A Survey On the Academia-Industry Gap

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1 Introduction

Employment-related benefits are one of the main reasons that students pursue degrees in higher education. Specifically, students typically perceive their undergraduate education as something that would help them discover their career path and develop career-related knowledge [7]. For students studying computer science and engineering (CSE), career development entails being prepared for tech-related roles in industry. But despite completing their undergraduate CSE education, many graduates often feel unprepared for their careers in the software industry [9, 13]. This disconnect between the knowledge gained in higher education and the skills used in the software industry is referred to as the *academia-industry gap* (hereinafter referred to as the "Gap").

The Gap was first identified many decades ago, yet still stands as a relevant problem to this day. The problem is felt by all parties involved in industry and in academia: students have mixed feelings about the usefulness of CS undergraduate programs as a preparation for industry [4] and new graduates often face difficulties in the early stages of their industry careers [3]; academia faculty generally see that industry preparation should be a key goal of CS education [13, 14]; and industry professionals indicate that new graduates in software engineering (SWE) often have deficiencies in both hard and soft skills [9], thereby limiting their company's productivity. The literature clearly indicates that those in academia and in industry acknowledge the Gap, and consider closing the Gap desirable. However, despite the decades of research surrounding it, the Gap persists. This survey paper aims to synthesize the literature surrounding the Gap by comparing the problems found by existing research, analyzing the proposed solutions to combat said problems, and identifying research gaps in order to guide future research.

Section 2 will identify the various stakeholders of the Gap and discuss their perspectives. In this section, we look at how each entity contributes to the persistence of the Gap. Section 3 will look at proposed solutions that address the causes from Section 2. We conclude in Section 4 in which we examine research gaps by pinpointing problems that have not been addressed and solutions that have not yet been carried out, guiding future research.

2 The main actors and their effects on the Gap

This section will identify the main entities concerned with the Gap, discuss how each entity may be contributing to the persistence of the Gap, and compare each of these perspectives with the results of current research.

2.1 The main actors

Oguz and Oguz [8] identify three parties that can be considered as the main actors that affect and are affected by the Gap: industry, academia, and students & software engineers. We define the three parties in the researchers' terms and explain their relationship with academia and industry:

Industry The software industry is where software is created as either the good or service itself or something that assists in the production of goods and services [8].

The industry bears a large part of the burden of the Gap. Radermacher et al. interview managers and hiring personnel from various software companies on how they perceive *knowledge deficiencies*—the skills and abilities that new CS graduates lack based on employer expectations—to gain insight into precisely which skills new graduates need improvement. The researchers identify a variety of knowledge deficiencies; the most frequently occurring ones include lack of project experience, unfamiliarity with configuration management tools, and problems with effective communication [9]. The industry is affected by the Gap because when it hires new CSE graduates and find that they exhibit knowledge deficiencies, companies will have to spend more time and resources on training them.

Academia Academia refers to the educators and professors of computer science and engineering in higher education. Academia plays two roles in the professional field: they *a*) educate students to become future computer scientists and software developers, and *b*) conduct research uncovering ground truths about CS and engineering that may guide best practices in industry [8]. For the purposes of this survey paper, the former is what we will consider as the primary contribution of academia to industry[1].

Because the Gap mainly concerns the difference between new graduate skills and employer expectations, academia does not directly feel the impact of the Gap. However, academia may end up bearing a lot of the burden of *closing* the Gap as many faculty members feel that it is the responsibility of their academic institution to better prepare students for industry [14]. Similarly, industry professionals and SSEs feel that higher education CSE programs can and should do a better job at including more industry-relevant material in their courses [3, 9].

[1]The latter is an important contribution as well, but this affects not so much the gap between academic experience and industry standards as it does the gap between theoretical possibility and technological capability & innovation, which is not in the scope of this survey paper.

These perspectives are justified since it is primarily higher education where new software developers learn their skills. However, it may actually be the case that CS programs in academia don't include enough industry-relevant material in their curricula to meet the standards of industry professionals [3, 9]. As a result, students who leave their academic careers and become software developers possess knowledge deficiencies when they begin work, which exacerbates the Gap.

