The Evaluation of a Requirements Engineering Training Program at Siemens
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Abstract
In 2003, the Software & Engineering department (S&E) at Siemens Corporate Research (SCR) initiated the training of Siemens employees worldwide in requirements engineering (RE). The first courses taught were customized for the target audience and taught on-site. In 2005, a standardized foundation course was created; the first course in a suite of offerings. To date, the course has been taught to over 200 Siemens professionals worldwide. In order to determine the impact of the training at Siemens, and to improve the course, a survey was conducted and the results are reported in this paper, along with an analysis of our findings.

1. Introduction
The S&E department at SCR has a long history of providing training workshops to Siemens professionals in architecture, programming languages, platforms and quality assurance. In 2003, training was expanded to include courses in requirements engineering (RE). In early 2005, RE was added as a program to SCR. As part of that program a set of training courses was created.

Learning Campus (LC) is the official training organization for Siemens. Learning Campus is responsible for providing all internal training with the exception of any operating company-specific or product-related training content [1]. In order to teach officially recognized courses within the Siemens family, the courses have to meet certain LC guidelines, and the instructors have to be registered. Consequently, the RE curriculum was created taught and revised through Learning Campus.

After each class, the students filled out feedback forms which generally gave high marks to the presenters and the material. For example, in the course given in January 2007, 50% of the students rated it “Excellent” and 50% rated it “Very Good”, with other possible ratings being “Fair”, “Poor” and “No Opinion”. Other researchers and practitioners have reported anecdotally that RE training is popular and effective [2][3]. In early 2007 SCR created an internal survey that was sent to all graduates of the Foundation RE Course (described below) to quantify any benefits to Siemens from the material that is, should the foundation training for a product manager be different than the training for a requirements analyst? Furthermore, it was hoped that the survey would provide useful information for both industry and academia:

- What subjects are not being taught at the undergraduate level that is needed by professional staff?
- Who benefits from internal RE training, e.g. is it only for analysts?
- Can internal RE training successfully teach skills not learned at university?
- Is the material taught in internal RE courses relevant, retained and used over time?

2. The Foundation RE Course
The foundation RE course is the first course in a series of courses offered by SCR, and is the prerequisite for taking any of the other courses. Other topics taught include advanced requirements writing, model driven RE, and advanced requirements management. The foundation course has evolved since its inception. The purpose of the course is to introduce the students to the field of requirements engineering and to cover all the major topics lightly so that there is a fundamental understanding of what kinds of skills are needed for each role. The course was assembled using in-house staff; however we did retain outside expertise to develop some of the content. Three individuals deserve special mention. Professor Dan Berry of the University of Waterloo [4] created the module on requirements writing, with some of the material provided by Professor Jane Cleland-Huang of DePaul University [5]. Professor Huang also provided course content on traceability. Dr. Jeremy Dick also provided material on rich traceability from his popular requirements engineering text [6].

Initially, material was included on International Organization for Standardization (ISO) 9003-2004 and the Software Engineering Institute (SEI) Capability Maturity Model Integration (CMMI) assessments. The material was later deleted as Siemens courses on ISO and CMMI were being taught by Siemens Corporate Technology, the parent organization of SCR.
2.1. Course Content and Duration

It was found empirically that three days was the longest period of time that professionals could break away from their work for training. Any longer than that and our enrollment dropped off sharply. Any less and the topics could not be adequately covered, even in a cursory fashion.

The course included content on product lines and product features, such as feature modeling, marketing, such as Kano and goal modeling, analysis, elicitation, management, conducting reviews and effective requirements writing.

The course was assembled from modules, where each module was either one quarter, one half or a whole day. Modularization had several advantages; the modules could be reused in custom courses, taught as a unit by instructors familiar with the material, and associated with module specific team exercises. Furthermore, the analysis module included material on hazard analysis, threat modeling, and reliability theory while the management topic included a detailed discussion of traceability.

