Multi-mode Digital Teaching and Learning of Human-Computer Interaction (HCI) using the VARK Model during COVID-19

Diana Pérez-Marín[1*], Maximiliano Paredes-Velasco[1] and Celeste Pizarro[2]
[1]Escuela Técnica Superior de Ingeniería Informática, Universidad Rey Juan Carlos, Spain // [2]Escuela Superior de Ciencias Experimentales y Tecnología, Universidad Rey Juan Carlos, Spain // diana.perez@urjc.es // maximiliano.paredes@urjc.es // celeste.pizarro@urjc.es
[*]Corresponding author

ABSTRACT: In this paper, a multi-mode digital teaching approach is proposed based on the use of the VARK (Visual, Aural, Read/Write, Kinaesthetic) model where students have different styles (one or more) that improve their learning (face-to-face and online). Our research question is on the effectiveness of this approach in terms of learning efficacy and students' satisfaction. An experiment with 41 students has been carried out for five months to answer the research question and to provide a first validation of using VARK for multi-mode digital HCI teaching. During the experiment, the theoretical sessions were given through videoconference using Microsoft Teams and with the support of Moodle. In the practical sessions, students had to create a software prototype following a User-Centred Design with a real client. For this, they used Discord to collaborate in their groups, Teams to ask questions to teachers and PowerPoint and Genially to present their work online to the class through a Teams videoconference. A regression model has been provided to predict the VARK indicated by the questionnaire to each student with a prediction success of nearly 77%. Using the VARK multi-mode digital teaching approach has proved valid, and effective and beneficial in the teaching of HCI with a significant improvement in the learning scores and satisfaction levels of the students even with respect to pre-COVID-19 where the teaching was face-to-face.

Keywords: Multi-mode digital teaching, VARK, Human-Computer Interaction, COVID-19

1. Introduction

Human-Computer Interaction is the discipline related to the design, evaluation, and implementation of interactive systems for human use and the study of the related phenomena (Card et al., 1983). The goal is to remove barriers in the dialogue between users and systems. The idea is that interfaces should be designed to facilitate users in accomplishing their goals, regardless of whether the goals are to complete a report or to play a videogame. HCI has undergone significant research in recent decades since the use of technological devices is no longer restricted to people with technical knowledge but to everybody (Stephanidis et al., 2019).

In our university, HCI has traditionally been taught face-to-face (F2F) in all Computer Engineering degrees. Students in groups of 40-100 were sat in a classroom following the traditional lecture combined with exercises in class and practical activities in the computer lab. A review of how HCI was taught at other universities also revealed that this is the common approach in F2F universities, at least in Spain (Pérez-Marín, 2018).

However, due to COVID, teaching of the subject had to move online in March 2020, even in F2F universities. Several approaches have been tried to hold online seminars (e.g., Seminar Series in HCI at Carnegie Mellon University in 2020), proposing recommended readings in HCI (e.g., Human-Computer Interaction course at the University of Cambridge), videoconferences using Microsoft Teams or Blackboard Collaborate, and/or uploading multimedia and teaching notes at virtual campus using Moodle or other e-learning platforms. A combination of these approaches following a multi-mode teaching and learning approach considering the students' preferences may be key to significant learning and satisfaction among students even during COVID-19. Our proposal is to use the VARK model (Fleming & Mills, 1992) to digitally teach HCI in a multi-mode format to university students. The research question is how effective a multi-mode digital approach using the VARK model can be in terms of learning efficacy and student satisfaction. An experiment with 41 HCI university students has been carried out to answer the research question and test the hypothesis.

2. Related work

This section provides the context of this research with a review of the theoretical background provided in Section 2.1. and more technical background in Section 2.2.

ISSN 1436-4522 (online) and 1176-3647 (print). This article of the journal of *Educational Technology & Society* is available under Creative Commons CC-BY-NC-ND 3.0 license (https://creativecommons.org/licenses/by-nc-nd/3.0/). For further queries, please contact Journal Editors at ets.editors@gmail.com.

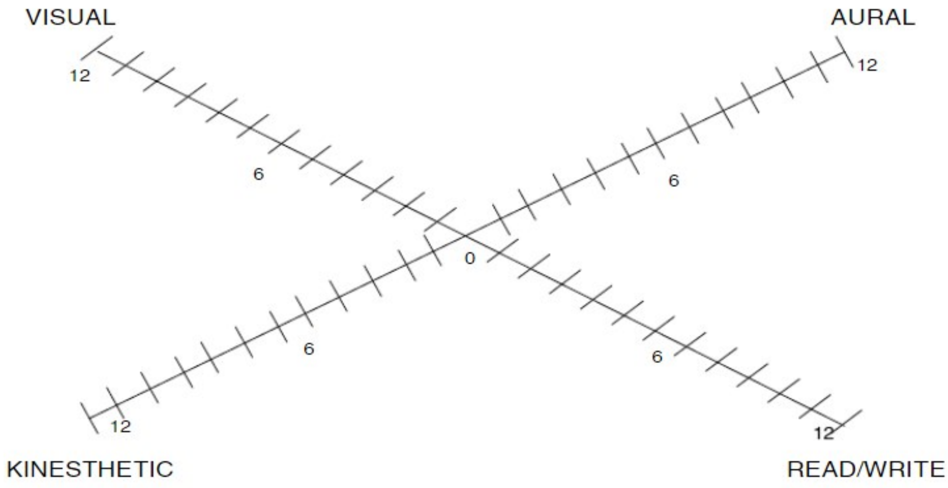
2.1. Theoretical background

Multi-mode teaching can be defined as the combination of multiple modes of knowledge representation such as oral and written language, visual, gestural, tactile, and spatial representations (Jewitt, 2008; Cope & Kalantzis, 2009). Much research has been focused on exploring how to design effective multi-mode digital teaching experiences (Bell et al., 2010; Cope & Kalantzis, 2009). A decade later, multi-mode digital teaching seems to have become key in overcoming the difficulties of teaching and learning during COVID-19 (Oyedotun, 2020; Teele et al., 2020). Multi-mode teaching facilitates imparting information, enacting collaborative learning, and preparing students for exploring concepts (Papageorgiou & Lameras, 2017). Moreover, combined digital learning technologies can help students develop technical and non-technical skills such as creativity, capacity of innovation and problem solving (Philippe et al., 2020).

According to Bakar (2007), there are at least five variables that should also be considered when creating an effective instructional model: active student involvement, attracting interest and attention, raising their motivation, individual principle, and displays used in lessons. When using online courses and students' learning styles are reflected in their design, their learning efficacy is higher (Lee & Choi, 2011; El-Bishouty et al., 2019). However, when searching IEEE Xplore, Elsevier, Web of Science and SCOPUS for papers on multimodal learning platforms and experiences using learning styles, much has been written focusing on styles such as those proposed by Felder and Silverman (1988), i.e., active/reflective, sensing/intuitive, visual/verbal, sequential/global, but there is a gap on systems and platforms using other models that could also benefit students in online courses such as the VARK model (Fleming & Mills, 1992).