Students and software engineers (SSEs) SSEs represent the same entity at different points in time. They are those gaining knowledge in academia and applying their skills in industry, respectively. While academia and industry are the two institutions between which the Gap exists, SSEs are the physical embodiment of the Gap itself because their skill set directly determines the state of the Gap [8].

SSEs are heavily affected by the Gap as well. The counterpart to the burden of training and costs carried by industry is the feeling of unpreparedness and subsequent stress experienced by new graduates working as software engineers in industry [3, 4, 8]. SSEs have the least experience among these three parties, yet they are expected to bridge the Gap as soon as possible.

2.2 How the industry affects the Gap

By definition, there is a Gap between academia and industry because the two parties are progressing at different paces or in different directions. The software industry's progress is not dependent on the progress of academia as an educational institution. Rather, its progress is determined by market factors such as cost, consumer demand, and scalability. This market-driven progress implies that, on one hand, faculty may not even want to keep their course curricula up to date with industry practice because this would mean incorporating business-related material in their CSE curricula that certain faculty may deem irrelevant [14]. On the other hand, even if CS faculty *do* want to keep their programs up to date with industry, they would struggle to do so since industry standards keep changing and academia simply cannot keep up given the slow and careful nature of curriculum design [8]. Thus, the industry is arguably one of the main driving forces of the Gap as it will inevitably contribute to the persistence of the Gap for as long as software industry trends remain dependent on the market and independent of CS education.

It seems as if the industry's effects on the Gap are not truly the fault of the industry; the industry is simply trying to keep up with the market because it has no choice, and academia cannot keep up to date with industry practices, therefore the Gap persists. However, this does not mean that the industry isn't culpable in this issue of the Gap. Alboaouh argues that the industry is not doing its part in remedying the Gap in his analysis of the intercommunication between industry, research, and engineering colleges. He claims that although there is feedback between research and colleges as an educational institution[2], the feedback between industry and colleges is missing, i.e. after schools send new graduates to industry, the industry does not provide feedback to the schools on how to better prepare students based on the new graduates' performance [1]. Alboaouh's analysis highlights that even though market factors lead the industry into inescapably helping the Gap persist, the absence of feedback from industry to academia may be a more mitigable cause of the Gap that the industry can and should address.

2.3 How academia affects the Gap

One of the impacts of academia on the Gap was briefly mentioned in the previous subsection: they affect the Gap because of their shortcomings in their ability to keep CSE curricula up to date with the latest industry standards and expectations [8, 13, 14]. But familiarity with industry practice is not the only means by which faculty can help students prepare for industry. There are more general skills such as "soft" skills, SWE skills, and interview preparedness that are imperative for one to succeed in industry but are not necessarily reflected in CS curricula either [14]. These shortcomings of academia can be viewed in two different ways: either *a*) CSE faculty don't view software industry preparation as a goal of CSE curriculum, or *b*) they *do* view it as a goal, but there are external factors preventing them from achieving it.

With regards to the former belief (*a*), there indeed are CS faculty members who believe that, as exclaimed by a famous CS professor in Stroustrup's article, "We don't teach programming; we teach computer science" [11]. This perspective is supported by Norton and Martini, who assert that faculty typically develop their curricula without keeping in mind students' motivation for attending higher education which, for many, is to enhance employability and prepare for industry [7]. CS faculty with these beliefs contribute to the persistence of the Gap since they may be less open to changing their curricula to consist of more industry-relevant material, especially if such changes go against the learning outcomes they desire for their students.

