Applying the TPACK model to HCI Education: Relationships between Perceived Instructional Quality and Teacher Knowledge

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ABSTRACT

Instructional quality in Human-Computer Interaction (HCI) education is crucial to ensure that students acquire the necessary skills to understand the complexity of socio-technical systems and design interfaces and interactions accordingly. Previous empirical evidence suggests that teaching quality is determined by teacher knowledge – domain-specific, pedagogical, and technological knowledge. Through a survey of N=54 HCI instructors, this paper reports on teacher knowledge and investigates its relationship with their perceived teaching quality at different levels of HCI education. Findings show that HCI instructors rated their domain-specific and technological knowledge rather high, while the components of pedagogical knowledge were rated lower. Yet, pedagogical knowledge was related to instructional quality, specifically the degree of cognitive activation provided to students. We contribute by documenting and discussing the strengths and weaknesses of HCI instructors' knowledge and teaching quality. We draw implications for instructors, institutions and the HCI education community.

CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI).

KEYWORDS

TPACK, teaching quality, higher education, cognitive activation, human-computer interaction

ACM Reference Format:
Margault Sacré and Carine Lallemand. 2023. Applying the TPACK model to HCI Education: Relationships between Perceived Instructional Quality and Teacher Knowledge. In *EduCHI 2023: 5th Annual Symposium on HCI Education (EduCHI '23), April 28, 2023, Hamburg, Germany*. ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/3587399.3587402

1 INTRODUCTION

Some teachers[1] are more effective at promoting student learning than others [81], meaning that effective teaching is fundamental to ensuring student achievement [35, 87]. We define teaching quality as the combination of teacher actions and behaviors that contribute to student learning [78]. Teaching quality is one of the most important determinants of student learning; its effect exceeds that of environmental factors – e.g., school and class composition – and of student factors – e.g., gender, socioeconomic situation, attitudes to learning [33]. Strengthening the quality and impact of teaching to improve student learning outcomes and support the overall success of higher education institutions is a research, education, and policy priority [39].

Research suggests that teacher knowledge is essential for instructional quality and can have a significant impact on student learning and motivation [7, 87]. Dimensions of teacher knowledge have been identified [8, 42], including domain-specific knowledge (Content Knowledge, CK) and Pedagogical Knowledge (PK). Those dimensions, as well as technological knowledge situated within content and pedagogical knowledge, have been combined and integrated in the TPACK framework [54], commonly used to investigate teacher knowledge. However, TPACK has not yet been studied significantly in specific domains [86], as Human-Computer Interaction (HCI).

As a young and interdisciplinary field HCI education entitles many specific challenges [71]. HCI draws on a variety of disciplines (e.g., computer science, psychology, sociology, design, linguistics) [14], which on the one hand, makes it difficult to identify the topics to cover and, on the other hand, requires the integration of these different perspectives in the instructional material. Further, the field of HCI is defined as an applied field, meaning that students must acquire practical experience – e.g., prototyping requires both theoretical knowledge and manual skills. Hence, HCI instruction often involves hands-on learning and projects [22, 67, 69, 90], whose implementation demand planification and evaluation skills. In addition to these pedagogical challenges, HCI is a dynamic and value-centered discipline; instructors need to keep up with the latest technologies, advancements, and best practices in the field [18], while always considering the implications of human values in design [26].

Although teacher knowledge is recognized as a strong influence of teaching quality, empirical evidence examining this relationship is scarce, all fields considered [7, 42, 87, 88]. As more and more people enroll in HCI courses [59], it is crucial to ensure quality instruction and improve practices in HCI education which, in turn, will foster deep student learning and understanding [55] of HCI perspectives and applications.

To gather empirical data on these relationships, we surveyed HCI instructors (N=54) using two Likert-type scales. We make the following contributions: (1) Documenting HCI instructors perceived TPACK and teaching quality, and the relationships between those two constructs and (2) Adapting and testing two general models

[1]The terms "teachers", "instructors" and "lecturers" are used interchangeably in this paper.

EduCHI '23, April 28, 2023, Hamburg, Germany

ACM ISBN 979-8-4007-0737-7/23/04.
https://doi.org/10.1145/3587399.3587402

to HCI education. We discuss the implications of our findings for HCI education community and, more specifically, what types of knowledge are more important for ensuring quality instruction in HCI courses and that should be reinforced in the training of HCI instructors.