The VARK (Visual, Aural, Read/Write, Kinaesthetic) model is based on the idea of empowering students by finding out their sensory preferences and adjusting their study methods accordingly. The core idea, in the words of Fleming (1995), is "in observing the best of teachers apparently there is no single best way to teach but teachers who cater for the different needs of students by using a variety of teaching approaches are rewarded with improved learning (p. 1)." There are, however, no hard boundaries between the styles and students can have one or more styles combined. To find out students' sensory preferences, a questionnaire with multiple-choice questions was created in English (VARK, 2021), and later translated into 14 languages (Fleming & Baume, 2006). It currently has 16 questions with four possible answers per question. Students are told to choose the option that best matches their perception, but if they do not feel that one single answer is the perfect match, they can choose more than one option. Students can leave a question unanswered if they feel the question does not apply to them. The minimum value for each preference is 0, and the maximum is 12 (Hawk & Shah, 2007) as shown in Figure 1.

Figure 1. VARK learning model (Source: Hawk & Shah, 2007)



A strong preference in a style can be identified by a score four or five points higher than any other. A difference below two points between preferences is not enough. A void—or a score of one—on a mode would suggest that it is a weak preference for that student. Fleming (2001) reported that about 41% of students taking the questionnaire online had single style preferences, 27% two preferences, 9% three preferences and 21% four preferences. Table 1 gathers activities that accommodate VARK preferences. The fourth preferences according to Fleming (1995) relate to different types of content and activity: visual students (V) prefer graphs, charts, and flow diagrams; aural students (A) prefer sounds and audio; read and write students (R and W) prefer documents and notes; kinaesthetic students (K) prefer experiences and samples; and multi-mode students (MM) prefer several possibilities.

Table 1. Suggested activities for VARK preferences (Source: Fleming, 2001)

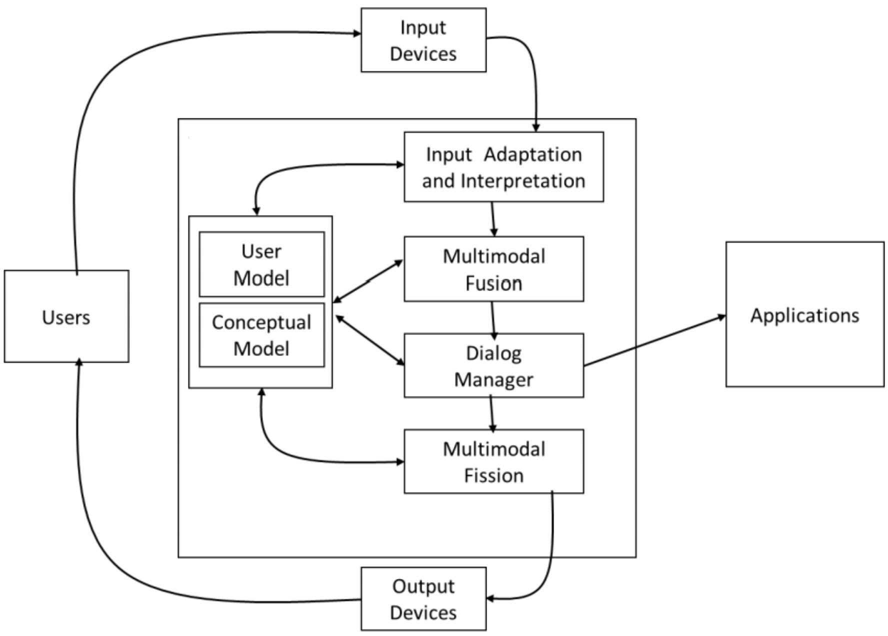
Visual	Aural	Read/Write	Kinaesthetic
Diagrams	Debates, arguments	Books, texts	Real-life examples
Graphs	Discussions	Handouts	Examples
Colours	Conversations	Reading	Guest lecturers
Charts	Audio tapes	Written feedback	Demonstrations
Written texts	Video+audio	Note taking	Physical activity
Different fonts	Seminars	Essays	Constructing
Spatial arrangement	Music	Multiple choice	Role-play
Designs	Drama	Bibliographies	Working models

2.2. Practical experiments

Fleming (2001) presented results revealing higher student performance when studying according to the VARK preferences indicated by the questionnaire. Fleming & Baume (2006) reported over 180,000 people having used VARK online between mid-March and mid-September 2006, and an attempt of validation although reliability values are not provided. Instead, a warning is given that the questionnaire is not to be used as a diagnosis tool, and explained by the creator as a stimulus to reflect upon. Experiments have been carried out to find out whether students found that the VARK preferences as indicated by the model are what they expected (Espinoza-Poves et al., 2019) and the pedagogical implications of the VARK model and how it can generally be used for online teaching (González, 2012; Hussain, 2017; Prithishkumar, 2014).

After performing an experiment with 92 Nurse Education students with a single group pre-post study, Alkhasawneh et al. (2008) found a significant increase in their grades after their VARK preferences has been taken into account. Their underlying teaching methodology was Problem-Based Learning. Moazeni and Pourmohammadi (2013) provided an automatic student modelling approach for distance education to optimise the teaching strategy to align instruction with students' learning styles using the VARK model. However, they did not provide any platform to implement and validate their approach. Similarly, Stojanova et al. (2017) highlighted the benefits of using the VARK model to teach a Data Structure and Algorithms course, which is the closest work to this paper together with Díaz et al. (2018) as it is also in the Computer Science domain (although not in HCI where literature is scarce). They used Moodle, presentations and animations using Java Applets and/or Flash and videos from YouTube. Neither a teaching methodology nor a framework to implement their approach is given.

Figure 2. Overview of the multimodal framework proposed by Vidakis (2017)



Lee and Kim (2016) proposed the Multimodal Teaching Learning Model (MTLM) based on providing the teacher with feedback and scaffolding to increase the interest of students. The use of technology using synchronous environments in small groups is considered beneficial in MTLM, although the use of learning preferences was not investigated. They carried out an experiment to test MTLM in the language-learning domain. A significant improvement in students' knowledge was found. Moreover, 54.9% of the students reported feeling a stronger bond with their teacher, and 62.9% of the students reported a stronger bond with their classmates, even in distance education.