However, more recent studies have shown that this viewpoint may be the exception rather than the norm. Valstar et al. investigate how faculty view the value of a CS degree and if such views are a potential cause for the persistence of the Gap. They find that, contrary to the views in the previous paragraph, there is general agreement among CS faculty that industry preparedness should be a main goal of CS education. If such is the case, then this implies (*b*): the Gap persists due to other academic-related barriers. One possible barrier the researchers propose in the same study is that the Gap is a resource gap [13]. In a follow-up study in which they *quantitatively* investigate faculty views on the goals of CS education, they indeed find that a majority of CS faculty commonly

[2]The feedback loop between research and engineering colleges, briefly: engineering colleges contribute to academic research, thereby helping researchers make new advances. Engineering colleges then update their curricula to reflect these new advances in engineering knowledge, which paves way for more research—and the cycle continues [1].

encounter these resource gap barriers, such as large class sizes and faculty being unaware of industry best practices [14].

An encouraging finding of the study is that a majority of CS faculty view their own institution—not the industry or the students—as the primary responsible party for students' industry preparedness. Along with the fact that most faculty would like their institution's CS programs to better prepare students for industry, this statistic is promising as it implies that academia is willing and ready to help remedy the Gap from an academic standpoint.

2.4 Students and software engineers

SSEs affect the Gap by the mere fact that they are the physical embodiment of the Gap; their skills and knowledge directly determine how closed or open the Gap is. Therefore, if a new CSE graduate's industry-relevant skill set is minimal, then they widen the Gap. Otherwise, they help narrow it [8]. Beyond this, views on the ways in which SSEs affect the Gap seem to be uninvestigated in CS research.

3 Solutions that address the causes of the Gap

Now that we've analyzed the causes of the Gap from the perspective of each of the different parties, this section will look at tried solutions that address the above causes. Each subsection looks at the ways each of the three parties can remedy the Gap from their point of view.

3.1 How the industry has attempted to remedy the Gap

3.1.1 Internship programs

As mentioned in section 2.2, there is an inevitable quality to the Gap because of how it's perpetuated by the industry, whose trends are influenced by the market. To try to alleviate this problem, companies in the software industry often run internship programs in which students can spend their free time during their academic careers in industry, solving problems that a full-time employee would regularly face. Early-career software developers who did internships in college claim that internships align closely with full-time industry experience, particularly in terms of the nature of the teams with which they worked and the software development tools used [3]. Internships also help students develop their personal and professional skills, thereby better preparing them for their future careers [4]. However, some developers feel that internships are still often more similar to a university experience as opposed to industry work because interns are often sheltered from the more stressful aspects of full-time work, such as legacy code, real customer demands, and high-risk work [3]. Thus, though internships are effective, they alone are not sufficient in closing the Gap.

Software industries can and should run more internship programs and encourage more students to take part in them. The industry is one of the biggest driving forces of the Gap, but by providing more internship opportunities, they help relieve some of the pressure on academia to remedy the Gap and help students develop greater familiarity with the industry early on.

3.1.2 Student pre-employment training

A novel idea similar to internship programs is pre-hiring, curricula-based supplementary training programs. Tuzun et al. [12] study its effectiveness by investigating such a program run by Havelsan[3] Academy, a summer program that trains candidate employees (i.e. undergraduate students) in knowledge areas (KAs) regarding the industry that aren't typically emphasized in their universities, such as Agile software development and Javascript programming. Many participants showed significant improvements in knowledge of the KAs after completing the program. More importantly, participants also learned to apply the theoretical concepts taught in university to problems in industry, which highlights that this pre-employment training program can assist in closing the Gap.

3.2 How academia has attempted to remedy the Gap

3.2.1 Open Source Projects in classes

As discussed in section 2.3, most faculty support strengthening industry-specific goals in CSE programs [14]. One way to do so is for faculty to utilize Open Source Projects (OSPs) in the classroom. OSPs are projects that are publicly available with no restrictions of deployment location or code ownership, and they have been shown to bring students closer to the software industry experience than "toy projects" in CSE curricula do. Nascimiento et al. find that OSPs not only very closely emulate the real SE experience, but they also help students gain a better understanding of what skills they need to work on independently to be more successful in industry [6].

