

Former Students' Perception of Improvement Potential of Requirements Engineering in Practice

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Abstract—Several authors have pointed out a significant gap between Requirements Engineering (RE) theory and practice. It is then natural that we try to find answers to questions such as: What is the nature of the gap? Which is the magnitude of the gap? Why does the gap exist? and What could be done to narrow the gap? In this paper, we try to answer those questions from the point of view of the former students of a RE course that have been involved in projects with a significant RE activity. We have surveyed over 70 former students to know how they perceive the degree to which a set of six RE artifacts are created in practice, and how they perceive the improvement potential of the creation of those artifacts in practice.

For each artifact, we asked a question on the use of the artifact, and one on the recommendation of use of the artifact. The usage question aimed at knowing the degree to which the artifact is explicitly created in practice. The recommendation question aimed at knowing whether or not the respondent would have recommended the creation of the artifact when it was not created. We believe that there may be an improvement opportunity of the RE practice when a significant number of respondents would have recommended the creation of an artifact in the cases in which it was not created. In the paper, we report the results of the survey. We try to identify the reasons why the artifacts were not created, and what would be needed to convince stakeholders and developers to create the artifact, when it is recommended to do it. Finally, we point out a few implications for RE practice and research that are suggested by the results of the survey.

Keywords-RE practice; survey;

I. INTRODUCTION

Several authors have pointed out a concern among researchers about a significant gap between Requirements Engineering (RE) theory and practice [1], [2], [3], [4]. If we accept that the gap exists, it is then natural that we try to find answers to questions such as: *Which is the nature of the gap? Which is the magnitude of the gap? Why does the gap exist?* and *What could be done to narrow the gap?*

There have been several attempts to respond to those questions. [5] presents a multiple case study with 60 companies that draws 7 key issues in RE practice, with recommendations for their successful implementation. In [1] a state-of-the-practice survey is presented for RE in 12 SMEs, stating that technology transfer in RE was marginal for these companies, and revealing 3 key RE development needs for the

future. To determine the actual use of conceptual modeling by practitioners and the most popular techniques and tools, [6] undertook an empirical study in Australia. [7] presents a qualitative study on 16 companies using agile software development approaches. [8] presents the analysis of in-depth interviews with 26 experienced conceptual modelers, and a descriptive theory of such practice. A diagnostic study of very small software companies in Chile is presented in [4]. [3] presents a survey assessing RE practice in 27 Malaysian software firms, where most practicing professionals are graduated from the local educational institutions. A similar survey for New Zealand is presented in [9], where results are analyzed and benchmarked with best practices and with previous studies from Australia and New Zealand. Finally, [10] reports the results of a survey of business analysts designed to investigate the eventual mismatch between RE education, training and practice, with a total of 9 preventing factors, with their implications for improvement.

In this paper, we try to answer those questions from the point of view of the former students of a RE course that are, or have been, involved in projects with a significant RE activity. To this end, we have surveyed over 70 former students to know how they perceive the degree to which a representative set of RE artifacts are created in practice, and how they perceive the improvement potential of the creation of those artifacts in practice. In the literature, there are reports of surveys on former students' perceptions of the impact of the education they received on their professional activities [11], [10]. However, as far as we know, this is the first time that such kind of survey is used to analyze the current practice of RE.

A comprehensive analysis of RE practice should take into account the activities performed, the methods, techniques and tools used, and the artifacts created. Such an analysis is beyond the scope of this paper. Instead, here we focus on the creation in practice of the set of RE artifacts consisting of the objectives (or goals) definitions, use cases, quality (or non-functional) requirements, glossaries, structural schemas (or class diagrams) and integrity constraints. The reasons why we chose this focus were that the mentioned artifacts are: (1) widely-recognized as necessary artifacts in one form

or another in most RE projects; (2) easily identifiable in practice; and (3) well-known by the students. Given that we focus on a single aspect of RE practice, our results do not provide a complete view of that practice, but nevertheless we believe that the results may be of interest and may trigger ideas on how to improve such practice.

For each of the six artifacts, we asked two main questions: one on the use of the artifact, and one on the recommendation of use of the artifact. Questions on usage are typical in most RE surveys, and in our case the question aimed at knowing the degree to which the artifact is explicitly created in practice. As far as we know, questions on recommendations have not been asked in RE surveys, and in our case the question aimed at knowing whether or not the respondent would have recommended the creation of the artifact when it was not created. We asked the recommendation question only when the response to the usage question was that the artifact was not created *often* or *always*.

We believe that there may be an improvement opportunity of the RE practice when a significant number of respondents would have recommended the creation of an artifact in the cases in which it was not created. If the artifact was created when it is recommended to do it, then the artifact would be created more often, and -we assume- the RE practice would improve.