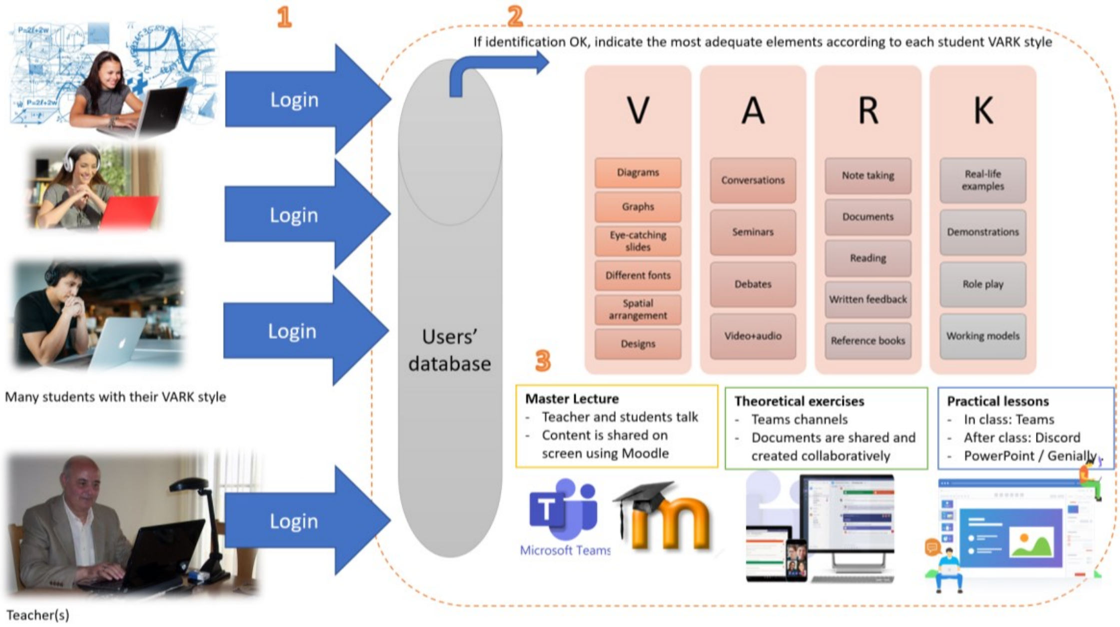
Vidakis (2017) described a multimodal framework to enable the deployment of more interaction modalities between students and online educational systems than just speech and touch. However, the paper does not mention the benefits of also considering the modality in the course contents. Figure 2 shows an overview of the multimodal framework proposed. No experiment is provided in which the platform has been implemented and used by students.

Finally, Díaz et al. (2018) highlighted how modified VARK styles and adaptive learning materials benefit both students and teachers. They proposed a platform to support the learning of object orientation with VARK learning styles. However, their focus was more on the creation of adaptive material as they called it, than in the computer system itself.

3. Proposal: Multi-mode digital teaching and learning of HCI using the VARK model

A shift from the traditional large-group teacher-centric teaching to a student-centric multi-mode digital approach is necessary (Prithishkumar, 2014). Models such as VARK are useful in highlighting the diversity of preferences among students and that there is no one teaching solution that matches all their preferences and domains. In this section, a proposal for multi-mode teaching and learning of theoretical and practical online lessons for HCI is described together with the architecture of a platform to support it given the lack of such platforms in the literature (see Section 2).

Figure 3. Overview of the multi-mode digital teaching model proposed



In F2F teaching, traditional theoretical lessons are associated with Master lectures. The reason why it continues to be used could be that it is cheap—one teacher with a relatively high number of students. However, with a Master lecture, it is not possible to manage the diversity of preferences among students; the lesson is just the same for all students with the possible consequence of bored students, unable to fully understand the lessons (Spanish Education Ministry, 2006). They should therefore be combined with exercises and practical lessons. Moreover, as already indicated by Lee and Kim (2016), the use of synchronous communications systems such as WhatsApp or Teams creating small groups is beneficial. Collaborative learning is the chosen underlying pedagogic model to mitigate the isolation feeling that students may have in distance education. Figure 3 overviews the proposal for multi-mode teaching and learning of HCI covering VARK styles.

As can be seen in Figure 3, initially (step 1) all students and teachers must login into the platform to identify themselves. This is a key step as the style of each student can be saved in the database. Thus, the system can indicate (step 2) which content elements from the VARK styles are the most appropriate for the teacher according to students' styles. For the Master lecture (step 3), teachers can use videoconference software such as Teams. As they talk, aural (A) students would benefit from listening to the lesson and visual (V) students would appreciate the use of eye-catching slides so that the knowledge is not only spoken but also written with a good design (e.g., using a template with different fonts, diagrams, graphs, and some spatial arrangement that leaves spaces between paragraphs). Read-Write (R) students will be taking notes during the lesson, and they will appreciate an activity such as writing a document to sum up the ideas of the lesson and to get some written feedback. A list of reference books is also suitable for R students to improve their learning. Kinaesthetic (K) students will appreciate the use of real-life examples, demonstrations, and working models as well as role-play exercises to understand the contents of the lesson better.

Creating channels in Teams is recommended to group students so that they can discuss the lesson and complete the exercises with another 4-5 students (Walter, 1983; Lee & Kim, 2016). Activities solely with the whole group are not advisable, as some students would not participate. For instance, as a possible exercise for the theoretical lesson for all VARK students would be that when teaching User-Centred Design (UCD, Lorés, 2002; Abras et al., 2004), after looking at the slides (V), listening to the teacher (A), note taking (R) and providing some detailed examples (K), students in their channels could think of one interactive system (e.g., a new videogame) to design following a UCD. V students would start creating the interface's diagram, A students would talk about the design and would understand the UCD better by listening to their classmates (not only the teacher) creating debate about what to do, R students would create a document to upload to the channel so that the teacher can check that their debate and thinking is correct (otherwise some spoken and written feedback should be provided to address the specific mistakes detected) and K students would have an example to understand the general UCD process.

For practical activities in the computer lab, the use of videoconference software such as Teams is also recommended for teachers to explain the activities to complete. Practical activities are a necessary complement to theoretical lessons (De Miguel, 2006) and the content should be at the same pace. Practical activities should follow the same recommendations previously provided for the Master lecture to address all different VARK preferences and channels should also be created for students to complete the practical activities for the reasons explained above. For instance, a possible practical project for all VARK students would be that when completing their practical work, they had images, diagrams, graphs, charts of a UCD (V), they could talk in their groups about the phases of a UCD and discuss them (A), they could read books describing the phases of a UCD (R) and write a report about that, and have a real example of creating a prototype following a UCD with a real client (K). Students should also present their practical work to their classmates (the whole class, not just their group). The goal would be for V students in other channels to see designs other than their own, A students would listen to different conversations about the topic, R students would have more documents to read and write about, and K students would have more examples to improve all their understanding. Students should be given the freedom to choose the presentation software to use. They may prefer traditional PowerPoint, just sharing their desktop, and talking about their activities from the documents created (no need to create new ones), or newer possibilities such as Genially. Students should have these new possibilities such as multi-layer content and animated templates explained to them to enhance interactivity and integrate knowledge.

V students will appreciate the aesthetic design of the templates in any presentation software. They will use them to make them easier to write their content. Moreover, they will not need to prepare different slides, because it is possible to create pop-ups that are shown as needed by clicking on them. A students will also appreciate the possibility of adding music and audio recordings to the presentation. R students will be reading the contents of the lessons and reference books to write the content of the presentation. Finally, K students will populate the contents of the presentation with many examples and specific cases to illustrate their points.

