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Key Skills to Work With Agile Frameworks in Software Engineering: Chilean Perspectives

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ABSTRACT Agile frameworks continue to provide positive evidence regarding the benefits of their use in the software products. Since these methods develop professional skills in those who practice them, their knowledge and use will acquire greater demand in areas other than software development. For this reason, it is essential to recognize the key skills for agile team building. The goal of this paper is to identify the agile professional skills that the Chilean industry considers key to conform high-performance agile teams. A survey was applied to agile community professionals in Chile to validate the results of previous work and to identify relevant information regarding learning processes, techniques, and tools for working with agile frameworks. The results allowed to establish three key skills for high-performance teams with their respective levels of achievement.

INDEX TERMS Agile frameworks, skills, agile teams, software engineering education.

I. INTRODUCTION

Agile frameworks continue to gain place and importance in the discipline of Software Engineering [1]–[3]. This new way of thinking and creating software projects has allowed teams to be self-manageable and ensured that customers perceive a higher value in their products [4]–[6]. Companies interested in adopting an agile approach need to adapt their processes through a framework that supports the agile transition process [7]–[9]. Nowadays, companies demand high levels of performance from their workers, which goes beyond the knowledge acquired by them during their training [10]–[12]. Many professionals are usually hired based on their aptitude for a position, but later some are fired for the working attitude they exhibit. To avoid this kind of situation, professional and technical skills must be integrated instead of being treated separately [13], [14].

In agile frameworks, high-performance teams are formed by highly cohesive people who can take decisions grounded on a common vision. These teams develop their activities through open communication, creating trust and sharing leadership, thus allowing a fruitful environment where innovation emerges from the individual differences [15]. High-performance teams are characterized by technical and behavioral excellence, and by continually practicing and experiencing challenges. A high-performance team must show autonomy, attitude and more productivity than a traditional team and, in general, feel great satisfaction in the work they perform [16]. For this reason, the concept of a high-performance team has a strong relationship with self-organization [17]. The idea of being able to form high-performance software development teams has been very attractive to companies. A widely known example in this regard is Google, which in 2015 released a report on one of its internal initiatives known as the Aristotle Project [18]. Google analyzed the traits and characteristics of the people who made up the teams in the company to identify the necessary elements of high-performance team formation. The results allowed the researchers to identify the following keys to obtain a high-performance team: Psychological safety, Trust, Structure and Clarity, Sense of work, and finally, Impact of work [18]. The characteristic that Google

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identified as the most influential in a team's performance was the presence of psychological safety, which is a climate in which people feel free to express relevant thoughts and feelings [19]. The literature indicates that using an agile approach, such as Scrum or XP, requires the formation of high-performance teams with a high command of agile practices [15], [17].

There is a gap between what is taught in the classroom and the daily reality of software development companies [14], [20], [21]. In Chile, this situation is reflected in the academic world and the discipline of Software Engineering. There is a demand for skills that must be developed among future professionals so that their learning experiences are highly influenced by practice, techniques, and working methods that require software development of industrial quality [5], [22], [23]. In fact, the software development industry increasingly requires a more significant number of professionals with the skills demanded by the market [24]. Important international organizations have proposed specific topics that every software engineer should master (ACM-IEEE [25], Tuning Latin America [26], SFIA Foundation [27], CDIO [28], and SWEBOK [29]). However, there is still no consensus on specific issues related to agile frameworks.

Therefore, it is crucial to identify the key aspects in the formation of agile teams. For this, the investigation began with a systematic mapping of the literature, reported in [30], to identify the skills necessary for the formation of agile teams. With these findings obtained, the present research work was designed, seeking to validate the previous results with Chilean professionals through a survey and five interviews. The survey was carried with a total of 83 professionals who actively worked with agile frameworks in Chile. The interviews were conducted with essential professionals of recognized companies to socialize and validate the findings obtained.

This article is organized as follows. Section II presents the antecedents regarding the definition of soft and technical skills and Section III presents some relevant works that tackle the problem of defining the most important skills required in the formation of agile methods. Section IV summarizes the systematic mapping of the literature previously carried out Section V explains the research method, research questions, goals, and the survey design. Finally, Section VI presents the survey results, and Section VII the conclusions and proposals for future work.

II. BACKGROUND

Agile frameworks have been increasingly adopted in software development projects worldwide [31]. There is clarity in the scientific and academic communities that a combination of technical and soft skills is required to develop quality software. The study on skills and their relevance in software engineering has kept the attention of researchers and professionals in recent years, especially with the wide use of agile frameworks in the digital transformation processes of companies.

In the literature, the definition of soft (or professional) skills is still confusing and ambiguous [32]. Even though there is no universal set of formally agreed soft skills [33], its concept is regularly related to those kinds of skills most associated with the professional behavioral dimensions of the individual. The literature also refers to soft skills as *non-technical skills*, *personal skills*, *interpersonal skills*, *social skills*, *generic skills* and *human factors* [34]. Kamin [35] defines soft skills as the interpersonal skills that demonstrate the ability to communicate effectively and build relationships while interacting with others. Boyce *et al.* [36] refer to soft skills as those general educational skills that are not domain or practice-specific. Such skills could encompass communicative skills, problem-solving skills, conceptual and critical skills, visual, oral, and aural skills, among others. Moreover, Hurrell *et al.* [37] define soft skills as those skills that are non-technical, not dependent on abstract reasoning (interpersonal and intrapersonal skills), and that easy the performance of the individuals in specific contexts. Finally, Grugulis and Vincent [38] list the following as soft skills: communication, problem-solving, team-working, the ability to improve personal learning and performance, motivation, judgment, leadership, and initiative.

The concept of *technical skill* is usually less confusing and ambiguous. It is related to the technical knowledge one must have to act with a certain level of performance in the context of some discipline. Considering that, different disciplines require distinct lists of technical skills that are measured according to a given level of performance that must be accomplished for the fulfilment of the required actions. Possible examples of technical skills in the context of the Software Engineering discipline are: computer programming, software testing and debugging, software development, cloud management, writing documentation, among others [39].

In the agile context, each framework concretely provides a set of technical skills necessary to form an agile team. Depending on the role to play, skills are added to better guide the work to be carried out. Agile practices are the competencies to be developed and allow a better definition of agile technical skills. However, the task of defining and listing a required soft skill set is not that simple. Agile practices also help to define soft skills, but in the end, they generate the same problems of ambiguity detected in other disciplines.