2 RELATED WORK

2.1 Educational Challenges in HCI

HCI courses are delivered in many curriculums, from computer science, information science, engineering, design or even psychology [3, 14, 22]. Its dynamic and interdisciplinary nature makes HCI a complex and challenging field to teach [14, 18, 71]. Oleson et al. [60] illustrated these challenges by uncovering students' difficulties in HCI courses – designing for diversity, avoiding biases, working with clients and teammates, taking design decisions; their study emphasized the necessity for competent instructors that would be able to recognize, understand and address them.

Because of the diverse backgrounds and values of HCI instructors, the content of HCI courses varies considerably from one country or even one university or educational institution to another [1, 32, 60, 91]. Addressing this matter, the ACM Special Interest Group on Computer-Human Interaction (SIGCHI) has strived to define HCI instructional practices and to create a *living curriculum* [19]. The concept of *living curriculum* refers to a repository of HCI educational resources and materials addressing the rapidly evolving aspect of the field as new technologies, design trends, and research findings [19, 83, 91]. This approach should allow the HCI curriculum to remain current, ensuring that students acquire the most up-to-date knowledge.

In an attempt to better understand practices in HCI education, Wilcox et al. [91] reviewed the most popular teaching approaches at a university level through a survey and a textbook analysis. They highlighted the contents taught by the instructors (e.g., topics, research methods, prototyping methods) as well as the teaching strategies they used (assessment methods and learning objectives). The HCI community is increasingly involved in sharing teaching experiences for the benefit of their peers. Papers reporting on HCI courses [14, 22, 37, 69] and on more specific methods such as design studio [31, 67] or project-based [70, 73] approaches have been published. However, studies on HCI teaching and education, specifically those that involve empirical data, are scarce – one example can be found in de Souza Vieira et al. [80].

2.2 Teaching Quality in HCI Education

Defining teaching quality in higher education represents a challenge and "more often reflects an interest in accountability and quality assurance than instructional improvement" [62, p.2]. Following a pedagogy-focused definition, widely adopted in educational research, teaching quality refers to teachers' characteristics and abilities that contribute to successful learning outcomes for students [10, 45]. Three dimensions of teaching quality have been identified: the degree of cognitive activation provided to students, effective classroom management and the degree of support provided to students [28, 45, 46, 50, 64].

Ensuring cognitive activation – or higher order thinking – refers to establishing instruction that promotes deep understanding of the content, by making students build on their previous knowledge, discuss contradictions and solve problems [29, 50]. Cognitive activation is positively related to achievement [29]. As an attempt to cognitively engage students, Rohles et al. [69] implemented a project-based course about human-centered design. Students had to develop a project, following and reporting on each phase. Another example is described by Dawood [22]: after learning about HCI concepts, students had to apply them to their projects, demonstrating a thorough understanding of the content. This type of activity has the potential to activate higher-order thinking – problem-solving and building on previous and new knowledge. However, to date, no empirical data exists to support this claim.

Effective classroom management strategies refer to actions taken by the teacher to ensure a smooth running of teaching and learning activities – providing order and efficient use of time during classes [44]. To create this environment, teachers need to identify desirable behaviors – by setting clear rules – and to prevent the undesirable ones – by staying aware of students' whereabouts [24]. Classroom management is positively associated with student subject-related interest [44] and achievement [24, 29]. With frequent collaborative or hands-on activities (sometimes with specific equipment), HCI courses require specific attention to classroom management [91]. Proper classroom management during these activities is necessary to ensure students' concentration and engagement.

Learning support refers to implementing a positive learning environment, by being sensitive of student needs. Constructive feedback, a positive attitude towards mistakes, caring behavior, and individual support represents key features for supportive teacher-student interactions [29, 50]. Learning support is associated with student motivation and moderates the relationship between interest and achievement [50].

2.3 Teachers' Knowledge for Teaching Quality

As demonstrated by the positive effects of professional development training, being knowledgeable as a teacher is essential to ensure teaching quality [30]. Possessing in-depth knowledge of instructional content and general and domain-specific pedagogy enables teachers to accurately interpret teaching situations and implement better instructional strategies [51, 72]. For instance, students may have misconceptions about HCI perspectives, methods and theories; understanding and overcoming them requires Pedagogical Content Knowledge [90]. However, few studies – and to the best of our knowledge, none in HCI – examined the relationship between teacher knowledge and their quality of instruction [41]. Mostly involving math teachers, these studies showed that PK and PCK are associated with the three dimensions of teaching quality [4, 8, 42, 45].