In this paper, we report the results of our survey [12] to former students on the use and recommendation of use of six RE artifacts. We try to identify the reasons why the artifacts are not created. We also try to identify what would be needed to convince stakeholders and developers to create the artifact, when it is recommended to do it. Finally, we point out a few implications for RE practice and research that are suggested by the results of the survey.

The structure of the paper is as follows. Section II briefly describes the RE course taken by the students that later participated in the survey. Section III describes how we designed and conducted the survey. Section IV presents the general results of the survey. Section V presents the results for each of the six artifacts and points out a few implications for RE practice and research. Section VI summarizes the conclusions and points out future work.

II. THE RE COURSE

In order to appreciate the results of the study reported in this paper, in this section we briefly describe the RE course taken by the former students that participated in the survey.

The course started in 2005 as an elective course of the speciality in Software and Information Systems of the five-year program of *Informatics Engineering* taught at the *Barcelona School of Informatics* of the *Universitat Politècnica de Catalunya (UPC) – BarcelonaTech*. Typically, students take the course during their fourth year in the program, after (among others) an introductory course to software engineering.

The course is taught using a variant of the PBL (*Project-Based Learning*) approach. The main activity of the course is the requirements specification of a software system. At the beginning of the course, the teachers establish a vision within an existing context [13], which varies each course. The students -working in groups of 5-7 people- have to study the relevant methods, languages and techniques and apply them to the determination and specification of the requirements of a system that realizes the vision.

The groups submit their work in two main deliverables: (1) Requirements Specification and (2) Conceptual Schema. Students have available selected deliverables from previous editions of the same course, which can be used as (good) examples. The structure of the requirements specification is an adaptation of the *Volere* template [14]. The structure of the conceptual schema is the classical one: structural schema (including integrity constraints) and behavioral schema [15]. The conceptual schema (written in UML/OCL) is formally defined using the USE tool [16], and it is tested by means of example instantiations.

The course emphasizes the artifacts of RE, rather than the process used to develop them. The main artifacts that are expected to be included in the deliverables are: Stakeholders' objectives, Use cases [17], Quality requirements, Glossary, Structural schema, Integrity constraints and Behavioral schema. Students must validate their artifacts using checklists [18, ch.29], and the satisfaction arguments [19] of stakeholders' objectives must be (at least) sketched, using *Toulmin* argumentation [20].

III. SURVEY DESIGN AND CONDUCT

We created a web-based survey [12] consisting of seven parts. The first part included two questions aiming at characterizing the number of years of professional experience, and the number of projects with a significant RE activity in which the participant has been involved. Each of the other six parts focused on a specific RE artifact, which were the definition of:

- Objectives (goals)
- Use cases (scenarios)
- Quality requirements (non-functional requirements)
- Glossary
- Structural schema (UML class diagram, ER schema)
- Integrity constraints (UML invariants)

For the moment we do not consider the behavioural schema (events, system operations, state transition diagrams) because the results of our study show that it is way much less understood and common in the practice of the participants than the other artifacts. The names of the artifacts in the survey were as indicated above, but it was made clear that in practice they may be called with different names, like the ones given above between parentheses. It was also made clear that the questions referred to explicit artifacts written in any language, including natural language, and at any level

of formality, not necessarily the same as those learnt in the RE course mentioned in the previous section.

The respondents were asked to answer the questions using a five-point Likert scale, with the values: 1 (*never*), 2 (*rarely*), 3 (*sometimes*), 4 (*often*) and 5 (*always*).

The structure of each of the six artifact parts was essentially the same, and consisted of four subparts. There was a fifth part on the evaluation of the RE education received, but this part will not be analyzed here. The first subpart consisted of only one question U on the frequency of use of the artifact in the projects:

U: “*In general, in the projects in which you have participated, the artifact was created ... ?*”

If the answer of the participant to U was less than 4, then he was asked to answer the set of questions of the other three subparts described below. The first was the influence of five causes on the absence of the artifact in the projects in which he participated. In general, the causes suggested were:

- The methodology used did not require the creation of the artifact.
- It was considered too difficult to create the artifact.
- Stakeholders considered the artifact unnecessary or its cost not justified.
- There was an implicit definition of the artifact.
- Lack of tools for creating the artifact.

There was also an open-ended question for collecting other causes, written in a free format.

The next subpart was a single question R on the recommendation of use:

R: “*In the projects in which the artifact was not created, would you have recommended its creation, taking into account the situation and the resources available at that time?*”

This was a crucial question of the survey, because its answer gives a clear indication about the potential increase of use of the artifact in practice.

The last subpart asked about what would be needed in order to effectively create the artifact in practice. The suggested means were:

- To know what the artifact is and how to define it.
- To be convinced that the creation of the artifact is needed for system development.
- Better tools for creating the artifact.
- To be convinced that the cost of creating the artifact is worthwhile.