As there is no formal and standardized proposal on these concepts, it is necessary to identify a set of agile skills that allow better orienting the professional training processes. To avoid confusion, our goal is to define the set of skills that we call *Agile Key Professionals Skills* and which involves both types of skills (soft and technical). We define Agile Key Professionals Skills as ''a set of individual capabilities that enable efficient and effective performance in teams working on software engineering projects using agile frameworks''.

III. RELATED WORK

Although there are some guidelines on the skills required to be a good software engineer (e.g., SWEBOK [29]), it is

still possible to observe a lack of information and definition about the skills and knowledge specifically necessary for developing software projects using agile frameworks. Several works have addressed the problem of defining the main competencies to be developed by software engineers. For instance, Sedelmaier and Landes [40] present a framework to describe software engineering skills covering various degrees of abstraction, called SWEBOS (Software Engineering Body of Skills). The detailed skills in this framework include professional collaboration, communication, structuring work, personal skills, knowledge of the problem, ability to solve problems, and additional skills. SWEBOS intends to serve as a basis for teaching and learning in software engineering courses but focusing only on soft skills. Moreover, in [41], [42], the problem of developing professional skills is raised to high-level software engineering studies. In these works, the authors describe how they integrated project-based learning for the development of software projects. The authors claim that these types of innovations deliver outstanding results in developing skills and highlight the high level of students' motivation to develop these types of activities in the classroom. In [43], the authors conducted a study to identify the skills needed for agile Scrum teams. Programming, interpersonal, and communication skills are the most required to develop teams when working on a global scale.

Every year, VersionOne[1] company publishes the results of the State of Agile survey worldwide. In May 2020, the fourteenth annual State of Agile survey was published, providing information on the application of Agile in different areas of the company. However, to identify specific using aspects of agile frameworks, it is necessary to conduct localized research. In this context, it is possible to find in the literature a series of works throughout the world that have allowed to characterize the agile software development industry in each country. Some interesting studies on this topic are [43]–[52].

Considering these researches, a work that we used as a reference to elaborate the questionnaire was the one presented by Diel *et al.* [46], where a questionnaire is applied to professionals in Brazil to identify the level of understanding among IT professionals located in different cities of the country. The most significant results indicate that 49% declared working with Scrum, 23% with XP, and 10% with Lean Software Development. The product backlog appears as the most used agile practice, followed by the sprint planning meeting, the retrospective, daily meetings, and Kanban. The least used practices are Behavior Driven Development (BDD), Test-Driven Development (TDD), and the scrum of scrum meetings. While analyzing the factors that challenge the adoption of agile frameworks, the biggest obstacle pointed out by the majority of respondents was a ''cultural change'' in the company. Factors such as ''resistance to change'' and ''collaboration with the customer'' were also mentioned as barriers in the agile framework adoption process. Furthermore, technological and technical factors, such as ''inadequate tools and technologies'' and ''lack of formal guidelines'' were indicated as low-level challenges in the adoption of agile frameworks.

Another reference for our research was a survey applied to the industry in Brazil [47], where they make a state-of-the-art about agile frameworks in Brazil regarding teaching, research, and practice in the industry. The results on the adopted practices and frameworks were: Scrum (51.2%), Scrum-XP (22.5%), and Lean (4.2%). The main causes identified behind the failure of adopting agile frameworks were the following: a lack of experience with agile frameworks, the culture/philosophy of the company being in disagreement with the main agile values, the external pressure to follow the traditional practices in cascade, a lack of orders and trained customers, low management expectations, and the lack of scope and control of the issues to manage external dependencies (especially in non-agile teams). Remarkably, Rodríguez *et al.* [53] conducted a survey on the adoption of agile and lean frameworks in the Finnish software industry. The results indicated the following main reasons for adopting the frameworks: increased productivity (67%), higher quality of products and services offered (62%), reduced development cycle and launch time to the market (58%), improvement of the quality of the development process (48%), and an increase in the capacity to work with the changes made in the applications (43%). Respondents indicated that the primary expected benefits while adopting agile frameworks are: improved team communication (50%), increased ability to work with changes made to the applications (50%), increased productivity (50%), improvement of the development process (49%), and improvement of the knowledge needed to develop work (49%). The factors that challenge the adoption of agile frameworks are the following: commitment from senior management (50%), the collaboration between the team and the client (48%), change of culture in the way of working (47%), and difficulty in measuring the adoption of the frameworks (48%). Finally, the most cited reasons for the non-adoption of agile frameworks were: lack of knowledge and training in the subject (47%) and organizational culture (43%).

Díaz-Oreiro *et al.* [54] compare the agility degree in software development activities between two countries (Spain and Costa Rica) and which are the most used methods and frameworks in each country. The results were obtained from an online survey with 51 responses from Costa Rica and 50 responses from Spain. The use of Scrum in Costa Rica is more widespread than in Spain, with 39% of respondents stating, ''We often use it'' and 41% ''We always use the framework'' (compared to 22% and 26% for Spain, respectively). Another important fact is the balanced use in both countries of Iterative Development, Kanban, and Test-Driven Development, which are also agile paradigms. Frameworks or practices such as Nexus and PRINCE show some use in Spain while in Costa Rica are practically unknown. The latter could be because the PRINCE project management methodology is widely used in the United Kingdom, where many Spanish companies carry out software projects. On the

[1] https://www.collab.net/products/versionone

TABLE 1. Synoptic table.