The "Technological, Pedagogical, and Content Knowledge (TPACK)" model (Figure 1) was first described by Mishra and Koehler [54] based on Schulman's work [79]. Schulman developed the idea of Pedagogical Content Knowledge as the combination of domain-specific knowledge with pedagogical approaches [86]. PCK supposes two knowledge components, Pedagogical Knowledge and Content Knowledge, and their combination. PK refers to "knowledge about instructional practices, principles, and strategies to manage classrooms and organize the teaching of the subject

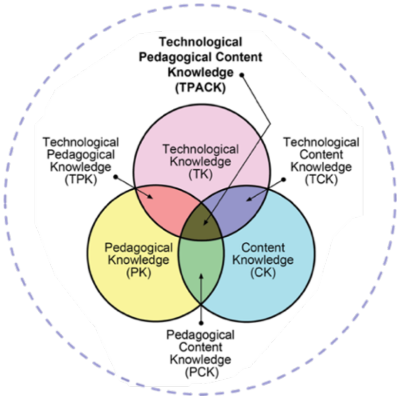

Figure 1: TPACK. Reproduced with permission of the publisher, ©2012 by tpack.org

matter" [75:2]. CK corresponds to domain-specific knowledge that instructors must teach [75]. The TPACK model includes four more components added to the initial model in reference to the competences needed to teach with technology: Technological Knowledge, Technological Pedagogical Knowledge, Technological Content Knowledge, and Technological Pedagogical Content Knowledge [54]. TK is teachers' knowledge about emerging technologies, which is hypothesized to be prominent among HCI instructors. TK can include everyday technologies (phones, tablets, browsers. . .) or specific ones (Augmented and Virtual Reality, Artificial Intelligence, conversational user interfaces. . .). TCK and TPK refer to the integration of CK and PK with the use of technology [86]. Specifically, TCK defines the knowledge of the application of technologies to depict domain-specific knowledge, regardless of the instructional purpose, e.g., employing simulation/VR to represent [49] TPK is the knowledge of how to use technologies to facilitate student learning, regardless of the content [49], e.g., using an audience response system provides students with immediate feedback, which, in turn foster learning outcomes [17, 92]. Finally, TPCK depicts the interdependence between PK, CK and TK [86]. Although they can be defined as sole components, they do not exist in isolation in the classroom; when designing and implementing teaching activities, teachers combine their different types of knowledge [54].

Originally designed to assess the knowledge of primary and secondary school teachers, the TPACK framework has recently been applied to document the knowledge of higher education instructors [2, 9, 12, 13, 20]. Studies revealed (1) that the framework is relevant in regard of higher education, (2) that higher education teachers displayed high knowledge or perceived knowledge [12], (3) that teachers with high PK were more likely to demonstrate TPCK, whereas no such relationship was observed between TK and TPCK [9, 12].

3 RESEARCH APPROACH AND OBJECTIVES

This study examines the TPACK of HCI teachers and its relationships with teaching quality with respect to two main research questions. First, while HCI teachers have extensive knowledge of technologies, little is known about their knowledge on how they use them for teaching and learning processes, nor on their content and pedagogical knowledge. To the best of our knowledge, no empirical studies have examined HCI teachers' knowledge to this day. Hence, the first aim of this study is to investigate HCI teachers' knowledge and address the following research question (RQ1): What is the extent of HCI teachers' TPACK?

Second, following prior work on teacher knowledge and teaching quality, we expect that HCI teachers' TPACK is positively correlated with the three above-mentioned dimensions of teaching quality. We will address the following question (RQ2): How is the TPACK of HCI teachers correlated with measures of their teaching quality?

This study adopted a cognitive perspective on teacher knowledge and teaching quality which, in contrast with a situated perspective proposes that those constructs can be "measured independently from the classroom context in which it is used, most often through a test" [23:22]. Daumiller et al. [21] showed that self-reported and student-reported teaching quality are highly correlated. Hence, similarly to previous research on teaching quality and teacher knowledge, this study relies on self-reported measures from the perspective of the teachers [21, 58, 89].