4. Research method

The research method used is a mixed quantitative and qualitative experimental research study with control and test groups. The theoretical justification for this method is the need to test a hypothesis and answer the research questions associated with a practical experiment in the field of software systems to gather data to perform both a descriptive and inferential statistical analysis, and to complement this quantitative data with the qualitative data provided by the users of the systems from answers to questionnaires (Goundar, 2013; Lorés, 2002).

Following an adaptation of the guidelines to report experiments in Engineering domains written by Jedlitschka and Pfahl (2005), and Wohlin et al. (2012) this section is structured as follows: 4.1. Goal, 4.2. Participants and Context, 4.3. Experimental Materials, 4.4 Procedure, and 4.5. Variables.

4.1. Goal

The goal of the experiment is to validate the proposed digital multi-mode teaching model using the VARK model as described in Section 3 in terms of learning efficacy, students' satisfaction levels and reliability of the VARK preferences. Although VARK is not a diagnosis tool, as explained in Section 2, we believe that it should be confirmed whether the VARK preference provided to students in the questionnaire reflects their personal preferences to really help them act accordingly.

The research questions together with the hypotheses are:

RQ1. Are the learning scores of students following the digital multi-mode teaching and learning model using VARK for HCI higher than the learning scores of students following traditional F2F lessons?

H1. Students following the digital multi-mode teaching and learning model using VARK will achieve higher scores than students following traditional F2F lessons.

RQ2. How satisfied are teachers and students following the digital multi-mode teaching and learning model using VARK?

H2. Teachers and students following the digital multi-mode teaching and learning model using VARK will be satisfied, and they will prefer it to F2F lessons.

RQ3. Are preferences provided by the VARK questionnaire valid?

H3. The preferences provided by VARK questionnaire are valid, as they will be supported by the answers from students to a preferences questionnaire.

4.2. Participants and context

The experiment was conducted in the first semester of the 2020/2021 academic year from September 2020 to January 2021 with 41 students enrolled in the third year of the Videogame design degree at the university. Of the students, 72% are between 20-22 years old, 20% are between 24-26 years old, and 8% are older than 26 years old. The split by sex is 80% men and 20% women. They have a high level of digital competence, enjoy using technology, and have a positive attitude towards its general use.

There were 44 students in the 2019-2020 academic year (control group) with a similar distribution of age and sex, digital competence level, and positive attitude towards technology. The main difference is that the Videogame design degree is a F2F degree at our university, thus the Master lectures and practical activities were F2F during that first semester from September 2019 to January 2020. For those students, therefore, the teaching and learning was F2F. However, due to COVID-19, it was agreed that Master lectures and practical activities should move online from March 2020. Therefore, students in the 2020-2021 academic year (test group) followed the online digital multi-mode teaching and learning model using VARK.

Both courses were taught by the same two teachers, one man and one woman who are both experts in HCI. All students were voluntarily asked to participate in the experiment. No increase of score or reward was given to any student. The motivation provided was focused on the goal of the experiment being to improve the teaching of HCI to more students, and that they learn about different modes of learning, and eventually get recommendations about their study preferences to improve their learning.

4.3. Experimental materials

All educational materials were created by the subject's teachers. The content of the subject in both the 2019/2020 and 2020/2021 academic years was the same, with the difference that the presentations were given in class in 2019/2020, and shared through the Teams videoconference system and uploaded to the digital campus hosted in

Moodle in 2020/2021. To cover all VARK preferences, the content was a set of slides with an eye-catching design, diagrams, written text, references, documents, and videos, as well as documents, videos, and external links to references in books and on websites.

4.4. Procedure

Students in the 2019/2020 academic year attended F2F theoretical lessons with the same content as in the 2020/2021 academic year. The exercises and practical activities were the same. The only difference was that the VARK multi-mode digital approach was followed in 2020/2021, and they were F2F in 2019/2020 without considering VARK preferences. The step-by-step procedure for the control group was:

(1) Lessons started in September 2019.
(2) For each week, students attended F2F classes on:
    2.1 Tuesdays (2 hours): Master lectures with theoretical exercises
    2.2 Fridays (2 hours): practical lessons
(3) Lessons finished in January 2020, and students took their final exam.

The step-by-step procedure for test group (using the multimodal methodology with VARK) was:

(1) Lessons started in September 2020.
(2) For each week, students attended classes online on:
    2.1 Tuesdays (2 hours): Master lectures with theoretical exercises
    2.2 Fridays (2 hours): practical lessons
(3) Lessons finished in January 2021, and:
    3.1 Students took their final exam.
    3.2 Students were asked to complete the VARK questionnaire.
    3.3 Students were asked to complete an online questionnaire about their experience.

Table 2. Final questionnaire for the students

Question	Possible answers	Measure
To see a Teams videoconference	1 (minimum) – 5 (maximum)	Preferences
To see a Blackboard videoconference	1 (minimum) – 5 (maximum)	Preferences
To talk about the exercises in groups	1 (minimum) – 5 (maximum)	Preferences
To write an individual report	1 (minimum) – 5 (maximum)	Preferences
To write a report in groups	1 (minimum) – 5 (maximum)	Preferences
To individually present the content	1 (minimum) – 5 (maximum)	Preferences
To present the content in groups	1 (minimum) – 5 (maximum)	Preferences
To create a video of the content on my own	1 (minimum) – 5 (maximum)	Preferences
To create a video of the content with my group	1 (minimum) – 5 (maximum)	Preferences
To read the slides	1 (minimum) – 5 (maximum)	Preferences
To take notes on paper	1 (minimum) – 5 (maximum)	Preferences
To take notes digitally	1 (minimum) – 5 (maximum)	Preferences
Do you think that presenting your practical work to the other students helped your learning of the subject?	Yes/No	Opinion
If face-to-face lessons were possible, would you prefer to attend face-to-face lessons instead of online lessons?	Yes/No	Satisfaction
Do you think that you would have learnt more following a face-to-face teaching approach?	Yes/No	Opinion
Do you think that you would have been happier if the teaching were face-to-face?	Yes/No	Satisfaction
Do you think that creating a prototype with a real client has helped your learning of the subject?	Yes/No	Opinion
Any other comment?	Free text	Opinion & Satisfaction

The Master lectures, theoretical exercises and practical work had the same structure, similar difficulty, content, weight in the final score (60%), and were evaluated on the same scale from 0 (minimum) to 10 (maximum). Samples of the practical activities have been published by Pérez-Marín (2018). The final exam was F2F in both courses with the same structure: three theoretical questions about the same concepts and with the same difficulty in both academic years with a maximum score of three points; one question to draw a prototype with a maximum score of four points; and one final question to write a report on assessing the usability of a videogame that they could freely choose with a maximum score of three points. The exam was completed individually without any help from the internet or reference books. It accounted for 40% of the final grade in both academic years, and the scale of the exam was also the same from 0 (minimum) to 10 (maximum). A sample exam can be found in Pérez-Marín (2018).