Reference	Goals / Scope Focus / Context	Data Collection	Focused on Agile	Type of skills	Important (or most used) Skills / Frameworks
Sedelmaier and Landes [40]	Body of skills for software engineering.	Grounded theory, informal conversation and interviews.	NO	Tech-Soft	Professional collaboration, communication, structuring work, personal skills, knowledge of the problem, ability to solve problems, and additional skills.
Gonzalez et al. [41]	Experiences of five years carrying out activities in subjects for the development of soft skills in the field of Software Engineering.	Data obtained in carrying out PBL activities with students in real companies. Satisfaction surveys.	NO	Tech-Soft	Search and classification of information, report writing, teamwork, client management, leadership, decision-making, conflict management, critical thinking, evaluation of results, and communication of results.
Diel et al. [46]	Understanding of IT professionals about how and which agile practices are being used in practice, and the main skills professionals need to work with such methods.	Survey	YES	Tech-Soft	Collaboration, responsibility, commitment, communication, mutual trust and respect. The most used agile methods are: Scrum (49%), XP (23%) and Lean (10%).
Melo et al. [55]	Present a report on the agile state of the practice in the Brazilian IT industry.	Survey	YES	Tech-Soft	Social and management skills, communication, commitment, cooperation, and adaptability. Developers autonomy, leadership, teamwork, and decision-making.
Rodriguez et al. [53]	Adoption and usage of agile and lean methods in the Finnish software industry.	Survey	YES	Tech	Wide use of agile and/or lean methods (58%). Lean is mainly used combined with agile. Most agile practices are usually used without great differences in use between practices. The Prioritized worklist is the most used agile practice. The collective code ownership is the least used.
Hidayati et al. [43]	Identification and ranking of the essential skills for Scrum Global Software Development teams.	Literature study, depth interviews, survey.	YES	Tech-Soft	Ranking hard skills (1. programming, 2. Scrum expertise, 3. specific, 4. spoken and written language, 5. database) and soft skills (1. interpersonal and communication, 2. analytical thinking, 3. teamwork, 4. management and planning, 5. leadership).
Asnawi et al. [44]	Description of issues facing the adoption of agile methods in Malaysia.	Semi structured interview	YES	Tech-Soft	The people factor and other social factors are more important than the technical factor. People factor can be classified as knowledge, mindset, commitment, management involvement, knowledge transfer, organizational structure, and communication.
Díaz-Oreiro et al. [54]	Agility degree of the software development activities and what are the most used agile method and frameworks in Spain and Costa Rica.	Survey	YES	Tech-Soft	Scrum is the most widely used in both countries. Balanced use of Iterative Development, Kanban, and Test-Driven Development.

contrary, Costa Rican companies have little participation in that market. Concerning the frameworks and practices used, it is important to mention that Scrum is the most widely used in both countries. Iterative Development and Kanban occupy the second position as most commonly used frameworks, both in Spain and Costa Rica. The classic waterfall process is still used in both countries, to a greater extent in Costa Rica than in Spain, despite current trends towards agile frameworks. Table 1 shows a synoptic summary of the research mentioned in this section.

IV. AGILE PROFESSIONALS SKILLS IDENTIFICATION

Firstly, a systematic mapping of the literature (SML) was carried out by following the guidelines of Petersen *et al.* [56]. Here we present a summary of the main aspects of this SML (more in-depth information can be found in [30]). The goal of this step was to analyze scientific evidence about the necessary skills to form agile software development teams by focusing on answering the following three specific research questions (RQ):

- RQ.1. What skills are necessary to be part of an agile development team?
- RQ.2. What methodological proposals exist to develop the teaching/learning process on agile frameworks?
- RQ.3. What evaluation methods are adequate to measure achievement levels in the skills detected in 1)?

TABLE 2. Results of the systematic mapping process.

Source	Results obtained	Primary studies accepted
Web of Science	25	3
Scopus	34	3
SpringerLink	224	9
ScienceDirect	138	7
Total	421	22

The citation databases used were Web of Science (WOS) and SCOPUS, while the databases of scientific publications were ScienceDirect and SpringerLink. As a result of the application of the search string, 421 articles were obtained in total. Table 2 and Figure 1 present the distribution of findings and the total number of primary studies that were selected.

From the analysis of the primary studies, it was possible to extract a wealth of valuable information regarding the skills required to build agile teams. Regarding the research question RQ.3 (*What evaluation methods will be adequate to measure achievement levels in the skills?*), the main findings were:

- The evaluation methods used correspond to mechanisms to measure the perception of students during the learning of agile concepts and practices.

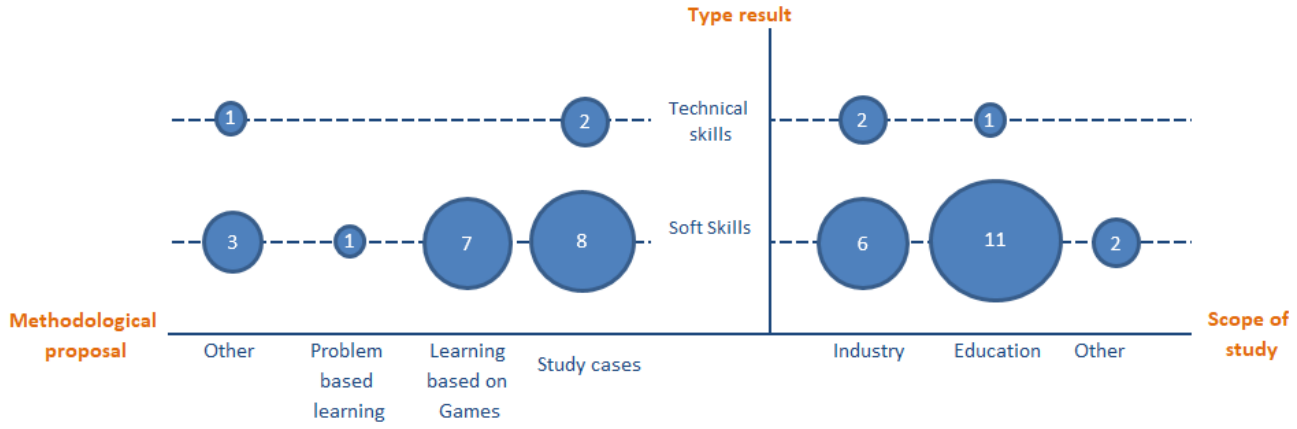

FIGURE 1. Distribution of the selected primary studies according to the type of result, the scope of the study, and methodological proposal.

- The most used evaluation instruments are surveys, observation, research-action, and expert judgment.
- There is consensus that the assessment of soft skills is a complex process. For this reason, it is necessary to combine different methods and tools to obtain a better appreciation regarding the level of performance of the ability that a student has. In this field, multimodal learning analytics (MMLA) offers interesting opportunities to gain a better understanding of skills that are complex to assess.

Regarding the research question RQ.2 (*What methodological proposals exist to develop the teaching/learning process on agile frameworks?*), the main findings were:

- The use of the gamification activities allows adequately addressing the skills to be developed for agile frameworks. However, the scarce empirical evidence prevents having data that allows analyzing the experiences in more detail.
- Game-based learning is the most widely used method in Software Engineering education.
- The great difficulty faced by education in Software Engineering is the possibility of generating educational environments as close to reality as possible. Problem/project-based learning has reduced the gap between what is taught in the classroom and the needs of the industry.

Finally, regarding the research question RQ.1 (*What skills are necessary to be part of an agile development team?*), the main findings were:

- Most of the selected primary studies describe exploratory experiences considering soft skills as the focus of study.
- A major problem identified is that there is no formal body of knowledge that guides the development of skills to build agile teams.
- There were very few references to technical skills. It was only possible to register evidence of work for the following skills: Knowledge of tools for work planning, specify the software requirements, knowledge of software development environments, and apply techniques for estimating effort.
- From the information analyzed, it is possible to propose a set of skills that we have called *agile professional skills*. The proposed skills are: Effective communication, adaptability, self-management, self-learning, creativity, collaboration, second language (English), and commitment.

