Perception of Scientific Evidence: Do Industry and Academia Share an Understanding?, Bogdan Marculescu m.fl.

Bogdan Marculescu 1, Ramtin Jabbari 1, and Jefferson Seide Moller1

1Blekinge Tekniska Högskola
{bogdan.marculescu, ramtin.jabbari, jefferson.moller1}@bth.se

Abstract

Context: Collaboration depends on communication and upon having a similar understanding of the notions that are being discussed, and a similar appraisal of their value. Existing work seems to show that the collaboration between industry and academia is hampered by a difference in values. In particular, academic work focuses more on generalizing on the basis of existing evidence, while industry prefers to particularize conclusions to individual cases. This has lead to the conclusion that industry values scientific evidence less than academia does.

Objective: This paper seeks to re-evaluate that conclusion, and investigate if industry and academia share a definition of scientific evidence. If evidence can be found of competing views, we propose a more finely grained model of empirical evidence and its role in building software engineering knowledge. Moreover, we seek to determine if a more nuanced look the notion of scientific evidence has an influence on how academics and industry practitioners perceive that notion.

Method: We have developed a model of key concepts related to understanding empirical evidence in software engineering. An initial validation has been conducted, consisting of a survey of master students, to determine if competing views of evidence exist at that level. The model will be validated by further literature study and semi-structured interviews with industry practitioners.

Results: We propose a model of empirical evidence in software engineering, and an initial validation of that model by means of a survey. The results of the survey indicate that conflicting opinions already exist in the student body regarding the notion of evidence, how trustworthy different sources of evidence and knowledge are, and which sources of evidence and types of evidence are more appropriate in various situations.

Conclusion: Rather than a difference in how industry and academia value scientific evidence, we see evidence of misunderstanding, of different notions of what constitutes scientific evidence and what strength of evidence is required to achieve specific goals. We propose a model of empirical evidence, to provide a better understanding of what is required in various situations and a better platform for communication between industry and academia.
1 Introduction

Researchers in software engineering often have the opportunity to take their theories and findings to industry and validate them in a practical setting. Empirical software engineering research is specifically geared towards collecting information from industry, analyzing and interpreting it, developing new solutions, and providing credible evidence to practitioners on how to develop software effectively and efficiently.

To achieve this goal, communication between industry and academia must rely on a common understanding of empirical evidence and its value. However, work by Rainer et al. suggests that researchers have a difficult time in demonstrating credibility in industry and that researchers and industry practitioners do not share similar values regarding empirical evidence [10]. Such a difference has a twofold impact on the relationship between industry and academia. First, it has the direct effect of hindering the research process, how information is collected, analyzed, and then disseminated. Second, such a difference in opinion can lead into question the education and values future practitioners receive in universities. A complete difference of opinion, however, would result in a complete inability to cooperate between industry and academia. Such cooperation does take place however. So a model of evidence is needed that accounts for the continued industry-academia cooperation, and the findings of Rainer et al. regarding the credibility difference.

The goal of this study is to investigate the suggested difference in values. First, by gaining a deeper understanding of empirical evidence, and developing a model for a more detailed classification. Once such a model is developed and validated, a quantitative tool for collecting the perception and attitude of students, academics, and practitioners can be developed.

2 Related Work

The Innovation Diffusion Theory (IDT) scheme describes a five stage model for of innovation adoption [12]. The first stage is related to becoming aware of empirical evidence regarding the innovation; whereas the fifth stage address the attitude, i.e. made a decision regarding the adoption of such innovation supported by given information. The model present useful insights to persuade practitioners to consider empirical evidence on their daily process, i.e. managing software projects and activities. IDT presents a broad spectrum of technology adoption defined by two key concepts:

Awareness is a consciousness or understanding of a specific subject, also impacted by the personal beliefs, i.e. ideologies, worldviews and values that shape practice and orient knowledge. Software engineering (SE) research and practice differ on the language and communication features. Practitioners rely most on technical folklore and beliefs built over a set of relationships and communication channels (e.g. previous experience, interpersonal communications) [10].