Only students in the test group in 2020/2021, when applying the VARK model as described in Section 3, were also asked to complete two additional questionnaires individually and online at the end of the course: (1) the Spanish translation of the VARK questionnaire (Sámano-Galindo & Preciado-Delgado, 2007); (2) a questionnaire to mark their preferences, and their satisfaction regarding the multi-mode digital teaching on a Likert scale (from 1-minimum to 5-maximum); to answer Yes/No to some opinion and satisfaction questions, and any other comment they may have, to give them the opportunity of freely expressing themselves. The questionnaire was not anonymous because the intention was to relate the values gathered with the results of the VARK questionnaire. In any event, no name or personal information was asked for because it would be contrary to Spanish law. A code was therefore created from their practical group number and their position on the list of group members. Without the list of groups, therefore, it was impossible to identify the students. Table 2 shows the questions with their possible answers and what they measure.

4.5. Variables

The dependent variables of the study were related, firstly, to learning efficacy, measured by scores obtained for the students at the end of the experiment, named *Score*. These ratings are divided into two groups, those who had F2F teaching and those who had digital multi-mode teaching; the factor variable named *Group* shows these differences. Secondly, a categorical dependent variable named *VARKL* collects the results of the VARK questionnaire into the four preferences described in Section 3: A, R, K and MM. Additionally, a group of 12 ordinal variables scaled from 1 to 5 collect the results gathered in the preferences questions described in Section 4.4. They will be called x_i in relation to the i-th question. Table 3 summarises the variables used in the experiment.

Table 3. Summary of variables

Aspect	Type	Variable	Name
Learning HCI	DV	Scores	Score
	IV	Use of the digital VARK multi-model	Group
Preferences	DV	VARK questionnaire	VARKL
	IV	i-th question in questionnaire for the students' preferences (i = 1, ... , 12)	x_i

Note. DV: Dependent variable, IV: Independent variable, name, and description.

5. Results

5.1. Learning efficacy

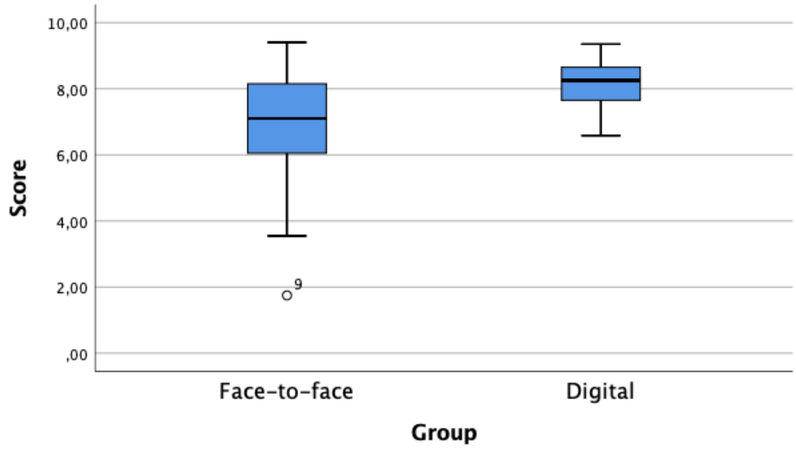
Table 4 shows the mean and median values (more representative than mean in asymmetric distributions) and standard deviations for the scores in the final exam of the control and test groups. In the F2F control group, the mean of the marks is 6.90, a value somewhat lower than the median, with a standard deviation of 1.71. In the test multi-mode digital group, the mean is more than one point higher at 8.10, again somewhat lower than its median of 8.25. For this group, in addition, the dispersion of the scores is much smaller, the difference with the previous case being more than one point: 0.69. Figure 4 shows a graphical summary of these data as boxplots.

After checking the normality of the data in both groups (Shapiro-Wilk test with $p > .05$), the t-test for independent groups was chosen. Table 4 shows the significant increase of the scores in the digital multi-mode group, with $p < .001$.

Table 4. Descriptive analysis of the scores in the final exam for both groups

Group	*N*	Mean	Median	*SD*	*t*-test	*df*	*p*-value
Control (F2F)	44	6.90	7.10	1.71	4.272	57.78	< .001
Test (Multimodal)	41	8.10	8.25	0.69			

Figure 4. Boxplots for the scores in the final exam of the F2F control and digital test groups



5.2. Students' satisfaction

Regarding RQ2, students seem satisfied with the multi-mode digital teaching with answers such as "Following this approach I think I learn a lot, so I like that", "I like that all theoretical lessons are practiced later with a real client" or "I like these lessons very much! Thanks!" to the final open question. In total, 84% of students considered that explaining the practical work to other classmates helped them as shown in Figure 5 and in general, they do not think that they would have learnt more in a F2F lesson (only 35% students answered that they would learn more in a F2F lesson as shown in Figure 6). In total, 56% of students thought that they would have enjoyed the F2F lessons more (see Figure 7).

When the HCI teachers were asked about their satisfaction with using the VARK multi-mode digital approach compared to classical teaching, they both agreed that they were more satisfied because they could combine multiple resources and saw that their students understood the lessons faster and better.

Figure 5. Satisfaction with the practical work (84% yes, 16% no)

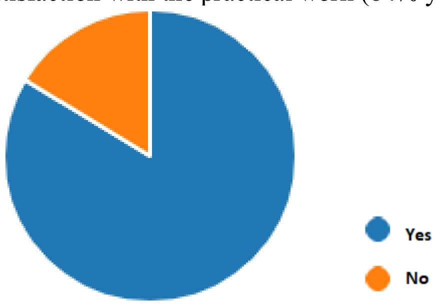


Figure 6. Opinion about whether they thought they would learn more with F2F teaching (35% yes, 65% no)

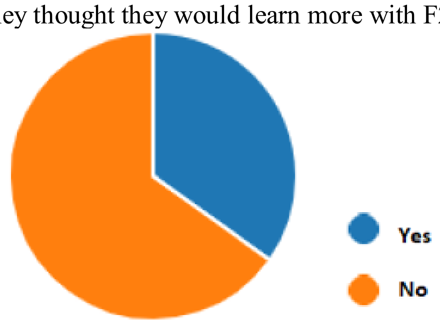
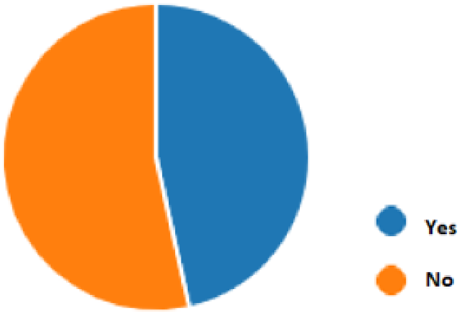


Figure 7. Answer to the question: do you think that you would be happier if the teaching were F2F? (47% yes, 53% no)



5.3. VARK validation

To see the possible relationship between the dependent variable VARKL and the 12 independent variables of the preferences questions, a multinomial logistic regression model was chosen, since the output variable is a categorical variable, and the predictor variables are ordinal variables. The absence of multicollinearity between the variables is first verified, with the FIV value being under 10 in all independent variables, and with a tolerance greater than 0.1 in all cases.

