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DevOps Didactic Transposition in IS Higher Education: A Systematic Literature Review

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Completed Research

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Abstract

Information System (IS) higher education is often challenged by declining students' academic performance and motivation. An alternative might be project-based learning (PjBL), due to its benefits for students, such as increased motivation. However, PjBL often focuses on the development phases and therefore lacks an operational vision. Against this drawback, DevOps might be seen as an advance of PjBL, arguing for a balance between the development and operational phases. Therefore, in this paper, we conducted a systematic literature review (SLR) to answer this question: What are the students' results when DevOps is applied to the IS teaching context? We collected 339 papers and selected 22 post-filtering. The two SLR main results were: i) DevOps emerged recently in IS education; ii) DevOps is highly related to PjBL; iii) DevOps benefited students' carrier development, scaffolds students' grades, and communication. The main contributions of this research are: to describe the state-of-art of DevOps in IS education; to provide a theoretical foundation for IS didactic transposition from IS Industry; to detail the students' results when utilizing DevOps is applied to the IS teaching context.

Keywords

DevOps, Teaching Method, Information System, Project-based Learning

Introduction

The academic performance of students is a challenge that impacts the overall context of higher education (Biggs and Tang 2011), including the context of Information Systems (IS) (Grotta and Prado 2021). Students' achievements were also worsened due to poor learning conditions during the COVID-19 period (Koen et al. 2021). On the other hand, the new IS academic curricula promote skills-based learning rather than knowledge-based learning (ACM and AIS 2020). In this context, IS students should be more proactive in building their solutions to current social problems (Queirós 2014). Therefore, these shifts require IS educational innovation. However, innovation in the field of education is often a complex and long-term challenge (Coleman et al. 2020).

Among the innovative practices of IS education, we focus on didactic transposition (DT) (Chevallard and Bosch 2020). DT advocates the transposition of practices from the external (social) context into the internal (university/course) context. In particular, the IS didactic translation (IS-DT) proposes the use of practices derived from the IS industry to develop teaching methods for IS (Hazzan et al. 2010). Examples of IS-DT methodologies are project-based learning (PjBL) and, most recently, DevOps-based learning (DevOpsBL) (Grotta and Prado 2021). DT, such as PjBL, may benefit traditional factors (TF) such as students' grades. And improve emerging factors (EF) such as students' vocational exploration (Grotta and Prado 2019a).

At least two major shortcomings occur in this context. First, IS-DT is still underutilized in the context of IS teaching, mainly because of the mismatch between the speed of industry innovation and IS education capabilities (Fernandes et al. 2020). Secondly, IS-DT methods remain highly focused on development methodologies such as PjBL and are therefore lacking in fostering a balance between development (Dev) and operations (Ops) such as DevOps (Pang and Hindle 2020). In this research, we investigate the *teaching context* (Achiam 2014) and related students' results when choosing DevOps (Grotta and Prado 2021)

In this context, this research aims to answer the following question: **What are the students' results when DevOps is applied to the IS teaching context?** To answer this question, we chose a systematic literature review (SLR) based on the following research objective: to describe, classify, and analyze the teaching context and the student's results.

This research was further divided into four phases. First, we performed an ad hoc literature review presented in the Theoretical Bases section. Second, the SLR methodological procedures were established, therefore we collected and analyzed the SLR data, as presented in the Research Methodology section. Third, the results were consolidated and presented in the Results section. Finally, the Conclusion section presents the conclusions of this research and suggestions for further research.

Theoretical Bases

In this section, we first present the DT. We then present the IS-DT and its relations with DevOps. We then detail the TF and EF in this context. Finally, we present the adapted version of the education continuum that summarizes the relationships between IS-DT and evaluation factors, benefiting IS students.

DT

The DT began in the mathematics teaching context, intending to deal with complex content, such as axioms and logic, and make it more accessible and practical to students. The original concept was later extended to teaching practices in general, but with more affinity with the teaching of exact sciences (Hazzan et al. 2010). Didactic translation, therefore, has many similarities with IS teaching methods. Computational mathematics and logic are fundamental for IS courses. IS learning requires a high cognitive workload from students, similarly to the mathematics teaching context (Giraffa et al. 2014). We distinguish two types of didactical transposition: external and internal. Both are permeated by aspects that transcend educational aspects, such as social, scientific, and technological aspects (Achiam 2014; Chevallard and Bosch 2020):

- *External DT*: its primary objective is to select general knowledge that will be taught, setting standards and regiments. That is frequently an assignment by government agencies, departments, and associations.
- *Internal DT*: its primary objective is to select specific knowledge from the external DT and make this knowledge "teachable". It may be divided into two different aspects. First, structuring or modifying IS courses and their curricular components. Second, is the *teaching context*, which deals with classroom matters such as teaching methods.