There was also an open-ended question for collecting other responses.

We targeted the survey to past students of the RE course indicated in the previous section. The potential number of survey participants was 369, but we were able to know the current email address of 182 people (49.3%). We sent them an email invitation (and reminders) to visit the survey

Table I
PARTICIPANTS BY NUMBER OF YEARS AND PROJECTS (%)

Years	Projects					
	0	1	2	3	>3	
≤ 2	1.39	2.78	5.56	0.00	1.39	11.11
3	0.00	4.17	6.94	5.56	2.78	19.44
4	1.39	0.00	0.00	4.17	8.33	13.89
5	2.78	4.17	2.78	1.39	16.67	27.78
≥ 6	1.39	2.78	2.78	2.78	18.06	27.78
	6.94	13.89	18.06	13.89	47.22	

website. We collected survey responses during October-December 2012. The survey was implemented using the web-based SurveyMonkey tool. The survey was initially tested through personal interviews with two former students with wide experience as practitioners.

The survey participants were asked whether or not they were willing to participate in a post-survey focus group. A few of the most-experienced respondents that were willing to participate were invited to a 90-minutes long focus group aimed at validating the survey results and conclusions. The discussions helped us to clarify answers and to point out improvement suggestions for increasing the use of RE in practice.

IV. SURVEY RESULT AND DISCUSSION

In this Section, we describe the general results of the survey. In subsection IV-A we summarize the number of participants in the survey by the number of years since they took the course, and the number of projects with a significant RE activity in which the participant has been involved. Subsection IV-B provides an assessment of the use of each artifact in their current practice, and subsection IV-C provides an assessment of the improvement potential in practice of each artifact.

A. Participant Characteristics

We received 72 complete responses to our survey, which represents a response rate of 39.6%. Table I shows the percentage of participants by the number of years since the course was taken, and the number of projects with a significant RE activity in which the participant has been involved. It can be seen that the 55% of the participants took the course five or more years ago, and that the 61% have participated in three or more relevant projects. These results indicate that a large fraction of the respondents have a considerable experience in RE. We call *most-experienced* respondents to those that have participated in more than three projects.

The table also shows that 6,94% of the respondents have not participated in any project with a significant RE activity. These responses have been ignored in the results reported in this paper.

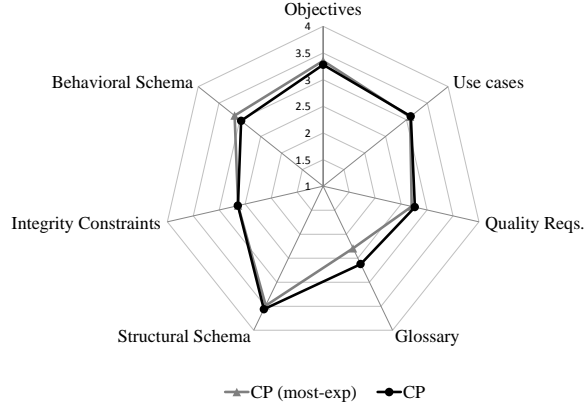


Figure 1. Average use of each artifact in the current practice

Table II
CURRENT PRACTICE BY ARTIFACT

	All			Most-experienced		
	M	SD	Mdn	M	SD	Mdn
Objectives	3.28	1.00	3	3.35	1.03	3
Use Cases	3.10	1.13	3	3.09	1.04	3
Quality Reqs.	2.76	1.10	3	2.71	0.99	3
Glossary	2.62	1.24	2	2.29	0.99	2
Structural Schema	3.56	1.20	4	3.48	1.18	4
Integrity Constraints	2.64	1.30	2	2.64	1.30	3

B. Current Practice

The first objective of our work was to obtain an assessment of the use of each RE artifact in practice, as perceived by former students. The assessment can be obtained from the answers to the U question. We computed the answer average in the Likert scale for each artifact, for all respondents and for the most-experienced. The result is shown in Figure 1.

It can be observed that there is very little disagreement between the perceptions of all respondents and that of the most-experienced. The largest disagreement is in the glossary, but the difference between the averages in this artifact (2.62 and 2.29 respectively) is only 0.33.

Table II gives the mean (M), standard deviation (SD) and median (Mdn) for each artifact, for all respondents, and for the most-experienced.

In order to obtain an assessment of the improvement potential in practice of each RE artifact, we classified the situations in the current practice into two groups:

- Current Low Practice (CLP). These are the situations in which the artifact is *never* or *rarely* or *sometimes* used (Likert scale 1, 2 or 3).
- Current High Practice (CHP). These are the situations in which the artifact is *often* or *always* used (Likert scale 4 or 5).