The model fitting information provided a $\chi^2(48) = 85.59$ ($p = .001$), i.e., the full model predicts the dependent variable better than the intercept-only model alone. Moreover, Pearson $\chi^2(108) = 43.643$ and Deviance $\chi^2(108) = 39.937$, both with $p > .005$. Pseudo Nagelkerke $R^2 = 0.626$, a medium value that measures the degree of improvement in the fit of the log-likelihood model with respect to the model without independent variables. The model gives an overall correct classification percentage of 76.9%.

6. Discussion

6.1. Theoretical contributions

The results of this study revealed that students following the VARK multi-mode online approach significantly improved learning outcomes with respect to traditional F2F students (scores 8.10 vs 6.90 respectively). Therefore, RQ1 is positive and H1 is accepted. As reviewed in Section 2, there are many studies regarding multi-mode teaching effectiveness. Yeh (2018) investigated students' perceptions with respect to their knowledge level in English as a foreign language, where students had to produce a digital video, reflective essays and PowerPoint slides employing multiple modalities and formats. Yeh discovered that students perceived that the process based on creating compositions, oral presentations and video editing improved their multiliteracies to learn the target language. Other works have not focused on the student's perception, but on self-assessment processes to determine multimodal approach effectiveness in an educative context, finding that a multi-mode blended learning model produces significant improvements in several language-learning skills (Chen, 2018; Lee & Kim, 2016). Santana-Mancilla et al., (2019) found that the use of teaching methods based on games in HCI education, which has multi-mode interaction, provides students with important skills in this area, such as involving users, task-centred system design, models of human behaviour, creativity and metaphors, and graphical screen design.

However, the previous multimodal models do not always consider students' preferences with an underlying pedagogic model. The multimodal teaching learning model proposed in the article is based on VARK, which groups several learning preferences and a collaborative learning approach together. Therefore, the paper contributes with a model that guides learning activities and instructional development considering different learning preferences and combines pedagogical methods with digital tools, the most appropriate way for HCI education.

The paper also has two more contributions regarding innovations in learning effectiveness. Firstly, most experience in previous research regarding learning effectiveness was mainly developed in a literacy education context. In this paper, the learning experience was developed in computer science learning, specifically Human-Computer Interaction, which has been poorly researched regarding multi-mode digital teaching approaches. Secondly, most research in the literature applies subjective assessment based on students' perception to measure learning effectiveness, whereas this study develops objective assessment using exam scores.

6.2. Theoretical implications

Regarding to the use of VARK in HCI education context, the results show that hypothesis H3 must be accepted. RQ3 is positive, as it has been possible to predict the preferences provided by the VARK questionnaire as the output value of a regression model with 77% success.

To the best knowledge of the authors, the use of VARK in HCI learning is rare. However, some work in learning programming, which is an educative context close to HCI can be found such as Stojanova et al. (2017), who applied VARK to learn data structures and algorithms with discussion tools using Moodle LMS. Additionally, they integrated visualisations of algorithms with VisuAlgo (see http://visualgo.net/) and discovered that the use of VARK improved interest among students and kept their attention in class. Díaz et al. (2018) carried out an experience with industrial engineering students of object-oriented programming courses. Students had access to an adaptive e-learning platform that proposed different learning contents and tasks according to VARK style. Díaz et al. (2018) discovered that the predominant VARK style preferences of engineering students were kinaesthetic and aural and that there were no visual style students. This finding is aligned with the results found in this paper, where the predominant preferences of the HCI students enrolled in the Videogame design degree were kinaesthetic, and only one student was visual.

6.3. Practical implications

Learning outcomes do not only depend on a pedagogy approach. There are emotional and affective factors that may increase learning efficacy (Lin et al., 2016; Urquiza-Fuentes & Paredes-Velasco, 2017). Students' satisfaction experienced with multi-mode digital learning has been analysed in this study too with the answer to RQ2 being that both teachers and students were very satisfied. In total, 84% of students were satisfied with the practical class model used and only 35% of students considered F2F to be more efficient. Thus, H2 is accepted. These results are aligned with other studies on HCI multimodal education. For instance, high satisfaction experienced by participants in the experience reported is similar to positive emotions experienced by other students that worked with multimodal interaction approach, "Regarding if they enjoyed learning using computer games, 100% of the students enjoyed the course" and "100% said that the knowledge acquired would have been lower [if the teaching process were not related to video game design]" (Santana-Mancilla et al., 2019, p. 9).

The authors consider that this phenomenon is explained by multi-mode environments influencing students' beliefs and perception about their skills and knowledge during the learning. Banzato and Coin (2019) carried out an experience where students had to develop multimodal narrative learning activities through gestural/mime languages, drawings, oral presentations and compositions and they found that a multimodal approach influenced students' self-efficacy beliefs about their narrative skills. Santana-Mancilla et al. (2019) stated that multimodal interaction in HCI education promotes students having a positive perception on the efficacy of the use design for practical works. In addition, the use of multimodal information spaces, rich in digital and physical resources (Facebook discussion, downwards projection, tablets, etc.) raise students' satisfaction and motivation, and contribute to their engagement and collaboration in HCI learning (Vasiliou et al., 2013). These studies are aligned with the results of the experience reported in this paper, where 53% of students perceived the use of practical work as the best way to understand theoretical contents and Teams and Blackboard video-collaborative platforms as the best tools to learn content digitally. The practical contribution of this paper is the digital ecosystem defined by the multimodal teaching learning model, which facilities applying multimodality in a practical way in HCI education and improving students' engagement and satisfaction.

6.4. Limitations

Regarding possible threats to this study, the following issues have been considered: all questionnaires were applied at the end of the experience to avoid influencing the results; repeat students did not participate in the experience so the pre-pandemic (traditional F2F) and post-pandemic (multi-mode online learning) groups were different; and, although the control group was from last year and test group from this year, learning contents, tasks and teachers were the same for both groups, pre and post-pandemic, with only the teaching and learning methodology changing. However, some threats to validity are recognised in the experiment presented (Campbell & Stanley, 1963; Cook & Campbell, 1979; Shadish et al., 2002):

- **Internal validity:** the scenario in which the test group was must be considered; in most cases, the student's home. This can be an advantage, as many of them operate in an environment that they consider safer than university. Others, on the other hand, may have worse digital media available, etc.