These findings allow obtaining a more concrete look when exploring the skills necessary to form agile teams. However, it is required to validate the results in the industry to state more specific proposals on the development of agile skills, thus the need for the present work. Section V describes in detail the validation process performed.

V. METHODOLOGY

With the results obtained in SML [30], as a first step, a survey was planned to gather more specific information regarding key agile skills. Semi-structured interviews with professionals in key agile roles were also planned. Both instruments were designed following the guidelines of Kitchenham and Pfleeger [57] and Mello *et al.* [55], with the goal to apply them to Chilean industry professionals who are actively working with agile frameworks. The Chilean software industry, with an annual growth of 11% [58], presents ideal conditions to validate the information obtained in the SML and to achieve the objectives set out in this research.

A. RESEARCH QUESTIONS AND GOALS

This is an exploratory study. Therefore, its findings can help to generate new hypotheses for future research [59]. We defined the following three research questions (RQ):

- RQ.1. What are the skills that Chilean professionals consider as key to working with agile frameworks?
- RQ.2. How did professionals adopt the knowledge to work with agile frameworks?

TABLE 3. Mapping research questions, surveys and interviews.

Research questions	Surveys and Interviews
RQ.1	SQ.7, SQ.8 IQ.3, IQ.4
RQ.2	SQ.3, SQ.4 IQ.2, IQ.5
RQ.3	SQ.9, SQ.10 IQ.6, IQ.7
Participant profile	SQ.1, SQ.2, SQ.5, SQ.6 IQ.1

- RQ.3. What knowledge should be considered by the academic community for integration into the training processes of professionals for working with agile frameworks?

The main objective of this research is to identify the skills that the Chilean industry considers key to conform high-performance agile teams. As secondary objectives, and based on the experience of Chilean professionals, we seek to understand: (i) how they acquired knowledge about agile frameworks, (ii) what difficulties they have in working with agile frameworks, and (iii) what are the skills they consider as key to success in the application of agile frameworks.

B. SURVEY DESIGN

Based on our experience and expert recommendations, we designed a survey focused on the stated objective and the research questions. This survey can be classified as exploratory and descriptive research because it is focused on deepening the knowledge obtained in the systematic mapping carried out. It was designed considering the guidelines of [55], [57], and the design strategy for the application of the questionnaire was based on [60]:

- Protection of confidentiality: In order to avoid conflicts with the confidentiality policies of companies, personal and contact information will not be transferred to third parties.
- Consideration of the duration of the instrument: The survey should not take more than 10 minutes to be answered.
- Consideration of existing instruments as a basis: For the survey design, the section on skills presented in [46] was reviewed; however, the questions were of a general nature, so we discarded them.
- Serious information treatment: The purpose of the survey was explained to each of the participants. We committed to send the results once the work was finished.
- Testing period: to avoid biases and improve the objectivity of the questions, the survey passed a test period, where it was applied to a group of 15 people to detect problems before mass distribution.

To answering each research question, two survey questions and two interview questions were prepared. Table 3 shows a mapping between the research questions (RQ) and both the survey questions (SQ) and the interview questions (IQ).

C. SURVEY QUESTIONS

The survey was published on Google Forms and distributed among professionals who voluntarily decided to collaborate in the research. The survey questions (SQ) were the following:

- SQ.1. How long have you used agile frameworks to develop software?
- SQ.2. What is the number of projects developed under agile frameworks in which you have participated?
- SQ.3. How did you acquire the knowledge necessary to work with agile frameworks?
- SQ.4. What do you think was the greatest difficulty that you had to face to adopt agile frameworks?
- SQ.5. What agile frameworks have you worked on?
- SQ.6. As defined in SCRUM and XP, which roles have you played?
- SQ.7. For each of the following skills, determine the level of achievement that you consider necessary for new professionals to cope with work that utilizes agile frameworks:

Effective communication	Collaboration
Self-management	Adaptability
Self-Learning	Creativity
Work under pressure	Teamwork
Second language (English)	Engagement

- SQ.8. According to the following skills, select the five that you consider key for new professionals to perform well in agile teams.
  (The skills consulted were the same as the previous question).
- SQ.9. According to your experience, what technical knowledge do you think is necessary to work under agile frameworks?
- SQ.10. Finally, we would appreciate your comments and/or recommendations regarding content / tools / experiences that universities should take into account to form future professionals better equipped to work with agile frameworks.

D. INTERVIEW QUESTIONS

These questions were sent to each participant in advance to facilitate the interview and generate a more fluid conversation. The interviews lasted an average of 90 minutes and were conducted in the workplaces of the interviewees. The interview questions (IQ) were the following:

- IQ.1. How long have you been interacting with agile practices? What are the positive and negative elements that you have observed in the use of these practices?
- IQ.2. In your experience, what is the real level of adoption of agile practices that work teams have in Chile?
- IQ.3. According to your experience, what are the elements that positively influence the performance of an agile team?
- IQ.4. Which metrics and/or indicators do you know that allow you to measure the performance of an agile team?

- IQ.5. Regarding companies that have adopted agile practices, how is the process of development and the strengthening of skills (soft and hard) for members of agile teams carried out?
- IQ.6. Regarding technical skills, what knowledge must be considered in the training of new professionals?
- IQ.7. How should universities ''train'' their students to make their process of adaptation to the agile mentality easier?

E. POPULATION

To select the participants, it was decided to work with the *ChileÁgil community*,[2] composed by more than 200 active professionals, motivated to share the knowledge that they acquired through experience in agile frameworks. A common validity threat when administering surveys is the lack of participant control. For that reason, we determined that the best option was to use the convenience sampling technique. This technique allows researchers to select those accessible cases that accept being included, based on the convenient accessibility and proximity of the subjects to the researcher [61], [62].

The interviews were conducted after a first analysis of the results of the surveys. The purpose of conducting interviews was to complement the analysis of surveys and compare the results obtained with experienced professionals in agile frameworks. To select the five participants were considered: Two professionals with at least 5 years of experience with agile frameworks, one professional belonging to the ''ChileÁgil'' community directory, one chief senior project and one academic who teaches certification courses Scrum Masters and Product Owner.