On the opposite side of the spectrum, Attitude is a position with regard a the given fact or state, or even the intentions towards a problem. When addressing such problem, practitioners stated will is affected by their awareness of the subject. However, some contradiction between the beliefs an the attitude upon it has been observed in SE [10, 9]. Rainer et al. conducted a number of empirical studies where they found that, in the project they studied, quantitative data was not collected and not valued [10]. Moreover,
developers stated that they wanted evidence, but preferred to rely on local opinion and local experts. They go on to speculate as to the possible reasons behind this preference. Yitzhaki et al. collected survey data from 233 respondents, of whom 119 (51%) were academics and 114 (49%) were industry practitioners, all of whom performed R&D functions [16]. They found that discussions with colleagues were the common to both groups, but that there was a significant and consistent difference with respect to most information sources. This seems to strengthen the speculation that the two groups have differing values regarding empirical evidence.

Brown et al. proposed a method of analyzing and assessing scientific reasoning in students [3, 2]. While their method is targeted specifically at middle and high school students, the concept of teaching how evidence and theories can be used to reach a conclusion is an important component of the scientific process.

Our work tries to build on existing definitions of empirical evidence to build a model of what empirical evidence is, and how industry and academia perceive knowledge and empirical evidence. This model provides a more finely grained understanding of empirical evidence and enables the development of a method to systematically assess the awareness and attitude towards evidence.

3 Research Questions
This study tries to answer the following questions

• RQ1. What model of scientific evidence in the context of software engineering can be proposed that accounts for the existing accounts of differing values between industry and academia?

In particular, we would like to have a more finely grained model of evidence in software engineering, to gain a deeper understanding of the concept itself, how industry and academia perceive it, and what aspects are valued differently and how.

• RQ2. What are the awareness and attitude students in the software engineering master program have of the scientific process, scientific evidence, and the their value to solving software engineering problems?

Our study aims to determine if the model of scientific evidence proposed can identify differences of opinions between software engineering students. If clearly distinct opinions can be found in the student body, we can expect that there is some truth to the model and proceed with a more in-depth validation.

• RQ3. Are the awareness and attitudes of students confirmed by participants with experience of both academia and industry?

Since the goal of the study is to perfect the model we have of evidence such as to improve communication between industry and academia, it is reasonable to plan to validate this model with both researchers and industry practitioners. Moreover, we believe it important to begin the validation from people that already have a good understanding of both sides of the argument. To this end, we would like to conduct an initial validation with industrial PhD students and other researchers that have experience working in industry.
4 Understanding evidence

We start by discussing the role of knowledge in general, as a medium for academia-industry communication. To facilitate this discussion, we have defined an initial model of the relationship between academia, industry, and knowledge. The model is described in more detail in Section 5.

The accepted view is that academia tries to add to the overall knowledge. Thus, academia focuses on collecting evidence, and generalizing from evidence to develop theories. Thus, academia is more concerned with ensuring that the knowledge being is novel, valid, and generalizable. This guides their focus towards systematic evidence collection and sources of evidence, and replicability of the evidence collection and analysis processes.

On the other hand, industry is perceived as trying to apply knowledge in a practical setting. Their focus is more on operationalizing theory, thus the focus of industry is to find knowledge that is applicable in their context, relevant to their problems, and successful in providing solutions for those problems.

Both academia and industry, thus, rely on evidence to achieve their goals. Academia generalizes knowledge from available evidence, so it values certain types of evidence that are better suited to that goal. Industry seeks to apply knowledge, so it uses different types of evidence to achieve that.

Evidence and knowledge are often intertwined concepts, as the understanding of a specific subject is usually achieved through interpretation of results supporting or modifying such subject. This relationship is rarely well-defined, as the same evidence could be interpreted differently [7].

Several factors can impact on the process of interpretation, as such the interpreter and the receiver beliefs, their previous knowledge regarding the subject, and the communication channels. Research indicates that an effective communication is important to the process of knowledge transfer (KT) [10].

4.1 Human Factors

Interpersonal communication is an important feature in the KT process, and the experts in both theoretical and practical aspects are particularly valued. These experts possess valuable knowledge of the subject, and the methods used to address it [10]. Academic researchers tend towards the theory and abstraction aspects, as while practitioners are closely related to the application and contextualized feedback.