4 METHOD

4.1 Participants

We conducted an online survey targeting HCI instructors. Our sample involved 54 participants (9 men, 18 women, 1 non-binary, 26 NAs) with a mean age of 39.5 (SD=7.98, median=38) and a mean teaching experience in HCI of 4.94 years (SD=4.87, median=3). Participants were reached through professional and social networks (targeted emails, Twitter, LinkedIn, Facebook groups and Slack communities). We only kept responses from participants that completed at least the first scale of the questionnaire (on teacher knowledge). Studies revealed differences in teacher knowledge according to their gender [25, 49, 75], age [40, 49], teaching experience [20, 49] and educational level [48]. Gender and teaching experience are also related to self-reported teaching quality [21, 65]. For these reasons, sociodemographic questions and questions regarding teachers' experience were included in the questionnaire. The Ethics Review Panel of the University of Luxembourg approved this procedure.

4.2 Material and Procedure

Our online survey, administered via LimeSurvey, included different scales and a sociodemographic questionnaire. Informed consent was obtained from all participants. To improve the questionnaire's quality and check its applicability in the context of HCI education, two pretests in the form of cognitive interviews [43] were conducted with HCI instructors. The instructors were asked to read the questions, interpret them aloud and explain how they would answer them and why. In cases where the questions or answer options were not fully understood, we discussed with participants ways to improve them and adapted them accordingly. No problem was detected, and the items seemed to fit the context of HCI education. All items are provided in Supplementary Material.

Aligned with previous studies conducted in higher education [2, 16], teacher knowledge was assessed using the questionnaire TPACK [76]. This 42-item questionnaire measures the seven dimensions of the TPACK model (Figure 1). All items were of 5-point

Table 1: Descriptive statistics for all subscales of the teacher knowledge and teaching quality questionnaires

	n items	M	SD	Med	Hist	ω
Teacher Knowledge TPACK (1-5)						
Content Knowledge (CK)	6	4.22	0.52	4.33		0.78
Technological Knowledge (TK)	7	4.13	0.62	4.14		0.90
Technological Content Knowledge (TCK)	6	3.92	0.64	4		0.89
Pedagogical Knowledge (PK)	7	3.8	0.76	3.86		0.92
Pedagogical Content Knowledge (PCK)	6	3.91	0.61	3.83		0.91
Technological Pedagogical Knowledge (TPK)	5	3.8	0.61	3.7		0.80
Technological Pedagogical Content Knowledge (TPCK)	5	3.87	0.67	4		0.79
Teaching Quality (1-5)						
Cognitive activation	7	3.88	0.65	3.93		0.73
Classroom management	7	3.25	0.48	3.29		0.76
Learning support	7	4.39	0.51	4.5		0.77

Likert-style (from 1 "strongly disagree" to 5 "strongly agree"). The questionnaire also included one open-ended question, related to pedagogical dimensions of the TPACK (PK, PCK, TPK and TPCK): "Describe a specific episode where you taught a lesson on HCI. Please include in your description: what content you taught, what technology you used (if any), and what teaching approach(es) or method(s) you implemented."

Teaching quality was measured with an adapted version of Baumert et al. items [6]. *Cognitive activation* was assessed with eight items; *Classroom management* included seven items regarding waste of time and monitoring students' doings. *Learning support* was assessed with seven items. All items were 5-point Likert scales (from 1 "does not apply" to 5 "does apply").

4.3 Data analysis

McDonalds' omega (ω) was computed for TPACK and teaching quality questionnaires and revealed adequate internal consistency (>0.7) for each subscale (Table 1). For our first research aim, descriptive analyses were conducted. Kruskal-Wallis tests and correlations were performed to compare the scores of TPACK components and teaching quality dimensions according to teachers' gender, level of education, age, and teaching experience. For our second research question, inter-correlations between TPACK and teaching quality were conducted using the Spearman method. A multiple regression analysis was carried out, with teaching quality as dependent variables and TPACK as independent variables. Sociodemographic variables were not included in the models due to missing data.