Formally, the CLP and CHP of artifact A are defined as follows:

$$CLP(A) = \frac{U_1(A) + U_2(A) + U_3(A)}{U(A)} * 100 \quad (1)$$

$$CHP(A) = \frac{U_4(A) + U_5(A)}{U(A)} * 100 \quad (2)$$

where $U_i(A)$, $i = 1..5$, is the number of respondents that answered i in the Likert-scale of the U question of artifact A, and $U(A)$ is the total number of respondents to that question.

Our rationale for the classification is that we consider unsatisfactory the CLP situations because the artifacts are created less than is expected by the RE theory, while the CHP situations can be considered satisfactory because the artifacts are created at least *often*. Strictly speaking, we could consider unsatisfactory all situations in which the artifact is not created *always*, but we thought that, at least initially, we should accept as satisfactory the situations in which the artifacts are created *often* or *always*. It would not be difficult to define CLP and CHP in a more sophisticated way, taking into account the number of projects and the average value of the answers to the questions. However, we thought that our simpler and easier to understand definitions would suffice for our purpose.

Figure 2 shows two bars per artifact. The top bar corresponds to all respondents, while the bottom bar corresponds to the most-experienced respondents. Each bar has three segments. The left segment represents the value of CHP, and the rest of the bar (shown by two segments as will be explained later) represents the value of CLP.

The artifact with the greatest value of CHP is the structural schema. The value is similar for both groups of respondents (close to 60%). The artifacts with the least values of CHP are the glossary and the integrity constraints definition (25%). However, for the most-experienced respondents, the CHP of glossaries is only the 17%, which is very low.

The results shown in figure 2 provide a (partial) answer to the questions of *What is the nature of the gap between RE theory and practice?* and *Which is the magnitude of that gap?*:

- (An aspect of) the nature of the gap is that important RE artifacts are not created in practice as specified by the RE theory. According to that theory, the artifacts defining the objectives, use cases, quality requirements, glossary, structural schema and integrity constraints should be mandatorily created in most, if not all, RE projects, but they are not created in a significant number of them.
- The magnitude of the gap depends on the artifact. The smallest gap is in the structural schema, and it is about 40%. The largest is in the glossary, and it is about 80%. For the other artifacts, the gap lies between these two extremes.

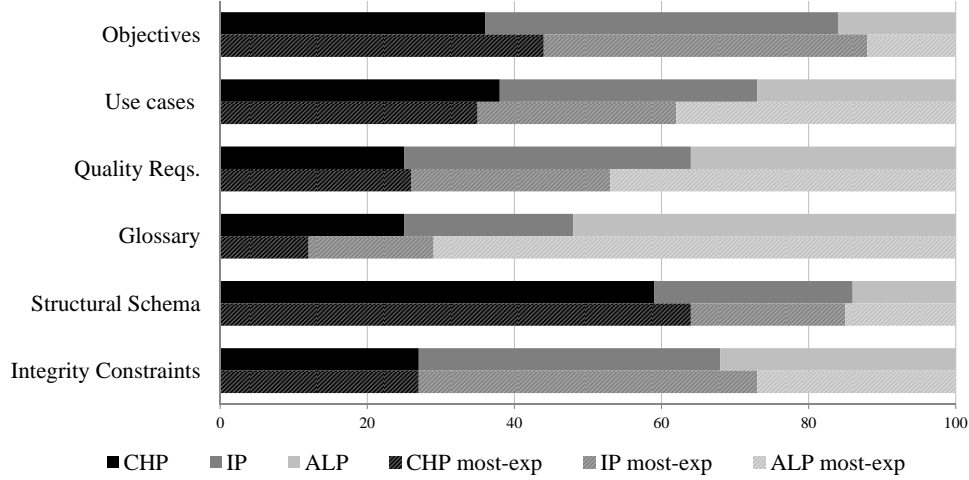


Figure 2. Current practice and improvement potential of each artifact

C. Improvement Potential

The second objective of our work was to obtain an assessment of the improvement potential in practice of each RE artifact, as perceived by former students. To this end, we asked to the former students in the CLP situation the R question, that we reproduce here:

R: “In the projects in which the artifact was not created, would you have recommended its creation, taking into account the situation and the resources available at that time?”

Based on the answer to this question, we say that there is:

- A situation with an *Improvement Potential* (IP) if the answer was *often* (4) or *always* (5), and
- A situation of accepted low practice (ALP) if the answer was *never* (1), *rarely* (2) or *sometimes* (3).

Formally:

$$IP(A) = \frac{R_4(A) + R_5(A)}{U(A)} * 100 \quad (3)$$

$$ALP(A) = \frac{R_1(A) + R_2(A) + R_3(A)}{U(A)} * 100 \quad (4)$$

where $R_i(A)$, $i = 1..5$, is the number of respondents that answered i in the Likert-scale of the R question of artifact A , and $R(A)$ is the total number of respondents to that question. Note that $CLP(A) = IP(A) + ALP(A)$.