Practitioners often disregard academic evidence, as they think many of them are poorly relate to the real projects problems, or biased towards the “ideal” projects. Moreover, academic reports usually lack appealing needed to motivate practitioners [14]. Local experts, on the other hand, tend to be more consistent with the real-life issues, responding much quicker to them with potentially more pertinent evidence [10, 17].

A need to bridge the gap between practitioners’ and researchers’ understanding on software engineering goals is identified in [15]. Researchers should provide useful models to support the practitioners needs on how to address the software process. Hertzum and Pejtersen [5] identified five obstacles that can impact on communicating evidence from the experts perspective: 1) cost/time; 2) intellectual/social effort; 3) confidential information; 4) memory; and 5) inappropriate information.
4.2 Information Sources

The differences between researchers and practitioners extends to the sources or channels of information utilized. Academic researchers value formal information such as a conference or journal papers, while practitioners are more willing to search information by interpersonal communications with colleagues [17, 4]. Such informal information channels also exist in the academic environment, in which peer researchers and supervisors act as communication agents.

Compared to academics, practitioners use less formal information services, however they rely heavily on textbooks, professional journals and technical reports as printed and electronic sources. Library resources and bibliographic databases are used only as a last resort. This behavior seems strongly related to the accessibility of the source and the information seeking techniques required in such channels [17].

Fidel and Green [4] suggest training practitioners in using databases of all sorts, improving familiarity with and the usage of these sources. The top five barriers for seeking written information identified by Hertzum and Pejtersen [5] are: 1) cost/time; 2) irrelevant information; 3) availability of information; 4) unfriendly tools; and 5) intellectual effort.

4.3 Information Collection Process

The academic approach to problem solving often starts from a review of relevant literature, often conducted in a systematic way [6]. For a deeper understanding, academic rely on a variety of different research methods, from case studies [13] to controlled experiments [15]. In all of these, the approach is to formulate a model for a solution, collect data to evaluate that model, and refine the model according to the new data. The academic perspective is that systematic data collection and interpretation is more likely to yield reliable results, with a great amount of emphasis being placed on a well described, documented, and repeatable methodology.

In industry, the software development process seldom allows for collecting and interpreting data. Subjective opinions from experts are deemed more credible [10] and are often preferred. The method to address a given issue in industry usually involves reasoning about the activities and actions to undertake, as well how to manage problems or supporting information. To introduce an innovation to the process, there is a need to convince practitioners on the usefulness of such innovation, and a deep knowledge of the organization beliefs are often required [9].

Software organizations are willing to adopt a new technology only if substantial improvements and low-risk introduction are guaranteed. However, few studies demonstrate considerable improvement on a innovative technique over a well-established one. Moreover, pilot projects and prototypes seems to help disseminate the changes in the organization better [14].

4.4 Interpreting Evidence

In academia, evidence is used to validate and refine theoretical models, with the end-goal of drawing general conclusions about the subject matter being studied. The emphasis is on objectively collecting and analyzing data, often using randomization and statistics [15] to account for differences in context. The scientific method has as a starting point the use of empirical evidence to validate theoretical models.
As mentioned above, practitioners still should be convinced to adopt empirical evidence as supporting tool for their decision making activities. A work by Rainer et al. [10] suggests that results presented as quantitative data usually have unappealing impact on practitioners, while contextualized insights (e.g. as provided by a case study) are more persuasive. On the other hand, Storey impressions [14] on interviews with practitioners are that the most credible data is quantitative data, and anything else and should be dismissed.

Both studies agree that the argumentation is stronger if the context of the evidence is alike or similar to the organization and/or its beliefs [10, 14]. Therefore, to improve the KT process is important that researchers and practitioners achieve a similar understanding regarding empirical evidence and its value for decision making.

Figure 1. Key concepts related to the scientific evidence. The left side shows an academic perspective, focusing on generalizability, rigorous analysis and documentation, and systematic processes. The right side shows the industrial perspective, focusing on a context specific analysis, working prototypes, and ad-hoc solutions for observed problems.

5. A Model of Evidence

Based this work, we developed a set of key concepts related to understanding scientific evidence, seen in Figure 1.