5 RESULTS

5.1 HCI Instructors' Knowledge and Teaching Quality

Table 1 presents descriptive statistics for all subscales of the teacher knowledge and teaching quality questionnaires. On the teacher knowledge subscales, histograms showed that TK and TCK distributions are left-skewed, meaning that more participants rated these subscales highly. The distributions of other teacher knowledge components appear fairly symmetrical, with a tendency towards a right skewness for PCK and TPK. Further, descriptives showed that HCI instructors highest TPACK ratings were on the CK subscale (M=4.22, SD=0.52) and lowest ratings were on the TPK subscale (M=3.8, SD=0.61). Kruskal-Wallis tests did not reveal any significant differences in TPACK components and teaching quality dimensions according to teachers' gender and level of education, with one exception: TK differed according to level of education ($\chi 2(2)$=7.77, p=.021). Teachers who held a PhD degree rated their TK higher than teachers with a master's degree (Med_{PhD}=4.29; Med_{Mast}=4.00). Spearman correlations (Table 2) showed that teachers' age was related to their CK, PK, TPCK and cognitive activation scores and that their teaching experience in HCI (in years) was related to their PCK and classroom management scores.

With the open-ended question, we asked teachers to describe a specific lesson they taught, including the content, technologies used, and teaching approaches implemented. The most mentioned topics were user-research methods (n=6), User Experience Design (n=5) and HCI-specific content (n=5). Most of the technologies used for teaching practices were basic: eight teachers reported using slideshows, five used digital whiteboards (e.g., Miro), three mentioned a Learning Management System (e.g., Canvas) and three used videoconference tools (e.g., Zoom, Teams). A real-time voting platform (Mentimeter), multimedia content from Youtube and file-sharing (Google Drive) were mentioned by one teacher each. Finally, a teacher used specific web platforms (e.g., ThinkApps). Regarding the teaching approaches, teachers provided lectures, project-based learning and group work, flipped classroom strategies, and one teacher reported implementing inquiry-based learning. Most teachers described their practices but did not label them, apart from a few exceptions of teachers reporting that they implemented flipped classrooms.

The teaching quality questionnaire shows a higher rating related to learning support (M=4.39, SD=0.51) and lower ratings attributed to cognitive activation (M=3.88, SD=0.65) and classroom management (M=3.25, SD=0.48). Quality of teaching is reflected in the teachers' answers to the open-ended question. For instance, some

Table 2: Intercorrelations between all the latent variables (Spearman method)

	Age	YTHCI	CK	TK	TCK	PK	PCK	TPK	TPCK	CA	CM
Age	–										
YTHCI [e]	.51** [b]	–									
CK	.38* [a]	.21	–								
TK	.07	-.06	-.06	–							
TCK	.25	-.17	.30*	.16	–						
PK	.62*** [c]	.41	.40**	-.07	.15	–					
PCK	.43	.30*	.45***	-.06	.23	.72***	–				
TPK	.16	.11	.45***	-.07	.28*	.37**	.55***	–			
TPCK	.33°	.15	.48***	-.03	.24°	.54***	.52***	.60***	–		
CA [f]	.38*	.23	.07	-.02	.15	.45***	.35**	.35*	.11	–	
CM [g]	-.03	-.24° [d]	-.10	.10	.11	.17	.13	.05	-.01	.15	–
LS [h]	.25	.06	.18	-.08	.11	.52***	.52***	.37**	.50***	.43*	-.14

[a] * p<.05; [b] ** p<.01; [c] *** p<.001; [d] ° p<.1; [e] Years teaching HCI; [f] Cognitive Activation; [g] Classroom Management; [h] Learning Support.

descriptions indicated a high degree of cognitive activation in the classroom, with activities that engage students to discuss contradictions and solve problems:

> "I showed them an empathy map and how it can help them categorize their research findings into what people do, say, think, and feel [. . .] Using a shared Miro board [. . .], I gave each team 15 minutes to read through the data and create their own empathy map. As a class, we went through each empathy map and identified similarities and differences" (P23)

> "We used a website that specifically violated many UI principles and conventions. [. . .] the students had to create their own sketches of an interface that follows convention" (P24)

> "the groups pitch their suggestion in 2 minutes, and we reflect/compare. This part is meant to develop critical thinking about methods and show that there is not one solution only" (P13)

Learning support was also featured by teachers, who provided constructive feedback and fostered positive learning environment: "I love that many students are comfortable asking ethical-related questions" (P05), "The students were free to use any alternative app." (P09), "I provided feedback on each deliverable, with individual feedback and some student examples at each step were selected to show different approaches to the task." (P06)