F. DATA ANALYSIS

To better understand the data, we use descriptive statistics for the analysis of the closed questions. For the open questions, the analysis was carried out by two researchers through the following steps: (i) each answer was analyzed separately, (ii) then, a coding scheme per question was defined to unify the concepts, (iii) each question was coded as defined, and, finally, (iv) the codings made by the researchers were crossed to unify the analysis.

G. THREATS TO VALIDITY

An important aspect in the design of any investigation is the control of threats to validity. For this, we consider the guidelines of Wohlin *et al.* [63] to try to eliminate threats when possible.

- Construct validity: The convenience sampling technique allowed us to ensure that the survey participants respond according to the research objectives. Each participant voluntarily answered the survey after knowing the objectives they were trying to achieve.

[2]https://chileagil.cl/

TABLE 4. Experience in agile frameworks.

Years of experience	n	%
Less than 1 year	10	12,0
Between 1 and 3 years	33	39,8
Between 3 and 5 years	17	20,5
Over 5 years	23	27,7
Total	83	100,0

TABLE 5. Experience in agile projects.

Agile Projects	n	%
0 projects	2	2,4
1 to 3 projects	26	31,3
4 to 6 projects	22	26,5
7 to 10 projects	10	12,0
More than 10 projects	23	27,7
Total	83	100,0

- Validity of the conclusion: The process of analysis of the results was carried out iteratively among the researchers. First, an individual analysis was carried out, and then a series of discussion meetings to reach a consensus on the research conclusions.
- Internal validity: For this, we consider in the design of the survey the guidelines proposed in [60].
- External validity: We mitigate this threat by considering participants belonging to the ChileÁgil community. Thus, it was possible to have the participation of professionals of different nationalities who work in various companies and different levels of experience. The sampling technique allowed us to have a certain degree of control over the participants with which it is possible to have quality levels in the responses.

VI. ANALYSIS AND RESULTS

In this section, we present the characterization of the participants and the analysis of results obtained.

A. CHARACTERIZATION OF PARTICIPANTS

As mentioned above, the non-probabilistic sampling technique was used for this investigation ''for convenience''. All participants were altruists and members of the ChileÁgil community. The survey did not consider questions that would harm the confidentiality of the participants and only considered those that were directly related to the objectives defined.

Table 4 and Table 5 show the results obtained according to SQ.1. and SQ.2, respectively. Note that around 48% of professionals declared be using agile frameworks for at least three years, and around 28% for over five years. Moreover, around 66% of the professionals have participated in at least four projects developed under agile frameworks.

Questions SQ.5 and SQ.6 of the survey provided us information on which agile frameworks are used and what are the roles that Chilean professionals mostly develop. 96% of the respondents said they work or have worked with Scrum, 70% with Kanban, 28% with XP, and 57% declared using hybrid agile frameworks. Regarding the roles played in Scrum, 77%

TABLE 6. Results obtained from question SQ.7 of the survey.

Skills	Achievement levels			
	Level 0	Level 1	Level 2	Level 3
Collaboration	0	7	19	57
Effective communication	0	7	49	27
Teamwork	0	5	26	52
Self management	0	12	28	43
Engagement	0	7	22	54
Adaptability	0	6	40	37
Self-Learning	1	14	37	31
Creativity	5	22	37	19
Work under pressure	21	26	22	14
Second language	18	30	24	11
Total	45	137	304	345

of the respondents declared having worked as Scrum master, 29% as product owner, and 34% as part of the team. Regarding the roles played in XP, 31% reported having played the role of programmer, 13% functioned as a tester, 0% as a tracker, 36% as a coach, and 18% as a manager.

The answers to the survey carried out voluntarily by the professionals show sufficient experience to consider their opinions as expert knowledge. Much of the experience and knowledge comes from the Scrum framework, where the main role declared is that of Scrum Master. The abundance of existing training courses and certifications has allowed many of the considered professionals to have fulfilled the role of facilitator or coach for team building.

The remaining results are categorized by research questions according to Table 3.

B. RQ.1. WHAT ARE THE SKILLS THAT CHILEAN PROFESSIONALS CONSIDER AS KEY TO WORKING WITH AGILE FRAMEWORKS?

Regarding the necessary skills that are considered key to work with agile frameworks, in question SQ.7, the participants were requested to indicate the level of achievement necessary for each of the skills identified in [30] and SQ.8, and choose the ones they consider most important or key. In Table 6, it is possible to observe the skills ordered according to the resulting ranking. 89% of the respondents pointed out that collaboration is the key skill to consider while working with agile frameworks. Following that, effective communication and teamwork appeared with 73% and 70%, respectively. The ranking of the key skills was completed by self-management and commitment, both with 66%. The least chosen skills were: creativity, working under pressure, and adopting a second language (English), with 16%, 8%, and 4%, respectively.

Since 2007, the Ministry of Education of Chile has adopted a methodology based on achievement levels to define skill standards. Achievement levels are descriptions of the knowledge and skills that students are expected to demonstrate. For this investigation, four levels have been defined:

- Level 0. Below the basics: Skill is not considered necessary, or its existence is not important to work with agile frameworks in software development.
- Level 1. Initial: Skill is necessary but not very important to work with agile frameworks in software development. The expected performance level for the skill is basic.
- Level 2. Intermediate: Skill is necessary and important to work with agile frameworks in software development. The expected performance level for the skill is satisfactory.
- Level 3. Advanced. Skill is extremely necessary and of great importance in working with agile frameworks within software development. The expected performance level for the skill is highlighted.

The survey asked professionals about their perception of the levels of achievement that a professional should have to eventually achieve a good performance working with agile frameworks. In the results, we found little dispersion of the results for the three skills identified in [30]. Figure 2 shows the maximum and minimum achievement levels obtained for each skill consulted in S.Q.7. In the figure, we also use a measure of central tendency (statistical mode) to identify the level of achievement that obtained the highest frequency for each of the skills. This measure allows us to see that the first five skills (collaboration, effective communication, teamwork, self-management, and engagement) are highly valued by professionals working with agile frameworks. There are four skills where the maximum value coincides with the statistical mode. This result reflects an overwhelming coincidence regarding the identification of key skills. For the rest of the skills consulted, more dispersed values are observed, and Level 0 values are obtained for some of them. The skills that require a higher level of development to work with agile frameworks are collaboration, effective communication, and teamwork; while those that require a lower level of development are work under pressure and command of a second language.