Thus, OSPs address a few of the causes identified in section 2. Firstly, it helps students gain project experience, which is a knowledge deficiency observed by companies [9]. Secondly, by incorporating the use of OSPs in their curricula, CSE faculty will be able to include more industry-relevant material in their courses, which is a goal many faculty members would like to achieve [13]. The use of OSPs helps close the Gap because not only do they allow academics to achieve their goal of including more industry-relevant material thereby strengthening CSE programs, students who want to enter industry will be able to more easily transition with the open-source project experience they will have gained from OSPs.

3.2.2 Promote soft skills in CSE programs

While OSPs may do a good job in strengthening students' industry-relevant technical skills, academia should also find a way to emphasize the importance

[3]Havelsan is a medium-size software and systems company based in Turkey.

and strengthen the soft skills of CSE students. The literature stresses that soft skills are of utmost importance in the software industry, but early-career software developers often feel unprepared for the degree of teamwork and communication required in their work [3, 5, 9]. A way for academia to close this part of the Gap is to assign projects and coursework that incorporate teamwork. For instance, Marques et al. propose the use of *ThinkLets*, a "process pattern to address collaboration problems," in CSE coursework. ThinkLets have been shown to mitigate a majority of recurring collaboration problems such in software development [5].

By emphasizing soft skills in CSE programs, students will be able to gain collaborative skills that are very transferrable to industry. If incorporated alongside the solution mentioned in section 3.2.1, students will be able to gain a holistic software development and engineering experience in their academic careers, which will help narrow the Gap.

3.3 SSEs: can they help remedy the Gap?

As mentioned in section 2.4, the Gap is a reflection of the skills of SSEs. This implies that attempts by them to remedy the Gap would involve more self-improvement strategies, therefore no solutions towards closing the Gap can realistically be "implemented" by SSEs themselves. But as section 3 has suggested so far, industry and academia, the two institutions between which the Gap exists should are the ones who should be implementing solutions and taking responsibility in making sure that SSEs have the proper skills when entering the industry.

4 Research gaps

In this section, I will identify the problems that have been brought up but unaddressed as well as some solutions that have been proposed by researchers but not yet brought into effect.

4.1 Problems and perspectives

4.1.1 Cost of solutions incurred by industry

Although it would be beneficial for the industry for the Gap to close, the effectiveness of industry-side solutions in section 3.1 are dependent on the willingness and enthusiasm of the software industry to carry out said solutions to begin with. As it stands, the software industry already has systems in place to close the Gap unilaterally: it trains new graduate hires before starting work, and they choose to hire those with higher GPAs to minimize knowledge deficiencies and reduce training time. Since the industry is motivated by market factors, it will likely choose to maximize profits. Thus, if it costs more to integrate more with academia and pre-employment programs than it is to simply train new hires, the industry might rather proceed with the status quo as opposed to help reform the hiring and educational system [1].

It must be shown first that these Gap-closing solutions are actually more beneficial for industries than new hire training. For instance, Tuzun et al.'s Havelsan Academy study estimates that its pre-employment summer program, given that it resulted in eight new graduate hires, *at worst* breaks even with all its incurred costs as compared to the average $3,000 per new hire cost of the traditional hiring process [12]. If similar programs such as internships are indeed cheaper than normal training processes, then the software industry might be more enthused by the idea of closing the Gap in other ways.

4.1.2 Cost of solutions incurred by academia

Similarly, while the industry has financial costs to consider, academia must also weigh the opportunity cost of making its CSE curricula more pertinent to industry standards. Points of view such as "we are not a trade school" [3, 9] and "we don't teach programming; we teach computer science" [11] are not without merit. If academia, especially computer science faculty, include more industry-relevant material in their curricula, then they will have to spend time developing such a curriculum, decide what existing educational material must be replaced, and risk teaching students outdated industry standards in any case due to the speed at which the industry changes its practice.