5.2 Relationships between Instructional Quality and HCI Teacher Knowledge

Intercorrelations between variables are displayed in Table 2. They showed that TK and TCK are unrelated to all other components of teacher knowledge, except for the relationship between TCK and TPK (r=.28, p=.040). CK, PK, PCK, TPK and TPCK are significantly and positively correlated to each other. *Cognitive activation* is significantly and positively correlated with PK (r=.45, p<.001), PCK (r=.35, p<.001) and TPK (r=.31, p<.001). Classroom management is not correlated to any knowledge component. Learning support is significantly and positively correlated PK (r=.53, p<.001), PCK (r=.52, p<.001), TPK (r=.37, p<.005) and TPCK (r=.50, p<.001).

Multiple regression analyses were computed to determine the possible predictive value of TPACK on teaching quality on each teaching quality dimension. The Variance Influence Factor (VIF) was computed to check for multicollinearity between variables. All VIFs were between 1.234 and 3.100, indicating no problems. Analyses of variance results and regression coefficients are presented in Table 3. The models predicting cognitive activation and learning support are statistically significant. Cognitive activation is positively predicted by PK and TPK – and marginally negatively predicted by TPCK. No knowledge component significantly predicted *learning support*.

6 DISCUSSION

Ensuring student learning outcomes remains a priority for higher education; institutions encourage the dissemination of high-quality instruction [57]. This improvement requires strong teacher knowledge [7, 87], notably in HCI education which entitles many pedagogical challenges [71]. Few evidence exists regarding how HCI instructors' knowledge can support their teaching practices.

6.1 Student-Centered Design, the Forgotten Ingredient of HCI Education?

In line with previous research [40, 48], surveyed HCI instructors rated their knowledge as generally high. Specifically, CK and TK were rated as the highest. Our participants have a strong self-reported theoretical and domain-specific background (e.g., concepts, theories), as well as of everyday life and specific technologies. For HCI education, TK is part of the common expertise, and one could argue that it could be included in the CK component. However, although both are rated highly, there is no correlation between them, suggesting that they may remain separate: in our sample, HCI instructors do not necessarily include their strong knowledge about technologies in their teaching.

Further, CK and TK were not related to any dimensions of instructional quality, suggesting that although domain-specific knowledge is necessary, it is not sufficient to provide efficient teaching. This

Table 3: Predicting teaching quality with TPACK: standardized regression coefficients

	Cognitive activation	Classroom management	Learning support
F (df)	3.959 (7,46)	0.745 (7,46)	3.785 (7,46)
p	.002	.636	.003
R2	.281	-.035	.269
Content Knowledge (CK)	-.13	-.19	-.17
Technological Knowledge (TK)	.02	.02	-.10
Technological Content Knowledge (TCK)	.06	.11	.00
Pedagogical Knowledge (PK)	.71*** [b]	.31	.23
Pedagogical Content Knowledge (PCK)	-.12	.03	.23
Technological Pedagogical Knowledge (TPK)	.40* [a]	.10	.07
Technological Pedagogical Content Knowledge (TPCK)	-.38* [a]	-.20	.26

[a] * p<.05; [b] *** p<.001. Age was not included in the models as it was strongly correlated with experience teaching HCI.

was also reflected in our qualitative insights: teachers mainly mentioned using very common types of technologies (e.g., slide presentations, videoconference tools, digital whiteboards), to support their teaching practices. How to integrate this high TK knowledge with pedagogy hence stays unclear; prior work identified opportunities of novel technologies in education, yet there remains a research gap in this regard in HCI education. This finding is in line with previous studies that showed that, at a university level, efficiency in research and in teaching are not correlated [34]. Doing more research and being more knowledgeable in the field does not automatically translate in being a good lecturer.

Findings also showed that instructors reported lower levels of knowledge on pedagogical components. Pedagogical skills, e.g., understanding student misconceptions, choosing teaching approaches, guiding student thinking, developing appropriate activities, assessing student work [77], must be formally learned to be effectively implemented in class. HCI instructors have a solid knowledge background but may find it difficult to incorporate it into their courses; to integrate domain-specific and pedagogical knowledge proves to be a complex matter. This suggest a lack of educational training in HCI, which applies more widely to higher education lecturers [36]. The median teaching experience in HCI of our sample less than 3 years may be another factor contributing to the low level of pedagogical knowledge. In alignment with Wiese [90], PCK was associated with experience in teaching HCI.