Technical skills, that is, those skills related to the knowledge necessary to perform a specific function, are necessary to work with agile frameworks, but are not relevant to perform well in an agile team. The interviewees continually reinforced that the important thing is the agile mindsight to guarantee minimum conditions of good performance since they have observed that the primary difficulties in adopting agile frameworks are more often related to soft skills than technical skills. According to the respondents, the existing standards in most Chilean universities guarantee to deliver professionals highly trained in technical skills to the market. Moreover, respondents insist that the nature of the specialty forces to be in a constant learning process of new methods, techniques, and tools.

Just as the results obtained in the surveys applied to the industries of Brazil [46], [47] and Finland [53], Scrum is the predominant agile framework in the software development industry in Chile. With the data in Table 6, together with the analysis carried out during the interviews (see Table 7), we propose a tentative definition of the levels of achievement for Scrum roles in the three skills considered as key. This proposal was designed based on the results shown in Table 6,

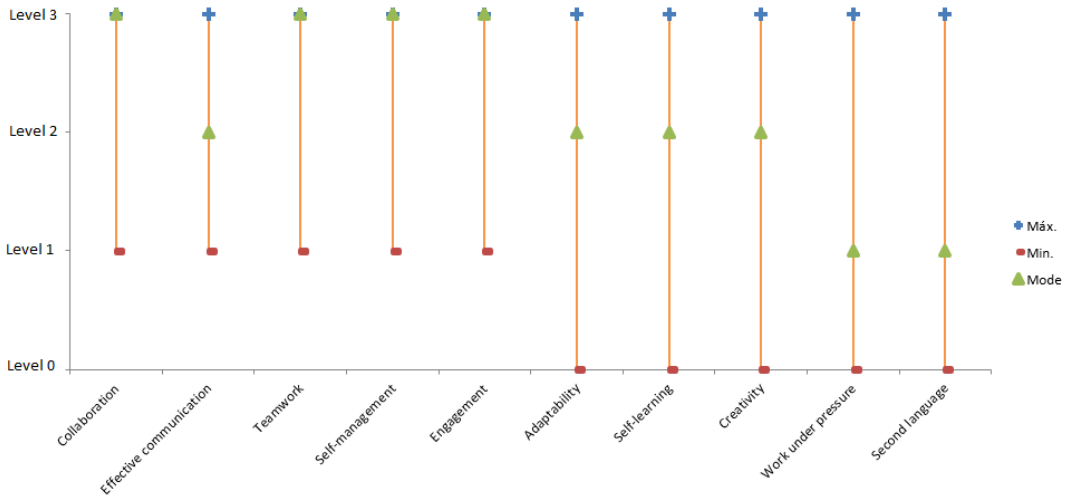

FIGURE 2. Achievement levels obtained in S.Q.7.

TABLE 7. Proposed levels of achievement for Scrum roles.

Key Skills	Level 2	Level 3
Effective communication	Team Scrum master	Product Owner
Collaboration	Team Product Owner	Scrum Master
Teamwork	Scrum Master Product Owner	Team

Figure 2, the definition of roles that appear in the official Scrum guide, and the valuable information provided from the interviews.

To evaluate a high-performance agile team, we must define metrics that allow monitoring performance. The metrics identified to evaluate the performance of an agile team are the following: speed, amount of user stories terminated by iteration, number of productive bugs, and customer satisfaction. Some less common metrics include: percentage of product backlog term, morale/happiness/mood of the team, and the number of productive deployments. The interviewees recognized the importance of implementing other metrics, such as cost/expense/investment vs. profit/return obtained. However, they recognized the difficulty of establishing metrics far from agile principles and values. They also stated that the issue causes a certain level of rejection from the teams because they are considered as distracting elements to work.

The interviewers were also openly consulted on what technical knowledge they considered necessary to work under agile frameworks. As indicated in Section V-F, the open questions were coded and categorized by two researchers. At each iteration of the analysis, the researchers agreed on how to code and categorize the questions. Figure 3 illustrates the result of the whole process. The most representative responses were:

- "A base is needed (. . .) to understand the principles of feedback cycles, which is by far what matters most is

FIGURE 3. Word Cloud obtained in S.Q.9.

the Agile mindset that goes beyond technical knowledge and has to do with new mental models, principles, and values."

- "Not much technical [knowledge]. It is necessary to understand the framework and what is going on, what is in the background, what is the main objective and the changes it brings. Open to drink something new."
- "It depends on the role and methodology used. For example, in Scrum, the product owner does not require much technical knowledge. The Scrum master does not need to have technical knowledge, although it is always a plus to communicate better with the development team."
- "Mainly soft skills by far. Knowledge of emotional intelligence, systemic thinking, motivation 3.0, teamwork."
- "In my opinion, it depends on the role played in the team; clearly, each role requires having different technical knowledge. If we talk about 'technical' from the

software perspective, I consider that the expert is the developer. But as the facilitator or team leader, you must have good knowledge as you are leading a team that makes software and must try to maintain best practices.''
- ''TDD, BDD, Pair Programming, CI, CD, SOLID, GRASP, Design Patterns, Clean Code, Refactoring.''
- ''The programmer who is part of an agile team must know TDD, BDD, programming of unit [tests], and automated tests. Understand the architecture of the entire application and be an expert in areas of IT.''
- ''Technically, you need to know about framework development, and some of continuous integration; it is always good to know about testing and have knowledge of business management.''
- ''Continuous delivery, continuous integration, pair programming, TDD, clean code, programming patterns.''
- ''Know the agile methodology and be clear on what you want to achieve with it. You must have clarity and some experience in the development tools to use. You cannot learn or use new tools with this type of methodology, because time is very limited. On the other hand, you have already developed the factor of synthesizing requirements, that is, to have the ability for the stakeholders to deliver a requirement and understand without much time what is sought (have experience).''
- ''Depending on the area of development, agility is used in areas that do not necessarily build software today, so technical knowledge will be those of the areas of competence.''
- ''The most relevant are the soft skills; technical knowledge can be learned with training. 'Soft/Professional' skills help to have a better adoption of the framework.''
- ''A lot of discipline.''
- ''It is necessary to improve the quality of professional technicality, the use of design patterns, clean code, continuous integration, test-based design, the promulgation of the prototyping and the generation of specific components for reuse and standardization of platforms, work with collaborative tools and collective psychology, respect in working hours, and necessary preparation of agile contracts.''
- ''Framework to use depending on the nature of the project; management tools for monitoring and feedback.''
- ''It will depend on the type of project and the role it will play, although we are looking for high-performance teams, where the team is mainly made up of experts. A recent graduate will not meet these parameters, so I recommend starting by managing a language, with a smaller framework, learn about queries to relational and non-relational databases, CSS, HTML, API development, use of tools such as Docker, GitHub, or BitBucket. In general, I have discovered that with commitment, people learn and deepen what is necessary to achieve the objectives of the project.''