Our rationale for the definition of $IP(A)$ is that we consider that situations have potential for improvement if they are in CLP but the respondents would have recommended *often* or *always* the creation of the corresponding artifact. That is, if the situation had followed the recommendation, then it would have been in the HLP situation.

Similarly, our rationale for the definition of ALP is that we consider that situations remain in an unsatisfactory state

if they are in CLP and the respondents would have not recommended *often* or *always* the creation of the corresponding artifact. That is, if the situation had followed the recommendation, then it would have remained in the CLP situation.

In Figure 2 the middle segment of each bar shows the value of $IP(A)$, and the right segment shows the value of $ALP(A)$.

The improvement potential of the seven artifacts (in descending order) is: objectives (48%), integrity constraints (41%), quality requirements (39%), use cases (35%), structural schema (27%), and glossary (23%). The results can be considered similar for both groups of respondents.

These results indicate that our former students perceive a large room for improvement of the current situation in each artifact, specially in Objectives definition, Integrity constraints, Quality requirements, and Use cases. The improvement potential of structural schemas and glossaries is similar, and lower, but their CHP is quite different.

V. RESULTS AND DISCUSSION PER ARTIFACT

In this section we focus on each of the six RE artifacts. We explain the main results of the survey for the artifact, and their implications for practice and research in RE. Due to its nature, the first artifact, objectives definition (Subsection V-A), received a specific treatment in the survey. The other five artifacts were handled in a uniform way, and the answers are summarized in Tables III and IV.

A. Objectives

As illustrated in Fig. 1, $CHP(\text{objectives}) = 36\%$ (44% if we only take into account the most-experienced respondents). This means that about 60% of the respondents perceive that the objectives are defined either *never* or *rarely* or *sometimes*. To these respondents, the survey asked the reasons why the artifact was not created. The reasons that

Table III
REASONS WHY THE ARTIFACT WAS NOT CREATED (AVERAGE OF ANSWERS)

	Use Cases		Quality Reqs.		Glossary		Structural Schema		Integrity Constraints	
	All	Most-exp	All	Most-exp	All	Most-exp	All	Most-exp	All	Most-exp
Methodology used did not require it	2.63	2.77	2.85	2.72	2.62	2.55	2.92	3.27	2.39	2.43
Too difficult to create it	2.80	2.23	2.60	2.56	2.04	2.03	2.75	2.91	2.95	3.13
Stakeholders considered it unnecessary or its cost not justified	3.20	3.18	3.20	3.38	3.74	3.69	3.33	3.36	3.55	3.57
There was an implicit definition	3.45	3.59	3.30	3.42	3.72	3.72	2.92	2.55	3.16	2.78
Lack of tools	2.55	2.41	2.62	2.46	1.98	1.76	2.58	2.45	2.66	2.52

Table IV
WHAT WOULD BE NEEDED FOR CONVINCING STAKEHOLDERS THAT IS NECESSARY AND USEFUL TO CREATE THE ARTIFACT (AVERAGE OF ANSWERS)

	Use Cases		Quality Reqs.		Glossary		Structural Schema		Integrity Constraints	
	All	Most-exp	All	Most-exp	All	Most-exp	All	Most-exp	All	Most-exp
To know what is the artifact and how to define it	3.55	3.45	3.64	3.60	2.98	3.10	3.71	3.82	3.73	3.78
To be convinced that the creation of the artifact is needed	4.03	3.95	4.02	4.04	3.83	3.90	4.33	4.36	4.00	3.96
Better tools	3.23	3.00	3.02	2.72	2.40	2.28	3.21	3.00	2.95	2.61
To be convinced that the cost of creating the artifact is worthwhile	4.10	4.00	3.91	3.80	3.83	3.86	4.13	4.27	3.74	3.55

obtained an average answer greater than 3 in the Likert scale were:

- Stakeholders preferred to indicate the system requirements rather than the objectives they wanted to achieve with the system (3.31).
- It was considered that the expected benefit of objectives definition did not justify its cost (3.21).

In the open-ended question, the reason mentioned more times was “lack of time”. In the focus group meeting, participants suggested that, in many projects, customers believe that they already know the objectives and they do not consider that sharing them with developers is valuable for the result of the project. Instead, they prefer to move directly to the discussion about what the system should do and experiencing prototypes of how the system is expected to be.

To the same respondents, the survey also asked the consequences of not defining the objectives. The three consequences suggested by the survey obtained an average answer greater than 3, and were:

- Problems in project development (3.86).
- Lack of exploration of alternative solutions to achieve the objectives (3.29).
- Lack of stakeholder satisfaction in project results (3.24).