- **External validity**: since the groups are not created randomly—it depends on the students enrolled in each academic year—there is no certainty that the sample is representative of the general population.
- **Construct validity**: an important part of applying the VARK method lies in the use of new methodologies. The use of audiovisual methods during the development of the subject is a novelty in some activities, such as debates, seminars, etc. According to Bracht and Glass (1968) there is a certain enthusiasm when there is innovation, and this can contribute to success.
- **Conclusion validity:** This is concerned with sources of random error and with the appropriate use of statistics and statistical tests (Cook & Campbell, 1979). They are also called SCV. The work presents a broad statistical study, which involves, firstly, a descriptive analysis of the data, combining descriptive and graphic techniques. Subsequently, an inferential study is carried out, in which the necessary conditions have been previously verified. Still, type 1 errors (incorrect rejection of the null hypothesis) and type 2 errors (not rejecting a false null hypothesis), although minimised, might be present.

7. Conclusions

The most relevant contribution to HCI education is a detailed and validated digital multi-mode teaching and learning approach using the VARK model. As indicated by Ioannou et al. (2015), this research contribution is particularly beneficial for HCI courses given that digital teaching is highly accepted by HCI students, provides satisfaction, and raises the acquisition level of HCI knowledge. The paper also contributes to multi-mode digital teaching and learning using the VARK model with a new validated approach supported by a framework of how to implement it that could guide other researchers and teachers to put it into practice in their lessons. It is particularly relevant as no similar framework has been found in the literature. Future research will focus on keeping investigating factors influencing the multimodal learning environment.

References

Abras, C., Maloney-Krichmar, D., & Preece, J. (2004). User-centered design. In W. Bainbridge (Ed.), *Encyclopedia of Human-Computer Interaction* (pp. 445-456). Thousand Oaks, CA: Sage Publications

Alkhasawneh, I. M., Mrayyan, M. T., Docherty, C., Alashram, S., & Yousef, H. Y. (2008). Problem-based learning (PBL): assessing students' learning preferences using VARK. *Nurse education today*, 28(5), 572-579.

Bakar, A. (2007). Pengaruh kemahiran teknikal pensyarah politeknik terhadap proses pengajaran dan pembelajaran mengikut persepsi pelajar [The influence of technical skills of polytechnic lecturers on the teaching and learning process according to students' perceptions] (Unpublished master dissertation). Universiti Tun Hussein Onn Malaysia, Batu Pahat, Malaysia.

Banzato, M., & Coin, F. (2019). Self-Efficacy in multimodal narrative educational activities: Explorative study in a multicultural and multilingual italian primary school. *Media and Communication*, *7*, 148. https://doi.org/10.17645/mac.v7i2.1922

Bell, T., Urhahne, D., Schanze, S., & Ploetzner, R. (2010). Collaborative inquiry learning: Models, tools, and challenges. *International Journal of Science Education*, *32*(3), 349-377

Bracht, G. H., & Glass, G. V. (1968). The External validity of experiments, *American Education Research Journal*, *5*(4), 437- 474.

Campbell, D., & Stanley, J. (1963). *Experimental and quasi-experimental designs for research*. Chicago, IL: Rand-McNally.

Card, S. K., Newell, A., & Moran, T. P. (1983). *The Psychology of Human-Computer Interaction*. L. Erlbaum Associates

Carnegie Mellon University. (2020). *Seminar series in human-computer interaction*. https://www.hcii.cmu.edu/seminar-series

Chen, Z. (2018). Teaching effect of the multi-mode blended learning model from students' perceptions. In S. Cheung, J. Lam, K. Li, O. Au, W. Ma, & W. Ho (Eds.), *International Conference on Technology in Education* (pp. 188–199). Springer. https://doi.org/10.1007/978-981-13-0008-0_18

Cook, T. D., & Campbell, D. T. (1979). *Quasi-experimentation: Design and analysis issues for field settings*. Boston, MA: Houghton Mifflin.

Cope, B., & Kalantzis, M. (2009). "Multiliteracies": New literacies, new learning. *Pedagogies: An International Journal*, *4*(3), 164-195.

De Miguel, M. (2006). Metodologías de Enseñanza Centrados en el Desarrollo de Competencias [Teaching Methodologies focused on the Development of Competencies]. Ediciones Universidad de Oviedo.

Díaz, F., Rubilar, T., Cubillos, C., & Silva, R. (2018). An Adaptive e-learning platform with VARK learning styles to support the learning of object orientation. *Proceedings of the 2018 IEEE World Engineering Education Conference (EDUNINE)* (pp. 6). https://doi.org/10.1109/EDUNINE.2018.8450990

El-Bishouty, M. M., Aldraiweesh, A., Alturki, U., Tortorella, R., Yang, J., Chang, T. W., & Graf, S. (2019). Use of Felder and Silverman learning style model for online course design. *Educational Technology Research and Development*, *67*(1), 161-177.

Espinoza-Poves, J. L., Miranda-Vilchez, W. A., & Chafloque-Céspedes, R. (2019). Los estilos de aprendizaje Vark en estudiantes universitarios de las escuelas de negocios [VARK learning styles in college students from business schools]. *Propósitos y Representaciones*, *7*(2), 384-414. http://dx.doi.org/10.20511/pyr2019.v7n2.254

Felder, R. M., & Silverman, L. K. (1988). Learning styles and teaching styles in engineering education. *Engineering Education*, *78*(7), 674–681.

Fleming, N., & Baume, D. (2006) Learning Styles Again: VARKing up the right tree! *Educational Developments*, *7*(4), 4-7.

Fleming, N. D., & Mills, C. (1992). Not Another Inventory, Rather a Catalyst for Reflection. *To Improve the Academy*, 11, 137-155.

Fleming, N. D. (2001). *Teaching and learning styles: VARK strategies*. New Zealand: Christchurch.

Fleming, N. D. (1995). I'm different; not dumb. Modes of presentation (VARK) in the tertiary classroom. In A. Zelmer (Ed.), Research and Development in Higher Education, *Proceedings of the 1995 Annual Conference of the Higher Education and Research Development Society of Australasia (HERDSA)* (Vol. 18, pp. 308- 313). http://www.vark-learn.com/wp-content/uploads/2014/08/different_not_dumb.pdf

González, B. (2012). El modelo VARK y el diseño de cursos en línea [The VARK model and online course design]. *Revista mexicana de bachillerato a distancia*, *4*(8). http://dx.doi.org/10.22201/cuaed.20074751e.2012.8.44282

Goundar, S. (2013). Research Methodology and Research Method. In S. Goundar (Ed.), *Cloud Computing* (pp. 2-43). Victoria University of Wellington.

Hawk, F., & Shah, A. (2007). Using learning style instruments to enhance student learning. *Decision Sciences Journal of Innovative Education*, *5*(1), 1-19. https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1540-4609.2007.00125.x

Hussain, I. (2017). Pedagogical implications of VARK model of learning. *Journal of Literature, Languages and Linguistics*, *38*, 33-37.