From the open questions of the survey and the interviews carried out, it is possible to identify the following technical skills:

- Ability to analyze problems.
- Systemic thinking.
- Mastery of programming languages.
- Apply Lean thinking.
- Develop peer programming.
- Understand agile philosophy.
- Knowledge in TDD and BDD.
- Know tracking tools.
- Work with version control.
- Apply continuous integration-delivery.

According to the analysis carried out on the data collected from the systematic mapping, surveys, and interviews, we propose to consider agile professional skills as key to effective communication, collaboration, and teamwork. As a first attempt to reduce ambiguity problems in the definition of these skills, we propose the following definitions:

- Effective communication: Ability to listen and understand the other, transmitting the information required by the agile team in a clear and timely manner. The individual must use and maintain open communication channels to fulfill the project objectives. The characteristics for each level of achievement are:
  - Level 0: Listens carefully to the members of the team. Communicates the ideas clearly and understandably. Asks the right questions to get the information needed to get things done. Maintains adequate communication with the members of the work team.
  - Level 1: Communicates ideas and convey information clearly and concisely. Listens appropriately to others and makes sure that understood exactly what they want to express. Takes advantage of existing formal and informal communication channels to obtain the information needed to carry out the tasks. Encourages open and fluid communication between the members of the team, achieving a proper functioning of the group.
  - Level 2: Listens to the opinions and points of view of others. Selects the most appropriate communication methods in order to achieve effective exchanges. Promotes the permanent exchange of information within the team in order to keep all people adequately informed about the issues that affect them. Effectively uses existing communication channels, both formal and informal.
  - Level 3: Listens and understands others, keeping communication channels open. Clearly and timely transmits the information required by others, facilitating the achievement of the team's objectives. Structures organizational communication channels that allow establishing relationships with all team members. Develops formal and informal contact

networks that allows to create a positive environment for intercommunication.

- Collaboration: Ability to support the agile team, respond to their needs and requirements, and solve their problems or doubts. This ability implies acting as a facilitator for the achievement of the team's objectives, creating relationships based on trust. The characteristics for each level of achievement are:
  - Level 0: Cooperates and supports people of the team when requested. Takes into account the needs of others. Maintains a good relationship with colleagues and establishes good bonds. Collaborates with the workgroup on subjects of the specialty. Being attentive and well disposed to job requirements.
  - Level 1: Supports and actively collaborates with the members of his team. Good disposition to help others. Active cooperation with the team members in the fulfillment of common objectives. A trustworthy person within the work team. Listens to the requirements of others to help them in the fulfillment of their objectives, without neglecting their own.
  - Level 2: Provides help and collaboration to the people of the team. Shows interest in the needs of the colleagues and supports them in meeting their goals. Creates trusting relationships. Actively promotes cooperation within the team. Uses the mechanisms that promote cooperation.
  - Level 3: Provides support and help to others (peers, superiors, and collaborators), and thus responds to the needs and requirements they present. Facilitates the resolution of problems or doubts, through anticipatory and spontaneous initiatives. Strongly supports other people and spread ways of relating based on trust. Promotes the spirit of collaboration in the team, and manages to become a facilitator for the achievement of objectives. Implements mechanisms to promote cooperation as an instrument to achieve common objectives.
- Teamwork: Ability to collaborate with others, be part of a group and work towards a goal. This ability involves having positive expectations of others, understanding others, and creating and maintaining a good work environment. The characteristics for each level of achievement are:
  - Level 0: Collaborates with other people belonging to the work team. Cooperates with others to achieve the objectives set. Acknowledges the successes and contributions of others. Subordinates personal interests to group goals and supports the work of other teams. Example of cooperation and good treatment with all people.
  - Level 1: Encourages the spirit of collaboration. Promotes the exchange of information and guides the work of peers to the achievement of set objectives. Acknowledges the successes of others, whether or not they belong to the work team. Subordinates personal interests to group objectives, in order to achieve goals and supports the work of other teams. Example for colleagues for the positive style of cooperation and for maintaining a good work environment.
  - Level 2: Encourages the spirit of collaboration within the area. Promotes exchange with other teams and guides the work of peers and collaborators to achieve the objectives. Expresses satisfaction with the successes of others, whether or not they belong to the work team. Subordinates personal interests to group objectives to achieve goals and supports the work of other teams. Example of collaboration within his team. Stands out for understanding others and generating and maintaining a good work environment.
  - Level 3: Encourages the spirit of collaboration at all times. Promotes exchange with other teams and guides the work of peers and collaborators to achieve the objectives of the course. Expresses satisfaction with the successes of others, whether or not they belong to the work team, and encourages everyone to work in the same way. Subordinates personal interests to group objectives to achieve goals, and supports the work of other teams. Example of collaboration within the team. Stands out for understanding others and generating and maintaining a good work environment.

C. RQ.2. HOW DID PROFESSIONALS ADOPT THE KNOWLEDGE TO WORK WITH AGILE FRAMEWORKS?

In this research question, we seek to find evidence that allows us to learn about how Chilean professionals acquired knowledge in agile frameworks. Remarkably, Table 8 shows that only 4,8% declare, in the first instance, to have received knowledge during their undergraduate studies and 8,4% in their post-graduate studies. This may reflect that initiative and implementation is still lacking with regards to the updating of the curricula and greater linkage of the industry with universities. 80,7% of the participants declared that they have acquired knowledge about agile frameworks personally (self-learning) and 62,7% have completed some training course (certification) in these subjects. It is important to note that respondents were able to select multiple options.

Table 9 shows the values obtained in SQ.4 concerning the difficulties faced by respondents while encountering the use of agile frameworks. The table shows that 29% of the respondents stated that involving the client in the project is the greatest difficulty faced, followed by the sense of collaboration and commitment in the team, with 22%.

According to the respondents, technical skills do not represent greater difficulty while working with agile frameworks since only 2% expressed this option.

TABLE 8. Results obtained in S.Q.3.

Training medium	n	%
Based on personal experience, mostly self-learning	67	80,7
Training in the company	37	44,6
Working in teams with experience	44	53,0
During my undergraduate studies	4	4,8
During my postgraduate studies	7	8,4
Diplomas Courses Certifications	52	62,7

TABLE 9. Main difficulties detected.