For team exercises, the class was split into teams of 3-5 students. The exercises had continuity, that is a feature model for a product would be created by the students, and that would be the starting point for the remaining team exercises. The teams would spend about 20-30 minutes doing their exercise, followed by a spokesperson for each team presenting the results. Finally, the class would comment on and critique the results of each team. The total length of a team exercise was approximately 45 minutes. In order to increase contact instruction time, the exercises were usually coupled with a class break or lunch.

Initially, advanced topics were included in the modules, but in order to better focus on the basics, the advanced and research topics were moved to an appendix of the course notes so that the student could optionally read the material on his or her own. In one or two of the classes taught in Europe, the students were offered the opportunity to voluntarily stay after hours to discuss some of the advanced topics; several of the instructors were conducting research in specific areas and were very knowledgeable in their fields.

A summary of the course material is shown in Table 1.

Table 1 Summary of Course Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Duration</th>
<th>Team Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Types of Requirements</td>
<td>1.5 hours</td>
<td></td>
</tr>
<tr>
<td>Requirement Quality Attributes</td>
<td>1.5 hours</td>
<td>Roll up competition quiz</td>
</tr>
<tr>
<td>Requirements Elicitation</td>
<td>1.5 hours</td>
<td>Brainstorming Exercise</td>
</tr>
<tr>
<td>Requirements Analysis</td>
<td>1.5 hours</td>
<td>Critical Requirement Review</td>
</tr>
<tr>
<td>Requirements Reviews</td>
<td>1.5 hours</td>
<td>Feature modeling and problem solving</td>
</tr>
<tr>
<td>Requirements Management</td>
<td>1.5 hours</td>
<td></td>
</tr>
<tr>
<td>Product Lines</td>
<td>Half day</td>
<td></td>
</tr>
<tr>
<td>Requirements Writing</td>
<td>All Day</td>
<td>Several team writing exercises</td>
</tr>
</tbody>
</table>

Only the major team exercises are shown in table 1, however the entire course had short class exercises after each topic. It was found that the educational pattern of concept->example->class exercise resulted in optimal retention of the material by students.

It was found by evaluating the course feedback forms that experienced professionals who also had good teaching skills made the best instructors. This may seem obvious, but there were occasions when experts without prior teaching experience were offered the opportunity to teach a module; professionals in other software engineering disciplines were occasionally permitted to teach a module or two in the foundation course to determine whether senior staff without operational RE experience could augment the RE teaching staff. It became very clear that the optimal teaching situation for the foundation course was where there were at least two instructors with teaching and practical RE experience.

3. Survey Constraints

An online questionnaire was created using Survey Monkey [7]. A link to the survey was sent via e-mail to all past students of the course in both the United States and Europe. Our marketing department advised us to limit the survey to as few questions as possible. After

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1 6 contact hours in a day
several revisions we determined that the 10 questions described below would provide the needed information; any more than that and there was concern that not enough Siemens professionals would respond to obtain statistically meaningful results.

3.1. Types of Questions
Questions dealt with the role of the student at Siemens, what was learned and applied in the workplace, what content the students felt was important in retrospect, whether time and money was been saved on projects since taking the course, and suggestions for future courses.

3.2. Structure of the Survey
Every question was one-dimensional. For example, “Did the course save you time?” or “Did the course save you money?” as opposed to “Did the course save you time and money?” Numerical and closed ended (multiple choice, categorical, scaled, ordinal) questions were posed rather than written response questions - these types were easier to answer and analyze. However, the respondents were given the opportunity to add comments to the survey.

3.3. Survey Questions
The questions asked in the survey were:

1. What was the role of the respondent (only one permitted)?
2. What was the Siemens Organization of the Respondent?
3. How often the participant uses the information that was learned during the RE Foundations Course (the choices were never, 1-3 times a month, once a week, 2-3 times a week and once a day or more).
4. Which topics had the participant used since taking the course?
5. How long ago did the respondent take the course?
6. How much money had been saved over time by using the course material?
7. How much of a reduction in effort in percentage was achieved by using the material learned from the course?
8. How significant were the topics taught to the respondent’s work, where each topic had a scale option and the participant chose a number from 1 to 5.
9. Which topic was most important and which was least important (done using check boxes)?
10. What future courses would the respondent be interested in attending (using check boxes and write-in)?