Even though a majority of faculty agree that industry preparedness should be a key goal of CS education, there is a non-trivial number of faculty who disagree [9, 13, 14]. For some, this viewpoint is not necessarily adversarial. Some faculty simply believe that teaching students a specific set of industry-related skills is too narrow and would only limit their career choices, therefore it is better to provide a more broad view of CSE in college [9]. Whatever the reason may be, the closing of the Gap will be slowed for as long as there exist dissenting views between faculty on the inclusion of industry-specific skills in academia.

4.1.3 Barriers to closing the Gap faced by faculty

Valstar et al. report that for those faculty who *do* desire to make their curricula more industry-relevant, the sheer number of different barriers preventing them from doing so is too large for any one solution to address. Some of these barriers make this goal infeasible, such as faculty not being aware of industry standards themselves and the need to keep course workload to a reasonable level. Additionally, there does not seem to be any discernible pattern between which/how many barriers exist, how many faculty members face such barriers, and the characteristics of a CS program [14]. There seems to be simply too much uncertainty regarding the barriers to success and why they exist. Thus, it might be beneficial to prioritize learning more about these barriers as well as how to lower them, which may consequently remedy the Gap in the process.

4.1.4 Is the Gap an educational problem or a pedagogical one?

The Gap doesn't exist only between CSE academia and the software industry. For instance, Büth et al. argue that there is a mismatch between engineering graduates' skills and manufacturing industry requirements, thereby necessitating additional graduate training for new graduate engineers [2]. Royle & Laing find that higher-education marketing programs don't seem to keep in line with the latest technological developments and the marketing techniques that are shaped by them, which creates a digital marketing skills gap [10]. Given that the Gap seems to pervade across many different industrial and academic fields, it's possible that, from an academic point of view, the Gap has persisted not due to problems with CSE *education* and its curricula, but rather due to issues in *pedagogy*. This is supported by the fact that the barriers to closing the Gap, as described by CS faculty, aren't a consequence of problems with CS education specifically—instead, they are all cited as problems related to effective classroom instruction such as those mentioned in section 4.1.3 [13, 14]. Thus, perhaps research should tackle the problem of the Gap not by suggesting ways in which CS programs should update their curricula to keep up with industry, but by investigating the ways in which general pedagogical beliefs and practices may be inadvertently sustaining the Gap.

4.2 Solutions to try

4.2.1 Establish feedback from academia to industry

As discussed in section 2.2, a problem concerning the Gap between engineering schools and industry is the absence of feedback from industry to academia. Alboaouh proposes multiple ways in which this feedback can be established. For instance, he suggests that academic engineering journals be an accessible venue in which industry engineers can publish work. He suggests developing a separate set of norms and standards for acceptance and rejection of papers submitted by engineers in industry [1]. Thus, industry professionals will be able to publish works that inform academia of industry standards and best practices. By allowing industry engineers to contribute to academic journals, academics are able to establish an avenue for feedback, thereby allowing them to be more informed of the latest trends in industry. In turn, faculty who wish to make their courses more industry-relevant may learn from these papers and update their curricula accordingly.

4.2.2 Summer internship in industry for CSE faculty

Section 4.2.1 touches on one of the biggest barriers hindering faculty from remedying the Gap: their lack of awareness of industry best practices. This incognizance raises doubts about academia's role in closing the Gap if they truly are so disconnected from industry requirements[4]. However, a large majority of CS

[4]As mentioned in section 4.1.2, such dissenting views are counterproductive as they themselves serve as a barrier toward closing the Gap.

faculty believe that industry preparedness should be a key goal of CS education, that their curricula should be more inclusive of industry-relevant material, and that the quality of their institutions' CS programs would improve if they could help better prepare students for industry. It stands to reason that if faculty *were* more aware of industry best practices, they could potentially be of great help towards bridging the Gap.

