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Approaching instrumental conflicts during an assessment activity with an interactive learning environment

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Abstract

Word processors are still supporting artefacts for the realization of learning activities by allowing higher education students to increase their writing skills. They can be hosted in Interactive Learning Environment (ILE) or desktop based. These artefacts are based on graphical interfaces which forces students to manage instrumental genesis that crosses the effects of didactic, pedagogical and technical artifacts between them, during the learning activity. Our paper investigates the impact of instrumental conflicts on the cognitive load of the students, during an assessment activity with Docyrus, an adaptable ILE. In particular, after a literature review on the instrumental approach and the cognitive load theories applied to the Human Computer Interaction (HCI), the empirical work (N=104) examines how far the customisation of the graphical user interface of an ILE, during the learning activity, influences the final achievement of a quiz. The main goal behind our approach is to understand from the educational engineering point of view, and within the framework of the instrumental approach, the adapted use of these environments with regard to the learning activities to take place there.

Keywords: ILE, interface, cognitive load, instrumental conflict

1. Introduction

Referring to the work of Rabardel (1995) and Marquet (2005 ; 2019), it is now clear that students face instrumental conflicts from didactic, pedagogical, and technical artefacts in their instrumental genesis with the interactive learning environments (ILE) they use. Despite the ever more designated and interactive interfaces, these ILEs are still based on standardized technical and pedagogical engineering principles, which still fail to reduce or circumscribe, the instrumental conflicts that learners face in their learning. Some authors (Hollender et al., 2010) suggest that “the optimization of cognitive load needs to be taken into account in the design of the software used by learners”. From the point of view of instrumental genesis (Rabardel, 1995), this paper focusses on the effect of the customization of a graphical user interface, onto the cognitive load. We investigate the impact of the possibility given to the learner to customize the graphical user interface (GUI) of an ILE, during the learning phasis, on the realization of an assessment activity in this same environment at the end of the course. We collect the traces of actions performed by the learner on the interface, in order to measure the effect of the customization on the learner's cognitive load (Sweller, 1994). We then analyse the impact of this cognitive load on the scores obtained in a quiz.

2. Literature review

2.1. Instrumental genesis and instrumental conflict

In the instrumental approach (Rabardel, 1995), the theory of instrumental genesis extends the field of research on the mediating role of tools in human activities. Drawing on constructivist epistemologies, this theory is based on the concept of instrument and the concept of instrumental genesis. The instrument is seen as a mixed entity that is constituted by the artefact, the material or technical part, and the subject's use patterns or behavioural part. According to this theory, an artefact becomes an instrument through transformations that involve the artefact and the user's patterns of use (Overdijk et al, 2012). If the notion of conflict appears, in Piagetian theory, as one of the essential elements in the study of the mechanisms of cognitive development, it is also present in the instrumental approach where, in the content and form of the teaching contents, the didactic and pedagogical artefacts are closely linked during the learning process, requiring the learner to manage to interweave the pedagogical dimension of the knowledge represented with the didactic dimension, the knowledge itself. According to Marquet (2005), e-learning, through the introduction of digital technology (software, learning platforms, ILE) in the learning activity, adds an additional level of appropriation to the didactic and pedagogical artefacts: the technical artefact. The use of the concept of instrumental conflict draws its relevance from the generalisation of the use of digital technologies as learning supports (Marquet, 2019). Indeed, in the case of a computerised pedagogical situation, the computer screens from their graphic interfaces, try to represent, adapt and make accessible, didactic objects initially represented

on paper supports. We retain the definition of Marquet (2005 ; 2019) who posits that the "instrumental conflict designates the failure of the instrumental genesis of at least one of the three artefacts at stake in a teaching-learning situation involving an ILE".

2.2 Cognitive load and Human Computer Interaction (HCI)

One of the major challenges that learners face today in their learning activities is that of being able to perform a familiar task on an interface in a reliable manner (Gajos & Chauncey, 2017). Learning contexts and situations are multiple and complex, contrary to the interfaces that were initially standardised for better adoption of the environments in which they were implemented and for the purpose of ever greater usability (Fleck & Massou, 2021). This unpredictability of Human Computer Interaction makes ILEs complex, especially from the point of view of navigation (Saadé & Otrakji, 2007) introducing, with reference to cognitive load theory (Sweller & Chandler, 1991) and the cognitive theory of multimedia learning (Mayer, 2005) cognitive overload (Chalmers, 2003; Amadiou et al., 2009) and disorientation (Demirbilek, 2004; Xiong, 2017 ; Bayazit et al., 2018; Bhatti et al., 2020). In our study, we consider the extraneous cognitive load, "caused by an inappropriate presentation of the learning material or by requiring students to perform activities that are irrelevant to learning" (Hollender et al., 2010). Learners experience information overload when the effort required to process a task exceeds their processing capacity (Eppler & Mengis, 2004). In ILEs, interface designers seek the best usability of the system by aiming for a minimum number of clicks from the mouse or trackpad used. This often results in a minimum number of screens displayed, each of which contains too much information for them to be suitable for learning due to the lack of progression. This abundance of information can lead the user into a state of cognitive overload (Chen & Chang, 2009; Li, 2017) who in confusion makes unsatisfactory and inappropriate choices.