Table 2 Survey Mailing and Responses

<table>
<thead>
<tr>
<th>Students</th>
<th>Sent</th>
<th>Undeliverable</th>
<th>Received</th>
</tr>
</thead>
<tbody>
<tr>
<td>American</td>
<td>128</td>
<td>13</td>
<td>115</td>
</tr>
<tr>
<td>European</td>
<td>41</td>
<td>1</td>
<td>40</td>
</tr>
<tr>
<td>TOTAL</td>
<td>169</td>
<td>14</td>
<td>155</td>
</tr>
</tbody>
</table>

3.4. Response to Survey
Table 2 shows the number of respondents surveyed. The response rate vs. time is shown in Figure 1. One hundred sixty nine requests to take the survey were sent to students who have taken our course. Fourteen were undeliverable due to staff turnover and divestiture. A total of fifty four Siemens employees responded to the survey, for a response rate of 35%.

Of the respondents, 29 were engineers, RE, developers, etc., 3 were from marketing, 10 were management, 6 were consultants, 1 was an administrator, and 6 were “other” using the write-in field.

4. Survey Results
The results of the survey were quite interesting. We were initially disappointed in the low response rate until our marketing department informed us that the number of responses 33% was just about average [8].

Figure 2 shows the rollup of the most important topic, regardless of a respondent’s role. There are no surprises, except that the coverage of hazard analysis and threat modeling received higher marks than we had anticipated. In retrospect, this makes sense as Siemens manufactures products in the medical and transportation domains where conducting a hazard analysis is mandated by regulation.

4.1. Most Important Topic Overall

![Figure 2 Most Important Topics](image-url)
Leading the topics as most important to the students was requirements writing, something that is sometimes neglected in academic programs; an area where the students universally appreciated the training.

One reason we feel that this topic ranked high was the fact that it was covered in greater detail than any of the other material, a full day of requirements writing training was included in the course. Because of the assistance of Professors Berry and Cleland-Huang, the training material was of very high quality. Even relatively jaded RE professionals were kept interested by techniques such as the use of different terminology and document partitioning to distinguish the environment and the interface(s) from the system being specified. [Jackson and Zave]

4.2. Most Important Topic by Role

The most important topic by role showed a very different picture, shown in Figure 3. While requirements writing was the overall winner in terms of popularity, it was not the favorite for all types of roles. For example, product managers found the product line material most important, while staff in consulting roles found the requirements writing aspects of proposals and requests for proposals of most interest.

The topics considered less important highlight one of the dilemmas of teaching an industrial foundation course. While reliability theory is needed only infrequently, only 1.8% of the respondents felt it was important, a misunderstanding or lack of knowledge of the topic when it is needed can be catastrophic.

4.3. Use Of The Material On The Job

It was hoped that questions on productivity increase and savings from use of the material would provide some insight into the return on investment from providing requirements engineering courses.

Two respondents reported savings based on the training of just under $100,000 per year. Every other respondent reported that they were unable to provide any data on financial savings.

Many of the respondents reported using the material learned in the course frequently (Figure 4), possibly enough to justify the cost of sending people to the training. However, one of the most interesting responses was to the question on productivity improvement. A significant number of respondents reported productivity
increases of 10-30% using the material learned from the course (Figure 5). Since we could not verify any of the respondent’s answers, the numbers reported have to be considered anecdotal, and cannot be used in cost savings calculations.

4.4. Respondent Comments
Most respondents did not add additional comments. The few comments added did not have any commonality and so could not be used to plan course improvements. The feedback forms completed after each course did a better job in that area. However, two of the comments submitted are worth mentioning:

**From an engineer:** “I recommend NOT dropping any subject currently taught, due to being “least important”. Importance may be linked to use; such as Kano Modeling, Tracing, and Reliability Theory. I’m glad all three were taught. If I ever need them, I have the materials. I would not know they exist, if they weren’t taught.”

**From an analyst:** “Toward the end [of the course] we used an actual example of an attendee’s requirements. If possible, more “real life” examples from attendees’ current work would help make the class more immediately impactful.”