For this research, we chose the o *teaching context* because it is accessible to educators. Educators bind knowledge, didactics, and the external environment via internal classroom matters such as teaching practices (Achiam 2014; Marques and Orengo 2021).

IS-DT and DevOps

IS-DT advocates the usage of IS industry practices to develop IS teaching methods (Hazzan et al. 2010). Given the broad range of aspects IS-DT might have, we chose the (Valentine 2004) classification. It is based on six mutually exclusive and well-defined categories, as follows: (1) Simple, which represents punctual studies, that might be simple and direct interventions, being an ornament in the broader context; (2) Descriptive, which refers to descriptive research, such as case studies; (3) Experimental, which are more complex studies, in which there are control groups for instance; (4) Tools, which primarily report tools, frameworks and other elements that support the intervention; and finally the difficult ones: (5) Philosophical, which deals with more theoretical educational subjects; (6) Complex, which are educational studies that cross limits of effort and dedication, such as multipart studies.

Furthermore, computing and IS systems are almost ubiquitous in modern society, from which many innovative working methodologies, such as Scrum, have been raised (Scrum Alliance 2016). DevOps is a stage further from PjBL. DevOps is a software engineering culture that combines software developers (the Devs) and system operators (the Ops). DevOps might be defined as a cultural and methodological relation of Dev and Ops roles, via promoting automation and monitoring of all phases of software construction (Airaj 2017). DevOps is a recent practice that has grown in adoption in the software industry. However, in the IS education context, often it has been given more emphasis on teaching Dev skills rather than operating Ops skills. Thus, although DevOps is well disseminated in the software industry, in the academic field there are few reports on the use of DevOps as a teaching method (Fernandes et al. 2020; Pang and Hindle 2020).

In summary, IS-DT might be described by three factors: Valentine's classification, the type of content being taught (such as curricular component descriptions), and the evaluation factors, detailed next.

Traditional and Emerging Factors evaluation factors

Students' academic achievement is more often evaluated by two TF: grades and attendance rates. TF is nearly pervasive in the context of formal higher education given it is almost universally used in formal higher education (Brookhart et al. 2016). One example of TF is student scores after passing a quiz exam (Brookhart et al. 2016). On the other hand, when teachers chose LcV methods such as PjBJ, it is often difficult to assess students' results solely via FE. One alternative to expanding that assessment is to consider multidimensional EFs (Brookhart et al. 2016), such as assessing the students' progress as future professionals. The most common EFs factors in PjBL are motivation to learn, students' professionalism, and students' communication (Grotta and Prado 2019b). TF and EF combined can best serve as scaffolding factors (Alexandron et al. 2016; Brookhart et al. 2016) to facilitate the transition to an IS competency-based model (ACM and AIS 2020).

IS educational continuum

We have adapted the educational continuum of (Biggs and Tang 2011) to IS, thus resulting in the IS educational continuum as shown in figure 1. This adaptation binds two main IS education aspects: the teaching methods and the evaluation methods. Starting with the teaching methods, they direct students' learning methods. Teaching methods can be based on at least two visions: Instructional-centric Vision (IcV) or Learning-centric Vision (LcV). For instance, when an IcV teaching method such as a lecture is chosen, it requires more passive learning skills from the students, such as memorizing or taking notes (Biggs and Tang 2011). On the other hand, if an IcV teaching is chosen, it requires changes in at least two students' aspects: students' behavioral (Act) (Duke et al. 2010) & students' constructivist (Construct) (Biggs and Tang 2011). These changes reduce the cognitive gap between students (Biggs and Tang 2011). These changes also stimulate the learning via a competency-based model (Brabrand and Dahl 2009), given the students are empowered by the learning process. In the end, both IcC and LcV target the acquirement of knowledge and competencies, but LcV focuses on competencies while IcC focuses on knowledge (Biggs and Tang 2011):