In the open-ended question, the consequence mentioned more times was “project delays”.

1) *Implications for Practice and Research:* According to the former students, the improvement potential of objectives

definition is 48% (44% for the most-experienced). This means that CHP(objectives) could be doubled.

However, to achieve that potential may be a challenge due to the context in which many projects are developed, and the role and influence of the people involved. A possible idea, based on the results of this survey, could be an action program targeted to key stakeholders and project managers, and aiming at helping them to realize that the effort put in to define the objectives of their projects is worthwhile, in the short term. When possible, the program should use statistical evidence from projects similar to those in which the targeted people are involved.

An intriguing result, that may be an implication for research, is the fact that there are many projects in which stakeholders prefer to indicate the system requirements rather than the objectives they want to achieve with the system. For this kind of projects the following research questions may be relevant: Is it possible to achieve (at least some of) the benefits of RE without the objectives definition? May it be worthwhile to try to infer (some of) the objectives from the requirements? How could we trace back the requirements? How could we ensure completeness? How could we validate the requirements when the objectives are missing or implicit?

B. Use Cases

As illustrated in Fig. 1, CHP(use cases) = 38% (35% if we only take into account the most-experienced respondents). This means that over 60% of the respondents perceive that use cases are defined either *never* or *rarely* or *sometimes*.

To these respondents, the survey asked the reasons why the artifact was not created. The reasons that obtained an average answer greater than 3 in the Likert scale were (see Table III):

- There was an implicit definition of use cases (3.45).
- Stakeholders considered use cases unnecessary, or its cost not justified (3.2).

The participants in the focus group meeting agreed that the definition of use cases is not a valuable deliverable for customers that prematurely expect “working” artifacts. Consequently, the effort and resources invested for its creation are not easily justifiable.

The survey also asked what would be needed for convincing stakeholders and developers that it is necessary and useful to create the artifact. The four suggested means obtained an answer average greater than 3 (see Table IV):

- To be convinced that the cost of creating the artifact is worthwhile (4.1)
- To be convinced that the creation of the artifact is needed (4.03)
- To know what is the artifact and how to define it (3.55)
- Better tools (3.23)

1) *Implications for Practice and Research:* According to the former students, the improvement potential of use cases is 35% (27% for the most-experienced). This means that the current high practice could be almost doubled.

In order to achieve that improvement in practice, it is necessary, first of all, to increase the knowledge of the artifact among practitioners. This seems feasible using an adequate professional training program. Once use cases are known, it should not be difficult to convince practitioners that:

- use cases are always created, although they often remain in the minds of developers (implicit),
- therefore, the cost of writing use cases (making them explicit) is very low, and
- use cases are useful not only for system specification, but also for development planning, testing and documentation.

An implication for research is the recognized need for better tools. There are already in the market several tools that help in the creation of use cases, but the challenge is to make those tools (or others) appropriate for any type of setting where use cases are (or need to be) created.

C. Quality Requirements

As illustrated in Fig. 1, CHP(quality requirements) = 25% (26% if we only take into account the most-experienced respondents). This means that 75% of the respondents perceive that quality requirements are defined either *never* or *rarely* or *sometimes*. To these respondents, the survey asked the reasons why the artifact was not created. The reasons that obtained an average answer greater than 3 in the Likert scale were (see Table III):

- There was an implicit definition of the artifact (3.3).
- Stakeholders considered the artifact of quality requirements unnecessary, or its cost not justified (3.2).

In the open-ended question, many comments reinforced the idea that “there was an implicit definition”. The focus group session confirmed that in most cases quality requirements are implicitly assumed by stakeholders. Moreover, the participants also suggested that these assumptions are usually maximal expectations from the customer point of view. Consequently, developers assume that these expectations are difficult to be accomplished taking into account the available resources. In this context, software engineers may prefer not dealing with them explicitly.

The survey also asked what would be needed for convincing stakeholders and developers that it is necessary and useful to define quality requirements. The answers are summarized in Table IV. The four suggested means obtained an answer average greater than 3:

- To be convinced that the creation of quality requirements is needed (4.03).
- To be convinced that the cost of creating the artifact is worthwhile (3.91).
- To know what is the artifact and how to define it (3.64).
- Better tools (3.02).

1) *Implications for Practice and Research:* According to the former students, the improvement potential of quality requirements is 39% (27% for the most-experienced). This means that the current high practice could be doubled.

A direct implication for practice is the need of increasing the knowledge of the artifact among practitioners, and of some of the existing lists of quality requirements types.