5. Analysis of Results
It is apparent from the responses to the survey that one area where the training of new staff is both necessary and appreciated is effective requirements writing. Misconceptions about the skills necessary to create high quality product specifications result in marketing staff, engineers, developers and subject matter experts (e.g. medical doctors and nurses) writing requirements documents with minimal training. Furthermore only a small fraction of the technical personnel (even at senior levels) hired by Siemens have the requisite skills to function as senior requirements engineers without some ancillary training.

One open issue is whether the foundation course should be partitioned into several different courses, in which there would be a heavier emphasis on doing, e.g. a separate course on hazard analysis. Partitioning was considered during course creation, however, in the real corporate world, we often get one and only one opportunity to give a student any training, and by lightly covering material, we make the student aware of the material. If additional training is useful, we can provide advanced courses or on-site mentoring.

We found that having students with different roles in the same course was a plus, as reflected in the survey results. For example, analysts might not understand the value of feature modeling or product planning in a course of all analysts; however when the analysts had an opportunity to interact with product and product line managers everyone gained from the experience. Each role could see the value of the other roles’ activities and techniques.

Some of the survey results were counterintuitive. For example, marketing staff found the hazard/risk analysis and threat modeling material very useful after the course, while engineers and analysts did not seem to need it.

Nearly all the roles found the common set of basic definitions and quality attributes for requirements useful, even though most of the Siemens companies already had such sets of definitions; the quality attributes were, for the most part, those found in IEEE Standard 830-1998 [9].

6. Conclusions
The foundation course is clearly valuable to the respondents. Depending on their role, 96% of them used the material they had learned at least a few times a month, and 84% of the attendees used the skills learned in the course at least once a week.

Optimizing training by providing in-depth single topic courses must be balanced against the difficulty that Siemens professionals have of breaking away from their work to attend training. While the students clearly appreciate the more focused material on requirements writing, many of them also recognize the need to know what other techniques are available if and when they should be needed.

We looked at our findings in the context of the Kirkpatrick four-level model [10]. Our feedback form instantly gave us level one results (reactions), universally positive, as mentioned in the introduction.

Level two information (learning) was obtained by observing the team exercises and reviewing the material
with the students post exercise. Keeping team sizes small also helped.

Level three (transfer) results were obtained from the survey are shown in Figure 5.

Level four (financials) results could not be obtained from the survey. Determining a rate of return for RE training appears to be a difficult undertaking. This confirms the observation of Kirkpatrick and others that as the level increases, it becomes more difficult to take measurements. Analysts whose skills improve in writing and reviewing requirements may not have access to the information necessary to determine whether the training they received has resulted in a net gain for Siemens. Rather, we have found that doing a root cause analysis of software defects before and [several months] after training is a better way to measure savings [11].

Anecdotally, it appears that our requirements engineering industrial training is working, as the majority of the course attendees that responded to our survey are using the material they learned on a regular basis.

Clearly, our findings and the findings of others [12] strongly indicate that industry would benefit from technical undergraduate programs, including business, marketing and sales, as well as formal requirements engineering training. University identification of RE as core material would help to dispel the perception that we and other researchers such as Madhavji have observed that RE is not perceived important to many software engineering lifecycle roles.

As mentioned above, everyone who took the course benefited from some aspects of the material. Furthermore the mixing of different roles in the course provided additional unexpected benefits, e.g. marketing staff and software developers had an increased understanding of each others needs.

7. Future Research

We intend to continue observing course graduates and their contribution to the software lifecycle to try to determine real savings in software improvement. We are also currently teaching RE as part of an internal architecture certification program; after several training cycles we hope to observe the impact of our courses on senior level architects at Siemens.

8. Acknowledgements

The authors wish to acknowledge the role of several Siemens colleagues. We thank Dr. Juergen Kazmeier for having the foresight to establish a focus program in requirements engineering; Dr. Arnold Rudorfer for championing the development of the training program; and especially to all our instructors including Dr. Oliver Creighton, Dr. Helmut Degen, Dr. Bea Hwong, Anne Hoffman, Dr. Sascha Konrad, and Dr. Pei Feng.

9. References