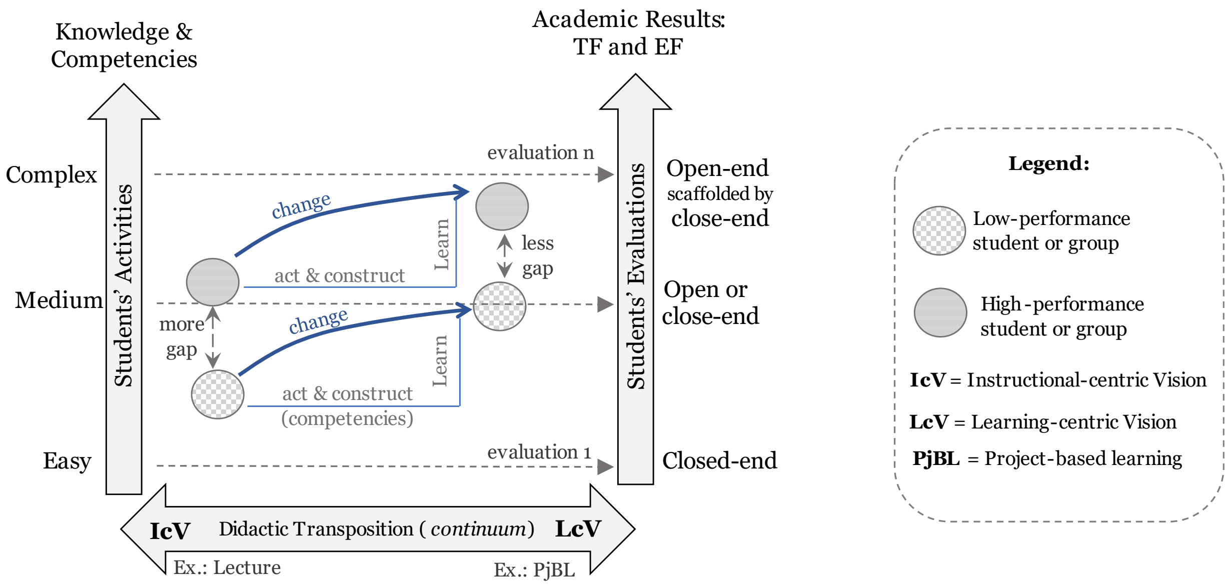

Figure 1. IS educational continuum

Figure 1 also presents a second aspect of the educational continuum, students' academic results, as TF or EF. TF applies well for both large and small groups, for labs with fewer or more education resources, among other aspects we should consider, given that TF is translated into two standard variables: grades and frequency (Brookhart et al. 2016). On the other hand, IS courses are shifting from a knowledge-based model to a competency-based model as described by (ACM and AIS 2020) while students' learning preferences are becoming more prone to LcV methods (Queirós 2014).

Thus, new skills and competencies may not be fully evaluated by TF but for additional factors (Biggs and Tang 2011) we named EF. EF may change depending on the chosen teaching method (Grotta and Prado 2019a). When using PjBL for instance, the main students' EF might be: motivation to learn, vocation exploration, and communication (Grotta and Prado 2019b).

On the other hand, EF ofter requires open-ended evaluation methods, such as creating/evaluating a project when choosing PjBL (Queirós 2014). To overcome this complexity, EF closed-end evaluation might be used to scaffold open-end evaluations. They can be used as on-the-fly evaluations. Examples of EF closed-end evaluations are a construct to evaluate students' motivation after a certain time (Grotta and Prado 2019a) or automating tools to evaluate students' projects bugs as they commit the source code (Ohtsuki and Kakeshita 2019).

Research Methodology

This research is an exploratory study. Thus, it aims to offer information about the object of study and guide the formulation of hypotheses for future research (Creswell 2009). This section describes the research steps. It also details the methodological procedures for collecting and analyzing data. We adopted the SLR for data collection given its advantages over an unstructured literature review. The three primary benefits of the SLR are: clear and repeatable steps; less bias; and an objective reporting format. Among the SLR methods, we chose the (Kitchenham and Charters 2007) method, supported by the guidelines of (Felizardo et al. 2017; Iowa State University 2022). We developed this RSL into two phases, RSL planning, and RSL conduction, as follows:

Phase 1: SLR planning. We recover the RSL objective as outlined in the introduction section: to describe, classify, and analyze the teaching context and the student's results. The following steps were chosen according to the SLR literature:

● Research Question. It was identified using the Population, Intervention, Control, Results, and Context (PICOC) criteria (Petticrew and Roberts 2006). The PICOC criteria aim to analyze the effects of an intervention on a given population, as follows. Population*: students of IS courses. Intervention: DevOps; Control: Students that had no participation with DevOps content or methods;* TF (grades and attendance rate) and EM (motivation, communication, and professional competencies), as described in the theoretical bases; Context: IS higher education.

