that curriculum.

One of the most significant planned contributions of this project is the establishment of a test bed for integrating RE research and education that directly impacts practice. While essential for the development and dissemination of RE best practices, this test bed need not be limited to RE. This framework is designed to be a reusable resource that is general enough that it can be easily extended to support research and education in any Software Engineering area.

Finally, software-intensive systems are now deployed in every aspect of human endeavor from national security to game playing. Here is a summary of a few of the broader impacts we are targeting for this approach which, again, will guide the implementation of the proposed integrated education and research approach:

- Broaden participation of under-represented groups. The on-line delivery mechanism for modules will broaden participation to full-time working professionals including members of under-represented groups who may not have the opportunity to attend traditional, on-campus classes.
- Broaden dissemination to enhance scientific and technological understanding through deployment of educational modules; publication of results in requirements research, software engineering education, and practitioner journals; and participation in joint academic/practitioner conferences such as the *IEEE International Requirements Engineering Conference* as well as practitioner-focused conferences like *Software Developer-East/West*, and education-focused conferences like the *Conference on Software Education and Training*.

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