The perspective currently attributed to the academic environment is on the left side. It reflects a focus on generalizability, systematic and repeatable data collection, rigorous analysis, and extensive documentation. Academics are perceived as being concerned with creating new knowledge, either from existing primary studies or by conducting their own primary studies. This new knowledge is reviewed by other academics, prior to publication, and the main concerns in this review are its novelty and the validity. Generalizing from evidence, how-ever, requires that the evidence is representative. Hence the focus on systematic and repeatable processes, on unbiased researchers, defined information collection processes, and detailed and reasonable analyses.
The industrial perspective is somewhat less clear, as industry lacks a unifying philosophy. Nevertheless, a consensus seems to be that the industrial perspective is to adopt knowledge and adapt it to the specific context of individual companies. Thus, the industrial perspective is less concerned with generalizability, and more concerned with applicability, the benefits that certain knowledge can bring to the company, the relevance of items of evidence for the specific context, goals, and problems encountered. Thus, the priority in the industrial perspective is in finding solutions to specific problems, even if those solutions may not be applicable in a more general setting.

While the two perspectives are different, both industry and academia do share a desire to increase the level of knowledge, to apply existing knowledge in practical settings, and to learn from those applications. Academics want to validate their theories in industrial settings, and to help achieve this goal experience reports, case studies in industry, quasi-experiments in industrial settings, and a host of other methods are being applied. Similarly, industry practitioners understand the benefits of being early adopters of methods, techniques, and tools originating in academia.

We can see, therefore, that there is a difference in focus. Academics are focused on generalizing from existing evidence to propose and validate theories, while industry practitioners are focused on operationalizing existing knowledge to specific context. In spite of these seemingly divergent goals, both industry and academia share an understanding in the value of using and adding to the overall repository of software engineering knowledge. The evidence academics use often comes from industry, with empirical studies being conducted in industry, or based on industrial experience reports.
or on industrial data. Industry practitioners collaborate with academics to make such data available and encourage the development of solutions to specific problems, especially problems for which a suitable solution has not been found in the repository of existing knowledge.

6 Validation

A first step towards validating this model of evidence in software engineering was to investigate the attitude and awareness of students in a software engineering master program. As future practitioners and academics, the students have some of the knowledge specific to the domain, although they lack the practical experience of either academia or industry.

A pilot survey was conducted with students in the Research Methodology course, an advanced level course in the international Software Engineering master program. The participants in the course were international students, with 88% being between 20 and 25 years of age at the time of the study. The survey instrument was designed to be applicable outside of that context as well, both in other courses and in an industrial setting. Questionnaires on the attitudes of the general public towards science and scientific evidence [1, 11, 8] were the basis for the development of the survey instrument.

The pilot survey focused on the awareness and attitude of respondents on different situations in their work and study activities that sought to assess their main sources of information (e.g., documents, persons in authority, own experimental activities, etc.) and the level of confidence they had in those sources.

The survey was designed according to the model presented above, and seeks to evaluate the awareness and attitude towards evidence with respect to the key concepts presented in Figure 1. We hypothesized that student opinions would be split between the context specific focus seen in industry and the generalizability focus they have been shown in their academic activities.

The results of the pilot survey have been analyzed from the perspective of the key concepts mentioned above. Figure 3 shows the responses to the survey questions, with the answers towards the left focused more on the academic, generalizable types of evidence, and those on the right focused on contextual, practical and applicable evidence. An initial evaluation shows that the both the generalized and the context-focused views exist in the student population. Figure 4 show the same information visualized as a heat map.

Moreover, it seems that some dimensions elicit different responses. This seems to show that the preference for a more academic or a more industrial point of view depends on the situation, the type of decision that needs to be made, and the type of evidence being considered, rather than being a bias in the person responding.

7 Discussion

This model shows industry and academia as focusing on different types of evidence, and using them to achieve different goals. Thus, we expect each academic and industry practitioner to value more the types of evidence that enable them to achieve their goals. This has a significant impact both on academia-industry communication, and on teaching
students. Understanding what goals academia and industry have, and what types of evidence they need to achieve those goals, could inform how communication is conducted, and improve a mutually beneficial collaboration.