2.3. Approaching instrumental conflicts with graphical user interfaces

In the literature, a human-computer interface is a means by which people and computers communicate with each other (Bonsiepe, 1990). The user interface (UI) is defined as "the part of the system that acts as an intermediary between the user and system facilitating the user to interact with the system in an efficient manner" davis (Saha et al., 2015), while the graphical interface characterises a visual operating display that the monitor presents to the computer operator (Harding, 1989). Research has shown that while many interface features are intended to improve the usability (Davis, 1989) and usability of a software (Debie et al., 2013), they do not necessarily reach their goal (Chalmers, 2003). However, despite the implementation of design rules of interfaces available in particular in computer environments supporting learning, researchers have noted conflicts between learning and the completion of the work required (Mikulecky, 1993), "which leads new users to try to skip the training, or to skip certain parts of it, sometimes with disastrous consequences... For the same reason,

experienced users are likely to use the procedures they already know, regardless of their effectiveness". As Monique Linard (2001) has clearly stated, in a learning situation, the interface is a device within which the cognitive universe of the designer's representation of the task, the cognitive universe of the designer's graphical and symbolic representations of activities and actions, and the learner's mental representations coexist. We therefore try to answer the following research question: to what extent does the customisation of the graphical interface of an ILE during the learning activity, does impact the results obtained in a Quiz on the same environment at the end of the activity?

3. Methodology

Word processors have been used for a long time to support many learning activities such as writing (Stevens, 1999), second language writing (Li & Cumming, 2001), Spell Checking (Warschauer, 1998), editing (Phinney & Khouri, 1993), Storage (Daiute, 1983). This type of software is still the central application in learning (Zeller & Marquet, 2020b) allowing the realization of memos or reports, after the realization of a strategic intelligence activity. Our study analyses the traces left by the user of a GUI of a specific ILE, Docyrus, which includes several modules: a first one dedicated to the consultation of educational resources thanks to video and a PDF players, a second one being a full word processor, a third one dedicated to the realization of quizzes and a fourth in charge of collecting and analysing learning analytics in real time. We asked students to complete assignments at home. They had to answer a Quiz on Docyrus, after having studied resources, and for the experimental group, after having customized the graphical interface of the environment for better usability. Answering the questions required writing a paragraph of 5 to 10 lines whose content was then semantically analyzed by the software.

4. The survey

4. Customisation of the graphical user interface of the ILE and performance on a Quiz

We hypothesize that each switch back and forth between the modules (the PDF, the Word processor and the Quiz modules implemented in Docyrus), is accompanied by a process of appropriation of the interface displaying contextual forms, ribbon, icons and buttons, which puts it prey to instrumental conflicts in its process of instrumentation of didactic, pedagogical and technical artefacts that mobilize a significant cognitive load that reduces the part that can be devoted to the learning itself (Marquet, 2005). Our general assumption is that there is a correlation between the additional cognitive load mobilised by the learner to personalise the interface of the environment in terms of the amount of actions required to achieve it and both the realization of the quiz. We also hypothesize that the interface personalised by the learner during the activity, allows him/her to adjust all the actions carried out on the interface to

answer the Quiz.

4.2 Sample and procedure

Our research was carried out on students enrolled in first and second year in a course in business intelligence and strategic intelligence at the University of Strasbourg. The activity requested to the 104 participants divided into a control and an experimental group, was to read and study methodological content related to data-mining and data curation methods at home. To do this, students had to read PDF documents uploaded in Docyrus. They were asked to go through the resources, taking notes if necessary, and then to take a Quiz at the end of the activity related to the content studied. We draw our attention to five variables : V1_Score : quizz score obtained by the student, V2_Quiz actions_of_navigation : sum of navigation actions performed during the Quiz phase, V3_PDF_actions_of_navigation : sum of navigation actions performed during the PDF reading phase, V4_WP_actions : sum of actions performed on the Word Processor module, V5_GUI_actions : sum of customization actions performed on the interface. The low-level traces that we captured were transformed into high-level traces. Thus, what we call action is the set of events, belonging to the same class of actions, realized jointly in the same temporality scale. For instance, an action carried out on the word processor such as the bolding of a selection of text, can be constituted by ten or so micro-events such as the selection of text, the movement of the mouse towards the formatting icon, the click on the icon and the deselection of the text. We present below the significant results we have obtained.

5. Results

5.1 Performances on Quiz

Variables have been compared with non parametric statistical tests, due to their non-normal distributions. A first comparison of the averages score obtained at the Quiz (V1), reveals that the experimental group, which was allowed to personalize the graphical interface of the ILE (G1), obtains a higher average score than the control group (G2) (V1: 4.17>3.64), but with no significant effect ($p = .405$). We then measure the sum of customisation actions performed on the interface (V5) for the experimental group. The control group could not customise the GUI. Surprisingly enough, we find that 0 actions were performed by the experimental group who was yet informed and trained to do so. We also compare the average of navigation actions performed for the completion of the Quiz (V2), the average of navigation actions in the PDF resources made available (V3), and the average of actions performed on the word processor (V4). The Mean Rank (Table 1) are systematically higher for the experimental group than for the control group: (V2: 58,87>45,07; V3: 61,53>41,97; V4: 61,15 >42,41). Those differences are all significant V2 ($p = .020$), for variable V3 ($p = .001$) and for variable V4 ($p = .002$).