How do these results compare with instructors in other disciplines? To date, little evidence exists regarding the extent to which lecturers in higher education are knowledgeable. Akram et al. [2] conducted a TPACK survey in 11 universities. Results indicated that TK was rated the lowest, in contrast to CK. Further, knowledge components including technology (TK, TCK, TPK, and TPCK) were scored higher in our sample. The study encompassed three departments - Social Sciences, Natural Sciences, and Arts and Humanities - yet did not explore potential differences between them. Apart from this study, most of the available data on teacher knowledge components is derived from surveys on pre-service and in-service schoolteachers. Comparison reveals that HCI instructors' CK and TK in our sample were scored higher than primary school, secondary school, and pre-service teachers [40, 48, 49, 77]; this pattern was not observed for the other knowledge components.

Taken together, these results seem counterintuitive for two main reasons: (1) the HCI field relies heavily on user-centered design approaches; (2) a significant subset of HCI research focuses on enhancing education through technologies [5]. On the first point, we could wonder why do HCI instructors not practice what they preach, by applying a student-centered process to the design and management of their courses? The second point hints at the fact that HCI instructors also would have the necessary research tools and skills to apply HCI education research to their courses (e.g., using them as testbeds for research on educational technology)? They are most likely aware of the educational benefits that HCI can offer but may lack the resources to implement HCI principles in the classroom.

6.2 Supporting Teaching Quality by Taking Advantage of HCI Multidisciplinary

Three dimensions must be addressed to provide students with high-quality teaching – *cognitive activation*, *classroom management* and *learning support* [50]; to implement these dimensions supposedly requires high levels of knowledge. The present study aimed to examine these relationships. In line with previous research [45], HCI instructors in our sample who promoted cognitive activation and learning support reported higher levels of PK, PCK and TPK; suggesting that pedagogical skills can promote these dimensions. Specifically, cognitive activation was predicted by PK and TPK. To cognitively engage students into tasks, understanding pedagogical concepts in general and specific to the field can be beneficial. Teachers need to be aware that engaging students in higher-order thinking is crucial for their learning, and they need to know how to do so. For instance, design fiction has been used in HCI courses as a way to help student reflect on designing technology, "encouraging them to explore its systemic consequences, critical issues, and hidden presuppositions" [66, p.2]. This type of knowledge can be acquired through experience [90], but could also be at least skimmed through formal training.

Moreover, HCI teachers reported that they provide high level of learning support to their students, ensuring that their mistakes are part of the learning process and building trust with them. Learning support was related to PK, PCK, TPK and TPCK – every component including pedagogical knowledge. Project-based learning, an ever-growing trend in HCI education, is an approach where the need for learning support is clearly apparent: it requires guidance to ensure the projects progress in the right direction, while also allowing students the freedom to explore and experiment [61].

HCI is at a crossroad of several fields, each of which has some pedagogical strengths that can be ultimately combined. For instance, lecturers with a design background tend to provide students with more hands-on activities, creative tasks, challenge-based learning, or role-playing learning; computer scientists focus on abstract thinking or problem solving; philosophers will emphasize ethical issues and critical thinking; psychologists can draw on their expertise in user research methods and reflexive practices [47, 74]. Lallemand et al. [47] for instance combined these strengths by using roleplay techniques to teach interaction designers about physical computing and sensors. Moreover, Abdelnour-Nocera et al. [1] highlighted that the topics taught in HCI vary not only according to teachers' backgrounds, but also by country. This diversity must be transformed into an asset. How can we leverage the best teaching practices in related fields of HCI to ensure teaching quality? To stay abreast of the ever-evolving technological landscape, the HCI education community proposed the concept of a *living curriculum* – a set of educational resources that should continually be updated to reflect the latest developments [18, 19, 38]. This curriculum should provide an opportunity for HCI instructors to share their practices and collaborate across fields, thereby improving instructional quality.