To address this concern, Craig et al. propose that CSE faculty should find time to gain some industrial experience and partake in a "summer internship in industry" in order to encounter what industry requires of newly hired SSEs [3]. This way, faculty members who do wish to make their courses more pertinent to industry skills can do so after learning more about the industry through an authentic experience. Of course, this might be a contentious solution given that the academic cycle might be inflexible for many academics and that taking part in this experience is a time commitment. When academics aren't teaching throughout the school year, they are likely pursuing their own research which makes this summer experience unfeasible for many. Thus, it might be worthwhile to explore similar avenues towards making CS faculty more well-informed about industry practices with a lower opportunity cost or better incentive so that academics may be more inclined to take part in such a reform.

References

[1] K. Alboaouh. The gap between engineering schools and industry: A strategic initiative. In *IEEE Frontiers in Education Conference, FIE 2018, San Jose, CA, USA, October 3-6, 2018*, pages 1–6. IEEE, 2018.

[2] L. Büth, V. Bhakar, N. Sihag, G. Posselt, S. Böhme, K. S. Sangwan, and C. Herrmann. Bridging the qualification gap between academia and industry in india. *Procedia Manufacturing*, 9:275–282, 2017. 7th Conference on Learning Factories, CLF 2017.

[3] M. Craig, P. Conrad, D. Lynch, N. Lee, and L. Anthony. Listening to early career software developers. *Journal of Computing Sciences in Colleges*, 33(4):138–149, Apr. 2018.

[4] A. Kapoor and C. Gardner-McCune. Understanding CS undergraduate students' professional development through the lens of internship experiences. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education*, SIGCSE '19, page 852–858, New York, NY, USA, 2019. Association for Computing Machinery.

[5] M. Marques and S. F. Ochoa. Improving teamwork in students software projects. In *2014 IEEE 27th Conference on Software Engineering Education and Training (CSEE T)*, pages 99–108, 2014.

[6] D. M. C. Nascimento, C. F. G. Chavez, and R. A. Bittencourt. The adoption of open source projects in engineering education: A real software development experience. In *IEEE Frontiers in Education Conference, FIE 2018, San Jose, CA, USA, October 3-6, 2018*, pages 1–9. IEEE, 2018.

[7] C. Norton and T. Martini. Perceived benefits of an undergraduate degree. *The Canadian Journal for the Scholarship of Teaching and Learning*, 8(1), Mar. 2017.

[8] D. Oguz and K. Oguz. Perspectives on the gap between the software industry and the software engineering education. *IEEE Access*, 7:117527–117543, 2019.

[9] A. Radermacher, G. Walia, and D. Knudson. Investigating the skill gap between graduating students and industry expectations. In *Companion Proceedings of the 36th International Conference on Software Engineering*, ICSE Companion 2014, page 291–300, New York, NY, USA, 2014. Association for Computing Machinery.

[10] J. Royle and A. Laing. The digital marketing skills gap: Developing a digital marketer model for the communication industries. *International Journal of Information Management*, 34(2):65–73, 2014.

[11] B. Stroustrup. Viewpoint — What Should We Teach New Software Developers? Why? *Commun. ACM*, 53(1):40–42, Jan. 2010.

[12] E. Tuzun, H. Erdogmus, and I. G. Ozbilgin. Are computer science and engineering graduates ready for the software industry? Experiences from an industrial student training program. In *Proceedings of the 40th International Conference on Software Engineering: Software Engineering Education and Training*, ICSE-SEET '18, page 68–77, New York, NY, USA, 2018. Association for Computing Machinery.

[13] S. Valstar, S. Krause-Levy, A. Macedo, W. G. Griswold, and L. Porter. Faculty views on the goals of an undergraduate CS education and the academia-industry gap. In *Proceedings of the 51st ACM Technical Symposium on Computer Science Education*, SIGCSE '20, page 577–583, New York, NY, USA, 2020. Association for Computing Machinery.

[14] S. Valstar, C. Sih, S. Krause-Levy, L. Porter, and W. G. Griswold. A quantitative study of faculty views on the goals of an undergraduate CS program and preparing students for industry. In *Proceedings of the 2020 ACM Conference on International Computing Education Research*, ICER '20, page 113–123, New York, NY, USA, 2020. Association for Computing Machinery.