Moreover, this understanding would enable universities to train students to perceive the different goals, to understand what kinds of evidence are needed to achieve them, and to provide them with the tools to obtain that evidence. This

Figure 3: Survey results, represented on a Likert scale. Answers towards the left reflect the right side of the Key Concepts diagram: a focus on rigorous documentation and generalizability. Answers towards the right of the diagram reflect a focus on context-rich,
practically applicable results. Note that the order of questions has been adjusted to clarify the effect.

<table>
<thead>
<tr>
<th>Question</th>
<th>1 (SD)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q9. I would be convinced to try a candidate solution that I have not tried before, if someone provided:</td>
<td>6</td>
<td>7.5</td>
<td>9.0</td>
<td>9.5</td>
<td>4.3</td>
</tr>
<tr>
<td>Q8. When I find a candidate solution that contradicts my opinions, I:</td>
<td>2.95</td>
<td>2.3</td>
<td>3.5</td>
<td>3.8</td>
<td>4.3</td>
</tr>
<tr>
<td>Q7. In order to decide whether a candidate solution can solve the problem described earlier, I:</td>
<td>3.35</td>
<td>3.1</td>
<td>3.8</td>
<td>4.1</td>
<td>4.7</td>
</tr>
<tr>
<td>Q6. When I come across a scientific paper relevant to the problem described earlier, I:</td>
<td>3.12</td>
<td>2.9</td>
<td>3.6</td>
<td>4.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Q5. When comparing two different candidate solutions for the problem described earlier, I:</td>
<td>3.38</td>
<td>3.1</td>
<td>3.8</td>
<td>4.0</td>
<td>4.7</td>
</tr>
<tr>
<td>Q4. When I have to compare two different candidate solutions for the problem described earlier, I look for information in:</td>
<td>2.60</td>
<td>2.3</td>
<td>3.0</td>
<td>3.5</td>
<td>4.0</td>
</tr>
<tr>
<td>Q3. When I am getting familiar to a new topic, I prefer to depend on:</td>
<td>2.98</td>
<td>2.6</td>
<td>3.3</td>
<td>4.0</td>
<td>4.7</td>
</tr>
<tr>
<td>Q2. In the Computer Science and Software Engineering domains, who do you think has more practical knowledge?</td>
<td>3.85</td>
<td>3.4</td>
<td>4.1</td>
<td>4.6</td>
<td>5.1</td>
</tr>
<tr>
<td>Q18. After successfully adopting the candidate solution for the problem described earlier, I:</td>
<td>3.40</td>
<td>3.1</td>
<td>4.2</td>
<td>4.7</td>
<td>5.2</td>
</tr>
<tr>
<td>Q17. After successfully adopting the candidate solution for the problem described earlier, my manager/teacher requires that I:</td>
<td>3.32</td>
<td>3.0</td>
<td>4.0</td>
<td>4.4</td>
<td>4.9</td>
</tr>
<tr>
<td>Q16. If something goes wrong or doesn’t work, I:</td>
<td>2.81</td>
<td>2.5</td>
<td>3.1</td>
<td>3.6</td>
<td>4.2</td>
</tr>
<tr>
<td>Q15. My success in solving the problem described earlier depends mainly on my ability to:</td>
<td>2.10</td>
<td>2.1</td>
<td>2.7</td>
<td>3.2</td>
<td>3.8</td>
</tr>
<tr>
<td>Q14. When I experience difficulty implementing the candidate solution, I:</td>
<td>3.05</td>
<td>2.4</td>
<td>3.0</td>
<td>3.6</td>
<td>4.2</td>
</tr>
<tr>
<td>Q13. When I have to explain/justify my choice for the candidate solution, I base my arguments on:</td>
<td>3.40</td>
<td>2.8</td>
<td>3.4</td>
<td>4.0</td>
<td>4.6</td>
</tr>
<tr>
<td>Q12. The results I can rely on most mainly come from:</td>
<td>3.07</td>
<td>2.5</td>
<td>3.1</td>
<td>3.7</td>
<td>4.3</td>
</tr>
<tr>
<td>Q11. The most reliable information regarding the application of such a candidate solution comes from:</td>
<td>3.60</td>
<td>2.9</td>
<td>3.5</td>
<td>4.1</td>
<td>4.7</td>
</tr>
<tr>
<td>Q10. The decision to adopt the chosen candidate solution is mainly made after:</td>
<td>3.40</td>
<td>2.8</td>
<td>3.4</td>
<td>4.0</td>
<td>4.6</td>
</tr>
<tr>
<td>Q1. In the Computer Science and Software Engineering domains, who do you think has more knowledge of the theory?</td>
<td>2.16</td>
<td>1.6</td>
<td>5.1</td>
<td>1.6</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Figure 4: Survey results, represented as a heat map. Answers towards the left reflect the right side of the Key Concepts diagram: a focus on rigorous documentation and generalizability. Answers towards the right of the diagram reflect a focus on context-rich, practically applicable results. Note that the order of questions has been adjusted to clarify the effect.
will result in them being better prepared to fit in the industrial context when they do become practitioners, and serve to improve the potential for communication between industry and academia even further.