6.3 Limitations

This study presents some limitations that could be overcome in future instances. First, our sample size does not allow for generalization of results and the present study can be considered as a pilot for future use of the measurement tools. Second, as the data used for the present study was cross-sectional, no causal inferences can be made. Third, only self-reported quantitative data were used; direct and indirect observations could be used as alternative methodologies to reduce the influence of self-report bias. This shortcoming may be the reason why TPCK negatively predicted cognitive activation: teachers with high TPCK could be more conscious that they are not cognitively activating their students. As a perspective for research, the measurement of students' perceptions of teacher knowledge, students' outcomes (learning gains) and the report of actual teaching practices would allow for a better representation of the constructs of interest, although the cognitive perspective selected for this study has been successful in different fields of research [21, 23]. Fourth, instructors self-selected to participate in the study; hence, it is possible that very efficient and knowledgeable teachers are overrepresented. Finally, the dimensions of teaching quality studied in this research were drawn from primary and secondary education, as these are the current main standards. However, teaching quality is beginning to be modeled from the teacher perspective in higher education; future research could use these models to investigate the relationship between teacher knowledge and teaching quality in HCI education.

6.4 Reflections for Practice

Increasing HCI instructors' pedagogical knowledge (PK, PCK, TPK, and TPCK) could help ensure high-quality instruction, thus improving student learning. Several directions for improvement can be explored; our suggestions cover the instructor level, the institutional level, and the community level.

6.4.1 Improving our Own Practice. A suggestion would be to practice what we preach, digging into our content knowledge in HCI and apply it to our practice. The Scholarship of Teaching and Learning (SoTL) is a movement that promotes the study and sharing of its own teaching practices in relation to student learning, "using established or validated criteria" [63:2]. The aim of SoTL is to develop teachers' pedagogical expertise and to understand how educational practices and approaches support student learning [11]. Being involved in SoTL means systematically researching the relationships between what we do as teachers and student outcomes and publishing the results of this research or applying for teaching excellence awards. This approach enables teachers to reflect on their practices, gain insight into students' perspectives, identify what is effective for them, and to assess and develop their teaching skills and knowledge [15]. HCI instruction could improve its quality by not only sharing resources trough the *living curriculum*, but also evaluating them and questioning them, for instance, as part of the SoTL movement.

6.4.2 Pedagogical Knowledge as a Starting Point. The necessity to provide professors with training encompassing a wide range of knowledge domains has already been recognized [20, 68]. Some higher education institutions have high requirements regarding teaching certifications: in the Netherlands, newly hired professors are required to follow courses and produce a well-documented teaching portfolio in which they must describe and assess their teaching content and activities [85]. Further, many institutions implemented student course evaluations which can have implications on lecturers' promotions. Global interest in the accountability and quality assurance of institutions is growing, but there is debate over whether it leads to better teaching practices [62]. Indeed, teaching development programs for educational training and support are very heterogeneous across institutions and not always based on theoretical foundations [35, 62]. Even without focusing on specific domains, the institutional level could provide educational training with a strong emphasis on PK and TPK. With this basis, teachers will be able to assimilate and integrate pedagogical concepts and principles into their content to then develop their PCK and TPCK. Even more, recent research showed that pedagogical development programs can additionally enhance teacher confidence, self-concept and self-efficacy [27, 56].

6.4.3 A New Direction for HCI Education. Many sharing initiatives are taking place in HCI education, through special issues (e.g., Special Issue on Human-Computer Interaction – EngageCSEdu Open

Educational Resources), research topics in journals (Teaching and Learning Human-Computer Interaction: Current and Emerging Practices – Frontiers in Computer Science) and the EduCHI symposium series [52, 53, 82, 84]. Although the latter proposes many tracks and enables HCI instructors to submit *teachable moments*, studies exploring HCI students' experiences and achievement about instructional practices stay scarce. The question is therefore: how to specifically value this direction and take advantage of the many possibilities to emphasize pedagogy in HCI education?

7 CONCLUSION

Students' learning outcomes are significantly affected by the quality of instruction. Although teacher knowledge is thought to have a strong influence on teaching quality, this relationship has not yet been investigated in HCI education. We explored this question by surveying HCI instructors on these educational dimensions. As pedagogical knowledge was associated with higher levels of cognitive activation and student support, we recommend its inclusion in pedagogical development programs in higher education institutions. We discussed implications for practice and encourage the community to take action at the individual, institutional and community levels.

ACKNOWLEDGMENTS

This research is supported by the Luxembourg National Research Fund (FNR): IPBG2020/IS/14839977/C21.

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