At the research level, the answers suggest that something should be done with respect to the concern of the “implicit definition of quality requirements”. In fact, the aspect of “implicit definition” appears explicitly in one of the most popular definitions of software quality: “Conformance to explicitly stated functional and performance requirements, explicitly documented standards, and implicit characteristics that are expected of all professional software” [21]. One of the points emphasized by the definition is: “A set of implicit requirements often goes unmentioned. If software conforms to its explicit requirements but fails to meet implicit requirements, software quality is suspect” [21]. However, as far as we know, an explicit list of the “implicit characteristics that are expected of all professional software” does not exist. It is likely that the implicit characteristics depend on the type of professional software, and that therefore there could be one list per type. We tend to believe that the development of such lists, if widely accepted, could be a significant advance in the RE practice.

D. Glossary

As illustrated in Fig. 1, CHP(glossary) = 25% (12% if we only take into account the most-experienced respondents).

These data indicate that glossaries are perceived as the least used artifacts. On the other hand, it is noticeable that the most experienced responders perceive a much lower level of high practice of glossaries.

This means that over 75% of the respondents perceive that glossaries are defined either *never* or *rarely* or *sometimes*. To these respondents, the survey asked the reasons why the artifact was not created. The reasons that obtained an average answer greater than 3 in the Likert scale were (see Table III):

- Stakeholders considered the glossary unnecessary, or its cost not justified (3.74).
- There was an implicit definition of the glossary (3.72).

From Table III, it is noticeable that glossaries are the artifacts for which the reason “implicit definition” has the greatest average value (3.72), and the reason “lack of tools” has the lowest one (1.98).

In the open-ended question, several respondents insisted on the fact that glossaries were not needed in their projects. The participants in the focus group meeting explained that the terminology used in each project/domain is learned by practice during discussions with the stakeholders.

The survey also asked what would be needed for convincing stakeholders and developers that it is necessary and useful to create the artifact. The answers averages are shown in Table IV. Two suggested means obtained an answer average greater than 3:

- To be convinced that the creation of the glossary is needed (3.83).
- To be convinced that the cost of creating the glossary is worthwhile (3.83).

The three respondents to the open-ended question indicated that glossaries are not needed when the meaning of the terms is already known by the involved people.

1) *Implications for Practice and Research:* According to the former students, the improvement potential of the glossaries is 23% (17% for the most-experienced). This means that the current high practice could be increased by about 100%. However, even if the improvement potential were achieved in full, the resulting high practice would remain below 50%.

To our view, the results of the survey suggest that RE theory concerning glossaries does not adequately deal with project settings in which project participants think that they already agree on the meaning of terms and, therefore, that they do not need defining those terms in glossaries.

E. Structural Schema

As illustrated in Fig. 1, $CHP(\text{structural schema}) = 59\%$ (64% if we only take into account the most-experienced responders). These data indicate that structural schemas are perceived as the most used artifacts in RE practice. This result is consistent with that of [22], which found that UML class diagrams were the most frequently used of seven UML components (including use case diagram and narrative).

About 40% of the respondents perceive that structural schemas are defined either *never* or *rarely* or *sometimes*. To these respondents, the survey asked the reasons why the artifact was not created. The reasons that obtained an average answer greater than 3 in the Likert scale were (see Table III):

- Stakeholders considered the structural schema unnecessary, or its cost not justified (3.33).
- Methodology used did not require the creation of the structural schema –only for the most-experienced– (3.27) .

Our results differ from those of [22]. A logical difference is that they found as main reason for UML diagrams not being used “a lack of understanding by analysts”, differing from our respondents who are trained in RE artifacts. Another difference is that our respondents give higher importance to the reason “insufficient value to justify the cost”.

According to the former students, the improvement potential of structural schemas is 27% (21% for the most-experienced). This means that the current high practice could be increased by about 50%. Therefore, structural schemas are the artifacts with the lowest relative potential increase with respect to the current high practice, although that practice is already the largest one.

The survey also asked what would be needed for convincing stakeholders and developers that it is necessary and useful to create the structural schema. The answers averages are shown in Table IV. The four suggested means obtained an answer average greater than 3:

- To be convinced that the creation of the structural schema is needed (4.33).
- To be convinced that the cost of creating the structural schema is worthwhile (4.13).
- To know what is the artifact and how to define it (3.71).
- Better tools (3.21).

Some participants in the focus group meeting explained that the level of formalism of the conceptual schema depends on the methodology (e.g. when agile practices are applied only an iterative sketch is defined) but they confirmed that some kind of conceptual schema specification is widely used for internal development purposes. Nevertheless, they suggested that better generation of prototypes and executable models from the conceptual schema could be very useful in order to make the conceptual schema a valuable artifact from the customer point of view.

1) *Implications for Practice and Research:* In order to achieve the potential improvement in practice, it is necessary, first of all, to increase the knowledge of the structural schemas among practitioners. This seems feasible using an adequate professional training program. Once structural schemas are known, it should not be difficult to convince practitioners that:

- structural schemas are always created, independently from the methodology used, although they often remain

in the minds of developers (implicit),

- therefore, the cost of writing structural schemas (making them explicit, more or less formally) should be low for trained practitioners, and
- structural schemas, due to their graphical representation, are recognized as one of the best means for improving the communication between the parties involved in the development process.