● Search String. Given that DevOps is a recent topic in IS (Pang and Hindle 2020), we have not restricted any study publication date. On the other hand, we utilized the following refinements: only complete studies, published and accessible in peer-reviewed conferences and journals; only studies related to SI or Education; and only studies published in English. Thus, the final search string becomes as follows. Title, abstract or keywords contain (("teach*" OR "instruction*" OR "pedagog*" OR "learn*" OR "education*") AND ("devops*")).

● Databases. Only web indexed databases, with search terms, and the following search filters: search string, publication year, and knowledge area categorization. We chose two general-purpose databases: Scopus and Web of Science. We chose one specific database for technologies, Technology Collection (Tech. Collection). We chose one specific education database, Education Resources Information Center (ERIC).

● Study selection criteria. In sum, we adopted one inclusion criterion and nine exclusion criteria. Inclusion (I1): the article must report an educational study using DevOps in the context of IS higher education. Exclusion: E1 - duplicate article among databases; E2 - superficial mention to DevOps; E3 - non-higher education's context; E4 – not in English; E5 – none or fractional access; E6 – panels, posters, and similar; E7 - article not peer-reviewed; E8 – An RSL; E9 – others: articles that report DevOps on non-IS education contexts, such as industry context, non-IS courses, and the article is not even related to training; E10 – Found any of the previous rejection criteria after a full-text review.

Phase 2: RSL Conduction. By applying the search string, we collected the articles from the databases in November 2021. RSL collected 339 studies initially. The Scopus database returned the largest number of records (192) and thus was defined as the backbone database. Whenever possible, the filtering process removed articles from the non-backbone database, as recommended by (Felizardo et al. 2017). The authors revised each other results, according to E1 to E10 exclusion criteria, and thus the I1 inclusion criteria. The final filtering process is shown in table 1:

Database	**Initial papers**	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**E9**	**E10**	**Final Papers**
Scopus	192	6	26	3	1	2	4		4	119	6	21
Web of Science	117	74	2	4		5	2			28	1	1
Tech. Collection	29	15	1	1				2		10		
ERIC	1	1										
Total	339	96	29	8	1	7	6	2	4	157	7	**22**

Table 1. SLR filtering process summary

Research Limitations

An SLR has two main categories of limitations (Felizardo et al. 2017): (1) bias in RSL execution processes. To remedy this, we have followed literature procedures (Felizardo et al. 2017; Iowa State University 2022; Kitchenham and Charters 2007); (2) data collection and presentation problems. To remedy this, we enhanced the process (such as several quality steps) and tools, as well as stabilized a collection form, according to (Felizardo et al. 2017). This is exploratory research, and it does not allow the results to be generalized to other educational contexts, but it may help to understand similar contexts in IS higher education.

Results

This section replies to the research question: "What are the students' results when DevOps is applied to the IS teaching context?". First, we present and qualify the SLR articles as recommended by (Felizardo et al. 2017). Second, described the IS teaching context found in the SLR. Finally, we reply to the students' results.

Articles presentation and qualification

The SLR final selection consists of 22 papers listed in table 2. Concerning the articles' year of publication, 72.7% of them have been published in the last three years, indicating an increasing interest in IS DevOps education. Approximately 23% of them were published in academic journals, while the remainder attended conferences.

ID	**Authors**	**ID**	**Authors**	**ID**	**Authors**
A1*	(Topi and Spurrier 2019)	A8	(Grotta and Prado 2021)	A15	(Alves and Rocha 2021)
A2	(Barendt et al. 2018)	A9	(Rong et al. 2017)	A16	(Ohtsuki et al. 2016)
A3	(Abirami et al. 2021)	**A10**	(Airaj 2017)	A17	(Hobeck et al. 2021)
A4*	(Ghantous and Gill 2019)	A11	(Kuusinen and Albertsen 2019)	A18	(Bai, Pei, et al. 2018)
A5	(Light et al. 2021)	A12	(Garcia-Maldonado et al. 2019)	A19	(Chatley and Procaccini 2020)
A6	(Bai, Li, et al. 2018)	A13	(Hills 2020)	A20*	(Pang and Hindle 2020)
A7	(Jennings and Gannod 2019)	A14	(Krusche and Alperowitz 2014)	A21	(Ohtsuki and Kakeshita 2019)
(continue…)		(continue…)		A22	(Kousa et al. 2020)

Legend: Bold = journals; * = course structuring subjects;

Table 2. SLR selected articles

There were no references to external TD, which indicates a lack of publication by external entities, such as associations. In terms of the *teaching context*, only three articles (marked by a star, which represents approximately 14%) referred to course structuring subjects. The remaining 86% of the article referred to internal *teaching contexts*, such as reporting an assessment tool or a teaching method.