A focus on generalizability, rigorous analysis and documentation is often perceived as a more “academic” stance, with researchers often presenting evidence in terms of peer-reviewed papers, well reputed researchers, and consisting of experimental results analyzed by statistical methods. Conversely, a more “hands-on” approach, with a focus on contextual information, working prototype software, and ad-hoc solutions is often regarded as more “industrial”. Our results show that both these opinions exist in the student population, and that they depend more on the situation presented, the type of evidence being considered, and the type of decision that is to be made.

While still initial, the results seem to indicate that a more nuanced view of what constitutes evidence, how it should be obtained and analyzed, and how it is to be presented could be beneficial. By establishing a common, and commonly accepted, framework, we could minimize misunderstandings between researchers and industrial practitioners.

Industry and academia seem to focus on different parts of the model, so it is worth discussing if any commonality can be found. Since industry-academia collaborations continue to be important in research, we can claim with some certainty that the goal we have mentioned, of adding to the overall repository of software engineering knowledge, is a shared one. Intermediate goals may be different, and academics and industry practitioners will focus on different short term objectives. Nevertheless, developing new knowledge, backed up by empirical evidence, industrial data, and validated in a real setting continues to be relevant to both industry and academia.

In a more immediate sense, a finer grained understanding of the different views of industry and academia would enable us to better prepare our students to face the difficulties that will arise regardless of the path they will take. Students that go on to be software engineering practitioners often see a shift in values and expectations, in addition to the difficulties in adapting to a new context and completing new types of tasks. By better understanding the goals and values of industry, and communicating these values to our students, we would enable a smoother transition to practitioner as well as improved communication with future practitioners.

So, do industry and academia share an understanding? It seems that the industry and academia share an understanding of the importance of developing, validating, and implementing new knowledge. Divergence exists in terms of which parts of the process each focuses on. In these terms, industry and academia don’t necessarily disagree on what constitutes empirical evidence. However, academics and industry seem to prefer types of evidence that better suit their focus and their intermediate goals.

Future work will be focused around validating the model of evidence in software engineering. The first step is to conduct interviews with industrial PhD students at BTH. The main reason for this choice is the experience they have in both the industrial and academic settings.

The long term goal, and long term plan for future work, is to develop the survey into a tool to evaluate the awareness and attitude of practitioners and academics towards the different key concepts of evidence in software engineering. Such a tool would enable the model to be validated and refined. It would also allow a common understanding of
evidence, and how evidence can be used to support the goals of software engineers, both researchers and practitioners.

8 Conclusion

We have proposed a model of empirical evidence in software engineering that accounts for the seeming contradiction between the value of empirical evidence in industry and in academia. According to this model, the contradiction is more a reflection of different goals and a preference for different types of evidence that support those goals, rather than different values.

Further work is still necessary to validate and improve the model, and to develop analysis and measurement methods to obtain further data. Nevertheless, we propose a common model for empirical evidence, that takes into account context, the goal of each of the participants, and the preferred means of achieving those goals. We claim that such a model is likely to improve academia-industry cooperation, as well as improving the degree to which students are prepared to take the role of software engineers in industry.

References