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TABLE 1 – Mann-Withney Test for V2, V3, V4.

	Group	N	Mean Rank	Sum of Ranks
V2_Quiz actions_of_navigation	1	56	58,87	3296,50
	2	48	45,07	2163,50
V3_PDF_actions_of_n avigation	1	56	61,53	3445,50
	2	48	41,97	2014,50
V4_WP_actions	1	56	61,15	3424,50
	2	48	42,41	2035,50
		V2	V3	V4
Mann-Whitney U		987,500	838,500	859,500
Z		-2,328	-3,298	-3,160
Asymp. Sig. (2-tailed)		0,020	0,001	0,002

In order to control confounding effects by statistical analysis (Pourhoseingholi *et al.*, 2012), we use a non parametric correlation test (Spearman) as a statistical model to examine the association between multiple covariates and outcomes. For the experimental group G1, we were able to establish one correlation (Table 2) between the variable V2 the variable V4 (Rho = .364; p <.001). We found two correlations for G2 (Table 3) between the variable V2 and the variable V3 (Rho = .457 p <.001), and between the variable V2 and the variable V4 (Rho = .535 p <.001).

TABLE 2 - Correlation between V2 and V3 and V4 variables in the Experimental group

G1		V3_PDF_actions of navigation	V4_WP_actions
V2_Quiz actions_of_navigation	Correlation Coefficient	0,214	0,364** p <.001
	Sig. (2-tailed)	0,113	0,066
	N	56	56

TABLE 3 - Correlation between V2 and V3 and V4 variables in the Control group

G2		V3_PDF_actions of navigation	V4_WP_actions
V2_Quiz actions_of_navigation	Correlation Coefficient	0,457** p <.001	0,535** p <.001
	Sig. (2-tailed)	0,001	0,000
	N	48	48

The non-normal distributions of our variables does not allow us to go further and perform linear regressions to measure linear relationships between our variables.

6. Discussion

These results show that if the difference in score is not significant between the experimental group and the control group (V1), the means to achieve it can be significantly differentiated. This is illustrated by the number of navigation actions (V2) during the Quiz, between the different questions, where students of the experimental group return more often to the questions they have already answered. Although the number of navigation actions in the documents (V3) is very close between the two groups, while the number of actions performed on the word processor is again higher for the experimental group (V5). But we note that there are absolutely no action of personalization of the interface which were carried out by the experimental group, in spite of the possibility of doing it and the communication of information and help allowing them to do it very quickly, during the activity, $V5 = 0$. This finding contradicts our hypothesis that the interface personalised by the learner during the activity, allows him/her to adjust all the actions carried out on the interface to answer the Quiz. These results also contradict those obtained since a study aimed to compare the relative effectiveness of animation- and static picture-based multimedia instruction in invisible infinitesimal phenomena (Yand et al., 2018). We suggest that the instrumental conflicts that students have to deal with from the interface, are tasks of such importance that they leave no room for additional interface customisation activity. The extra activity of the experimental group in terms of actions carried out on the interface in the different modules (Word processor, PDF, Quiz) with no significant difference in the average score obtained in the Quiz, is in line with the results of studies already conducted on the impact of the interface on the cognitive load from the point of view of navigability (Chevallier et al., 2004), where the "ergonomic" version of the same website requires a greater cognitive load than a standard version and often leads to disorientation (Demirbilek, 2004; Xiong, 2017 ; Bayazit et al., 2018; Bhatti et al., 2020). The achievement of a higher average number of navigation actions in the Quiz and of the average number of actions on the word processor for the experimental group, as well as the correlations established between the variables $V2_Quiz_actions_of_navigation$ and $V4_WP_actions$, for each group, suggest the effect of the instrumental conflicts staged from the graphic interface of the learning environment, with more activity observed on adaptable interfaces than on adapted interfaces, and this, even without any customisation action of the adaptable graphic interface.

7. Conclusion

In this study, we evaluate the impact of the interface customisation of the ILE by the learners

on the cognitive load. Results reveal that instrumental conflicts increase the cognitive load of the experimental group that had the possibility to customise the interface of the ILE. It can be measured by the increasing number of actions on the interface to perform the Quiz with no significant scores differences between the control group and the experimental group. But they also suggest that these instrumental conflicts are so pervasive that all the students in the experimental group refrain from using any interface customization action during the learning and completion phases of the Quiz, even though they have been prompted and documented to do so with only 2 mouse clicks. However, the limitation of our study is that it only uses desktop computers. Further studies could be based on mobile terminals using an adaptable and *ad hoc* developed ILE.

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