Ioannou, A., Vasiliou, C., Zaphiris, P., Arh, T., Klobučar, T., & Pipan, M. (2015). Creative multimodal learning environments and blended interaction for problem-based activity in HCI education. *TechTrends*, *59*, 47–56. https://doi.org/10.1007/s11528-015-0839-9

Jedlitschka, A., & Pfahl, D. (2005, November). *Reporting guidelines for controlled experiments in software engineering* [Paper presentation]. IEEE International Symposium on Empirical Software Engineering, Queensland, Australia.

Jewitt, C. (2008). Multimodality and literacy in school classrooms. *Review of Research in Education*, *32*(1), 241-267.

Lee, Y., & Choi, J. (2011). A Review of online course dropout research: Implications for practice and future research. *Educational Technology Research and Development*, *59*, 593–618. https://doi.org/10.1007/s1142 3-010-9177-y

Lee, K., & Kim B. (2016). Cross space: The Exploration of SNS-based writing activities in a multimodal learning environment. *Educational Technology & Society*, *19*(2), 57-76.

Lin, H., Su, S., Chao, C.-J., Hsieh, C.-Y., & Tsai, S.-C. (2016). Construction of multi-mode affective learning system: taking affective design as an example. *Educational Technology & Society*, *19*(2), 132-147.

Lorés, J. (2002). *La Interacción Persona-Ordenador* [Human-Computer Interaction]. Asociación Interacción Persona Ordenador.

Moazeni, S., & Pourmohammadi, H. (2013). Smart teaching quantitative topics through the VARK learning styles model. In 2013 *IEEE Integrated STEM Education Conference* (ISEC) (pp. 1-7). IEEE.

Oyedotun, T. D. (2020). Sudden change of pedagogy in education driven by COVID-19: Perspectives and evaluation from a developing country. *Research in Globalization*, 2. https://doi.org/10.1016/j.resglo.2020.100029

Papageorgiou, V., & Lameras, P. (2017). Multimodal Teaching and Learning with the Use of Technology: Meanings, Practices and Discourses. *14th International Conference on Cognition and Exploratory Learning in Digital Age (CELDA)*, 133-140.

Pérez-Marín, D. (2018). *Proyecto Docente* [Teaching Project]. Publicaciones de la Universidad Rey Juan Carlos. http://hdl.handle.net/10115/17069

Philippe, S., Souchet, A.D., Lameras, P., Petridis, P., Caporal, J., Coldeboeuf, G., & Duzan, H. (2020). Multimodal teaching, learning and training in Virtual Reality: A Review and case study. *Virtual Reality & Intelligent Hardware*, *2*(5), 421-442. https://doi.org/10.1016/J.Vrih.2020.07.008

Prithishkumar, I. J. (2014). Understanding your student: Using the VARK model. *Journal of Postgraduate Medicine, 60*(2), 183-186. https://doi.org/10.4103/0022-3859.132337

Sámano-Galindo, R., & Preciado-Delgado, E. (2007). *Traducción del cuestionario VARK al español* [Translation of VARK questionnaire to Spanish]. https://vark-learn.com/el-cuestionario-vark/

Santana-Mancilla, P. C., Rodríguez-Ortiz, M. A., García-Ruiz, M. A., Gaytan-Lugo, L. S., Fajardo-Flores, S. B., & Contreras-Castillo, J. (2019). Teaching HCI skills in higher education through game design: A Study of students' perceptions. *Informatics*, *6*(2), 22. https://doi.org/10.3390/informatics6020022

Shadish, W. R., Cook, T. D. & Campbell, D. T. (2002). *Experimental and quasi- experimental designs for generalized causal inference*. Boston, MA: Houghton Mifflin.

Spanish Education Ministry. (2006). *Propuesta para la renovación de las metodologías educativas en la Universidad. Consejo de Coordinación Universitaria* [Proposal for the renewal of educational methodologies at the University. University Coordination Council]. Secretaría General Técnica. Subdirección General de Información y Publicaciones. http://publicaciones.administracion.es

Stephanidis, C., Salvendy, G., Antona, M., Chen, J., Dong, J., Duffy, V., Fang, X., Fidopiastis, C., Fragomeni, G., Fu, L.P., Guo, Y., Harris, D., Ioannou, A., Jeong, K., Konomi, S., Krömker, H., Kurosu, M., Lewis, J.R., Marcus, A., Meiselwitz, G., Moallem, A., Mori, H., Nah, F., Ntoa, S., Rau, P., Schmorrow, D., Siau, K., Streitz, N., Wang, W., Yamamoto, S., Zaphiris, P., & Zhou, J. (2019). Seven HCI grand challenges. *International Journal of Human–Computer Interaction*, *35*(14), 1229-1269. https://doi.org/10.1080/10447318.2019.1619259

Stojanova, A., Stojkovikj, N., Kocaleva, M., Zlatanovska, B., & Martinovska-Bande, C. (2017) Application of VARK learning model on "Data structures and algorithms" course. In *IEEE Global Engineering Education Conference (EDUCON)* (pp. 613-620). https://doi.org/10.1109/EDUCON.2017.7942909

Teele, A. A., Sindelar, A., Brown, D., Kane, D. A., Thatte, N., Williams, R. J., Gueverra, J., & Wolbrink, T. (2020). Online education in a hurry: Delivering pediatric graduate medical education during COVID-19. *Progress in Pediatric Cardiology*. https://doi.org/10.1016/j.ppedcard.2020.101320

Urquiza-Fuentes, J., & Paredes-Velasco, M. (2017). Investigating the effect of realistic projects on students' motivation, the case of Human-Computer interaction course. *Computers in Human Behavior*, *72*, 692–700. https://doi.org/10.1016/j.chb.2016.07.020

VARK. (2021). *On-line VARK questionnaire in English.* https://vark-learn.com/the-vark-questionnaire/ with the description of the modes at https://vark-learn.com/introduction-to-vark/the-vark-modalities/

Vasiliou, C., Ioannou, A., & Zaphiris, P. (2013). Technology enhanced PBL in HCI education: A Case study. In P. Kotzé, G. Marsden, G. Lindgaard, J. Wesson, & M. Winckler (Eds.), *Human-Computer Interaction – INTERACT 2013* (pp. 643–650). Springer. https://doi.org/10.1007/978-3-642-40498-6_56

Vidakis, N. (2017). A Multimodal interaction framework for blended learning. In *EAI Endorsed Transactions on Creative Technologies, 4*(10). https://doi.org/10.4108/eai.4-9-2017.153057

Walter, R. (1983). La realización de estudios de casos en educación. *Ética, teoría y procedimientos* [Conducting case studies in Education. Ethics, theory, and procedures]. In W. Dockrell & D. Hamilton (Eds.), *Nuevas reflexiones sobre la investigación educativa*. Narcea.

Wohlin, C., Runeson, P., Höst, M., Ohlsson, M. C., Regnell, B., & Wesslén, A. (2012). *Experimentation in software engineering*. Springer Science & Business Media.

Yeh, H.-C. (2018). Exploring the perceived benefits of the process of multimodal video making in developing multiliteracies. *Language Learning and Technology*, *22*, 28–37.