IS DevOps teaching context

In this subsection, we describe the IS teaching context. As per the Theoretical Bases, the teaching context is divided into three different aspects, as summarized in table 2: Valentine's complexity, Curricular components, and teaching methods.

T.	Group	Description	Article	Σ
VC	easy	Simple	A19	1
	medium	Descriptive	A2, A7, A10, A11, A14, A22	6
		Tools	A5, A6, A9, A12, A13, A16, A18, A21	8
		Experimental	A3, A8, A15	3
	difficult	Philosophical	A1, A4, A20	3
		Complex	A17	1
CC	upper median	Software Engineering	A12, A13, A18, A19, A21, A3, A6	7
		DevOps	A10, A17, A7, A22	4
	lower median	Other names	A1, A2, A4, A5, A8, A14, A15	7
	Not available		A11, A16, A20, A9	4

T.	Group	Description	Article	Σ
TM	IcV	Lectures	A2, A3, A4, A6, A7, A8, A10, A14, A15, A17, A19	12
		Read or watch content	A7, A12, A17, A22	4
		Follow a tutorial	A14, A19	2
		Theoretical exercise	A11, A21	2
	LcV	PjBL	A1, A2, A4, A6, A7, A8, A9, A10, A11, A12, A14, A15, A16, A17, A18, A19, A21	17
		Practical activity	A11, A15, A13, A19	4
		Class Discussions	A15, A17	2
		Reversed class or presentation	A2, A17	2
		Other methods	A2, A3, A4, A12, A14	1

Legend: T. = type; **Σ** = total; **VC** = Valentine's complexity; **CC** = Curricular Component; **TM** = IS teaching methods;

Table 3. DevOps IS-DT

● **Valentine's complexity**: The results show that approximately 77% of the selected articles were medium in complexity, such as describing scenarios, using tools, and conducting educational experiments. On the other hand, there were four difficult studies, three of them were philosophical studies and one was a complex study – a tale of two faraway universities. This is probably because DevOps is still a recent topic (Fernandes et al. 2020). Finally, results show that no simple studies have been conducted. This may be a gap to be explored, as previous steps toward more complex perspectives or pilot research projects.

● **Curricular components.** The most common content types that utilize DevOps, according to the upper median, were: #1) software engineering, a component that addresses software production processes (Kuusinen and Albertsen 2019); and #2) DevOps, which is the focus of this research.

● **Teaching methods**. There was a predominance of LcV methods, which stimulate the active learning of students. Among these methods, there was the prevalence of PjBL, with represented 77% of articles. The PjBL characteristics justify its relation with DevOps. PjBL is a method for real-life exploration and problem-solving. PjBL relies on practical activities through an LcV (Morimoto 2016). On the other hand, IcV methods were also relevant given they were used in 68% of the articles. Among the IcV methods, the lecture was the most used one. There were various types of lectures, such as source-code demonstrations (A2) and video lectures (A12). As reported, the IcV methods aim to provide students with preliminary knowledge before starting a project. These results are consistent with earlier PjBL results, as projects often require prior knowledge – the preconditions – for a project to be completed (Grotta and Prado 2019a).

Students' results: TF and EF

Students' results, regarding both TF and EF factors, are presented in table 4. The three major results were positive citation frequency. EFs vocational exploration (15 references), grade (8); TF motivation (8 references each). A vast majority of 92% of the articles cited positive impacts of DevOps, while 5% referred to neutral results and a minor 3% of drawbacks.