An implication for research is the recognized need for better tools. There are already in the market several tools that help in the creation of structural schemas, but the challenge is to make those tools (or others) convenient for use in any type of setting where structural schemas are (or need to be) created.

F. Integrity Constraints

As illustrated in Fig. 1, CHP(integrity constraints) = 27%. Exactly the same value is obtained if we only take into account the most-experienced responders. These data indicate that the definition of integrity constraints is perceived as one of the least created artifacts. The survey asked the reasons why integrity constraints were not defined. The answers averages are shown in Table III. The reasons that obtained an answer average greater than 3 were:

- Stakeholders considered the artifact unnecessary, or its cost not justified (3.55).
- There was an implicit definition of the integrity constraints (3.16).

Both groups of respondents considered that the artifact of integrity constraints is the most difficult to create. In the focus group session, the participants suggested that integrity constraints are not usually considered necessary because they are implicitly assumed. However, they explained several experiences in which an early identification of constraints would have improved the result and reduced the cost of the project.

According to the former students, the improvement potential of integrity constraints definition is 41% (46% for the most-experienced). This means that the current high practice could increase by over 150%. Therefore, integrity constraints definition is one of the two artifacts with the largest relative potential increase with respect to the current high practice.

The survey also asked what would be needed for convincing stakeholders and developers that it is necessary and useful to explicitly define the integrity constraints. The answers averages are shown in Table IV. The three suggested means that obtained an answer average greater than 3 are:

- To be convinced that the definition of integrity constraints is needed (4.0).
- To be convinced that the cost of defining the integrity constraints is worthwhile (3.74).
- To know what is the artifact and how to define it (3.73).

1) *Implications for Practice and Research:* In order to achieve the improvement in practice, it is necessary, first of all, to increase the knowledge of the artifact among practitioners. This seems feasible using an adequate professional training program. Once integrity constraints are known, it should not be difficult to convince practitioners that:

- integrity constraints are necessary for ensuring the integrity of the system database,
- lack of integrity normally has negative consequences, which in some cases may be serious.

VI. CONCLUSIONS

In this paper, we have focused on the recognized gap between RE theory and practice, and we have tried to provide answers to the questions of: *What is the nature of the gap? Which is the magnitude of the gap? Why does the gap exist? and What could be done to narrow the gap?* To find (at least partial) answers to those questions, we have surveyed over 70 former university students to know how they perceive the degree to which a set of six RE artifacts are created in practice, and how they perceive the improvement potential of the creation of those artifacts in practice. The artifacts were the explicit definitions of the objectives, use cases, quality requirements, glossary, structural schema and integrity constraints.

We have shown that (one aspect of) the nature of the gap is that important RE artifacts are not created in practice as specified by the RE theory. According to that theory, the above mentioned artifacts should be mandatorily created in most, if not all, RE projects, but we have seen that they are not created in a significant number of cases.

We have classified the situations of use of an artifact into two groups: low and high practice, such that the number of situations in low practice is an indicator of the magnitude of the gap. We have shown that the magnitude of the gap depends on the artifact. The smallest gap is in the structural schema, and it is about 40%. The largest is in the glossary, and it is about 80%. For the other artifacts, the gap lies between these two extremes.

We have described the reasons why the gap exists. We have seen that the reasons depend on the artifact considered. In general, the two main reasons are that in practice there is an implicit definition of the artifact, and that stakeholders consider the explicit artifact unnecessary, or its cost not justified.

Our survey included a recommendation question that has allowed us to assess the extent to which the current situation can be improved. We have shown that the improvement potential of the six artifacts (in descending order) is: Objectives (48%), Integrity constraints (41%), Quality requirements (39%), Use cases (35%), Structural schema (27%), and Glossary (23%). These results indicate that the former students perceive a large room for improvement of the current situation in each artifact.

We have suggested ideas on what should be done to achieve the improvement potential. This depends also on the artifact. In general, what is needed is to convince the stakeholders that the creation of the artifact is needed, and that the cost of creating it is worthwhile. A few implications for practice and research that may help achieving the improvement have been suggested.

As is usual in similar research works [10], the results reported in this paper are subject to some threats to their general validity. One is the geographic and domain bias created by drawing the respondents from the former students of an RE course offered by a particular university. Another possible threat is bias introduced by the form of the questions asked in the questionnaire. The closed set of responses might have led respondents to available responses rather than take more time to provide open-ended answers requiring more time and cognitive effort. However, the focus group meeting we held allowed us to validate and, in some cases, to clarify the results of the survey.

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