Difficulty	n	%
The discipline with the methodology	14	16,9
Role Definitions	6	7,2
Sense of collaboration and commitment to the team	18	21,7
Technical skills	2	2,4
Communication with stakeholders	6	7,2
Involve the client in the project	24	28,9
Define deliverables and project closure	3	3,6
Properly document work	5	6,0
Manage the project properly	5	6,0
Total	83	100,0

Respondents have pointed out that in order to face the main difficulty —to involve the client in the project— companies as a whole must adopt an agile philosophy and guarantee time and space to people who play the role of Product Owner. Another widely used strategy is that the company in charge of software development has a person with experience and high knowledge in the client's business area to fulfill the role of Product Owner.

Regarding the actual level of adoption of agile practices, there are different perspectives. On the one hand, the capabilities of professionals are recognized by joining the principles and values stated in the manifesto; however, the environment surrounding the teams does not always facilitate the work. In order to ensure that the benefits of agile frameworks can be fully observed, all areas of the company transform and adopt agile principles, values, and practices. When this does not happen, over time, there is confusion and a loss of focus on the agile team. Thus, the importance of the Scrum Master is reinforced as the one in charge of solving the impediments that the team has and ensuring that the process is developed as closely as defined in the framework.

Slowly, companies in Chile have been adopting agile practices in powerful digital transformation processes and also adopting new management models, such as Management 3.0, which guarantee better results in the future.

D. RQ.3. WHAT KNOWLEDGE SHOULD BE CONSIDERED BY THE ACADEMIC COMMUNITY IN THE TRAINING PROCESSES OF PROFESSIONALS FOR WORKING WITH AGILE FRAMEWORKS?

In general, a large part of the opinions recommends generating instances that allow students to absorb the mentality and work culture necessary for agile frameworks, based on the four values and the twelve principles established in the agile manifesto.

Integrating agility into the training of professionals must be a gradual and continuous process because it is impossible to concentrate all the knowledge in a group of specific subjects. Agile culture should be promoted from the beginning and maintained while the professional maintains a link with the University. Therefore, all those who participate in the training process must apply the principles and values of agility, that is, a total culture change.

For the most part, professionals working with agile frameworks in Chile focus their attention on the current difficulties of adopting agile frameworks, with barriers and impediments similar to the international experiences analyzed in [46], [47], [53]. For this reason, they recommend that efforts should focus on strengthening soft skills because they have a direct impact on the development of an agile culture around work.

From the information collected in the surveys and from the interviews carried out, it is possible to propose the following knowledge, which should be part of subjects throughout the curricula:

- *Agile Theory*: Lean Thinking, Kaizen, agile frameworks (Kanban, XP, Scrum and Lean).
- *Frontend techniques and tools*: Html, CSS, javascript, Node.js, angular, react.js, Rest, Sass.
- *Interface design and prototyping techniques and tools*: Sketch, Adobe XD, Marvel App, InVision.
- *UX techniques*: Guerrilla testing, Lean UX.
- *Backend techniques and tools*: Java, Node.js, REST, OWASP, Spring, TDD, GIT.
- *Continuous deployment techniques*: SonarQube, Jenkins, Bamboo.
- *Project management techniques and tools*: Jira, Rally Software, Version One, Trello.

To complement the above, we present some quotes from the opinions issued by professionals:

- "In all subjects, you can begin to incorporate the values of agility, not necessarily as a subject in itself, but in practice (. . .)"
- "(. . .) teach on a non-deterministic basis (. . .) teach your students to forget that we have control under a context of complexity (. . .) also that they stop 'making wonderful plans' and start executing and learning by doing (. . .)"
- "Please give a real look to the students so that the change of theory to the real-life of computer scientists makes sense (. . .)"
- "Group dynamics encourage the creation of strategies to better perform the flow of solution/problem management and new requirements (. . .)"
- "From my experience, when one begins with professional training at the University, some people have the profile of a developer and others a profile oriented toward networks or focused on management. Regarding this developer profile, it would be ideal for academics to be able to detect these skills (. . .)"
- "They have to work on soft skills, especially in teamwork: most of the tests at the university are individual

and not group. Foster collaboration and how to be a helpful leader, since, in these times, the team is about the individual (. . .)''

- ''A lot of practice since the first semester. They must carry out work for projects and products rather than isolated materials. Integration with the industry. Teaching by professionals who practice in the industry (. . .)''
- ''That they learn to learn for the rest of their professional life (. . .)''

VII. CONCLUSION AND FUTURE WORK

The main aim of this work was to identify the necessary skills and knowledge, according to the software development industry in Chile, required to improve the professional training processes. In addition, we seek to better understand, based on the experience of Chilean professionals, (i) how to acquire knowledge about agile frameworks, (ii) what difficulties there are to work with agile frameworks, and iii) what are the key skills for success in the application of agile frameworks.

The results obtained from this study agree with those analyzed in the international experiences presented in [46], [47], [53]. Scrum appears as the most frequently used agile framework in Chile. The role of Scrum Master is the most often developed by professionals. The Agile Key Professional Skills to work properly with agile frameworks are collaboration, effective communication, and teamwork.

We believe that the lack of a consensus and a body of knowledge on the theoretical and practical aspects necessary for the use of agile frameworks has led to disorientation and a lack of clarity in the training processes of new professionals. Today, research activities are oriented towards aspects, such as evaluation metrics, process improvement, tools to support agile practices, training, and teamwork [1], [35], [64]. The official scrum guide [65] defines that Scrum Teams are cross-functional, which means that members have all the necessary skills to create value in each Sprint. A multifunctional team does not mean that each member should know everything, but that each member of a cross-functional team must be trained to do more than what they are specialized [66]. Based on the results obtained, we believe it is important for each member of a team to know the levels of achievement that she has in each of the Agile Key Professional Skills. This information will allow the team to know their strengths and weaknesses when facing a particular software development project.

Regarding technical skills, the community of professionals in Chile considers that these aspects are not entirely relevant while applying agile frameworks since current training provides the basic elements to work properly. The same conclusion was reached by Asnawi *et al.* [44], who interviewed 13 software development practitioners from seven organizations. They found that soft skills are more important than technical aspects while using agile frameworks. Furthermore, they added that the agile teams themselves are responsible for technically leveling a member when there are technical gaps. Collaboration and transparency are applied at all times in agile teams, which has allowed the creation of work culture around the same collaboration.

As future work, a set of metrics could be defined to evaluate the level of achievement in the defined key skills. In addition, it is pending to develop a proposal to define a body of knowledge to guide the training process of professionals working with agile frameworks.

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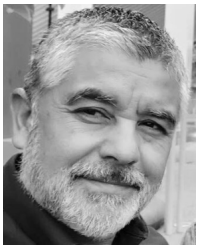

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