Article	Result Type					Article (cont.)	Result Type				
	TF		EF				TF		EF		
	Grade	Presences	Motivation	Comm	VE		Grade	Frequency	Motivation	Comm	VE
A1					+	A12	+				
A2					+	A13					
A3	+		+	+	+	A14	+		+	+	+
A4					+	A15			+		+
A5			+			A16					+
A6				+	+	A17			+		+
A7					+	A18	+				
A8	+	+/-	+			A19					+
A9						A20	+		-		+
A10					+	A21	+	+	+		
A11	+/-		+		+	A22	+				+
Legends: + (positive); - (negative); +/- (neutral);						***Positive***	**8**	**1**	**8**	**3**	**15**
Comm: Communication **VE**: Vocational Exploration						***Neutral***	***1***	**1**	**0**	**0**	**0**
						Negative	***0***	**0**	**1**	**0**	**0**

Table 4. TF and EF students' results

Starting with the most cited benefit in table 4, students' professionalism, formally known as vocational exploration (Flum and Blustein 2000) reported positively by 68% of the articles. The three main forms of vocational exploration were: alignment of students and academia to market expectations (A11, A17, A18, A7), real-world and local IS industry experience (A2, A14, A15, A17), and professional development (A10, A19, A20, A22), among other specific ones.

Another DevOps key benefit was student motivation as seen in table 4. For higher education students, one of their primary goals is to learn a profession. Consequently, methods and knowledge that contribute to the student's professional career should be analyzed as motivating factors for students. The student expects from IS more than just acquiring knowledge, but a way to become a professional, through authentic academic experiences, leading them to professional and personal maturation (Flum and Blustein 2000).

There were positive effects on motivation as well as seen in table 4. It is reasonable to relate motivation with higher scores, and vice versa. However, more motivated students do not always score higher (Boruchovitch 2008). And yet, if we consider that students have learned more content (new technologies and methods) while maintaining academic standing, it is a clear indicator of increased performance. This phenomenon was previously observed in our study (Grotta and Prado 2021). There was one report of unmotivation (A20).

In terms of communication with students as seen in table 4, we recall that this SLR had a prevalence of PJBL. PJBL relies extensively on communication (Morimoto 2016). As result, DevOps methods have led students to a more intense practice of communication in various ways. These findings are aligned without previous research, that has shown that PjBL fosters students' verbal communication (Grotta and Prado 2019a).

Finally, in table 4, only two articles addressed the topic of frequency: one reported a benefit (A21), and the other reported neutral (A8). It is recommended to encourage students' participation as much as possible, given there is a strong correlation between university attendance and scores (Credé et al. 2010).

Conclusion

The objective of this research was to describe, classify, and analyze the teaching context and the student's results. For achieving this goal, we planned and conducted an SLR driven by the following research question: What are the students' results when DevOps is applied to the IS teaching context? After all the SLR process, it resulted in 22 articles from 339 studies initially selected.

According to the SLR, DevOps in IS teaching context is a relatively new topic, starting in 2014 (A14), and is gaining momentum in IS context, from the classroom context and expanding to the general SI courses, as seen in table 2. As seen in table 3: i) The main curricular components (courses) utilizing DevOps are named Software Engineering, followed by courses named DevOps; ii) The major types of teaching methods with DevOps are PjBL (77.2 %) and lectures (54.5 %); iii) the most frequent research types are tools (36.4 %) and descriptive cases (27.2%).

Regarding students' results when in contact with DevOps, the SLR has shown it was very positive. Around 92% of the mentions – to sum up, both EF of TF – were positive; 5% were neutral, and one article (2%) reported motivation drawbacks, as seen in table 4. The most relevant DevOps contribution in table 4was to the students' professionalism (formally known as vocational exploration), with a score of 68% positive reports. Both motivation and grades had 36% positive citations.

DevOps has been one of the recent relevant cultures in IS Industry by advocating a balance between the Dev and Ops phase (Pang and Hindle 2020). Thus, this research may contribute to at least three topics of IS Education. The first contribution refers to the DT theoretical foundations. The IS educational continuum bounds instructional and learning-centric visions towards a model that embraces both the knowledge and competencies model. This might be especially relevant for the new IS competency model (ACM and AIS 2020).

The second contribution of this research regards the DT of DevOps, from IS Industry to IS higher education, as summarized in table 3. It gives insights into which teaching methods have been used so far, and what courses are dealing with DevOps. It also identifies which types of research have been done, thus indicating possible open topics for future research. The third contribution is the DevOps benefits to the students, summarized in table 4. As seem, DevOps has high potential to scaffold students towards their vocational exploration, while also enhancing grades, motivation, and communication, with minor drawbacks. These contributions might be especially relevant for both IS higher education and IS Industry by giving a perspective of how to implement and what to expect from DevOps in IS education field.

This research is part of a larger research, and in future research, we plan to use these results as input for field research phases.

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