To Use or Not to Use Tools in Interactive Learning Environments: A Question of Self-Efficacy?

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Abstract

This study attempted to optimize tool use in interactive learning environments (ILE's) by investigating the impact of tool presentation (embedded vs. non-embedded), the explanation of tool functionality and self-efficacy on tool use. This paper also investigated the effects of tool use and self-efficacy on performance. Moreover, tool use was studied quantitatively (frequency and time spent on tool) and qualitatively (correctness of answers in adjunct questions). One hundred and forty students were confronted to a hypertext and randomly distributed over four conditions: Embedded and non-embedded with explained functionality; and embedded and non-embedded with non-explained functionality. Results revealed that in the embedded conditions tools were used more quantitatively, but quality of use was higher in non-embedded conditions. A slight effect of explained functionality was found. Self-efficacy had a negative effect on quantity of tool use. Only quantity of tool use along with self-efficacy influenced performance significantly. Theoretical implications are discussed.

1. Introduction

Interactive Learning Environments (ILE's) are intended to support learner knowledge construction [1] through the use of different types of (learning) tools which can be informative, cognitive or scaffold [2]. The different kind of tools provide distinct learning opportunities. Informative tools, for instance, give information to be learned or used in face of an assignment or problem (e.g., dictionaries); cognitive tools extend enhance or augment thinking (e.g., adjunct questions, concept maps) and scaffold tools guide learning efforts (e.g., study guides, guiding questions) [2]. Unfortunately, evidence suggests that providing tools does not necessarily result in learning gains as learners tend to avoid the use of tools and when they use the tools, the usage is suboptimal [3-5]. Research has pointed out that the problematic of tool use can be attributed to two main factors [4, 5]. One of them relates to characteristics of the tools. The other factor is linked to characteristics of the learners.

2. Tool characteristics

Relevant tool characteristics are tool presentation and tool interventions. Tool presentation refers to whether the use of tools is optional or obligatory for the learners [6]also known as non-embedded or embedded tools[5]. Tools are non-embedded when learners have the choice and decide themselves whether or not to use tools and they are embedded when learners have no choice but to use the tools [5].With this in mind, one would assume that by increasing learner control thus by not embedding tools, the probabilities of using tools would increase. However, empirical studies have often falsified this claim. For example, in the study of Greene and Land's [7] learners were provided embedded scaffold tools, namely guiding questions. The results indicated that learners tended to omit questions and/or give superficial answers. In a more recent research, it was revealed that learners with embedded tools use tools more than those with non-embedded tools, but learners with non-embedded tools used tools more qualitatively [8]. Thus, evidence seems unclear on what path to take regarding tool presentation. As a consequence in ILE's, tool interventions have been implemented. Tool interventions aim at increasing tool use probabilities without 'forcing' the learner, making the tool functionality more discernible and encouraging the use of tools more adequately [9]. These interventions have been addressed in literature as instructional cues [10], advice[11] or pedagogical agents [12] among others. They either provide guidance during a learning task [12], encourage the use of tools that provide information that the learner has not accessed [10] or strictly specify the functionality of the tools as the benefits that can be obtained by using the tool(s) [11]. While evidence points out their positive effects on tool use [12] mixed effects have also been revealed [11].

3. Learner characteristics

Literature has pointed out that independent of the characteristics of the tools and the different kinds of characteristics learners possess (cognitive or metacognitive characteristics), if they are not motivated the tool usage tends to fail [3]. Therefore, motivation seems to be a crucial learner characteristic that would lead to (optimal) tool use. Given that the nature of the motivation is broad, different associated constructs exploring different motivational aspects have been identified [13], such as self-efficacy. Self-efficacy is considered a key element of the social cognitive theory [14]. It is defined as the thoughts and beliefs about one's capabilities to organize or perform activities to produce a given achievement [15]. Evidence [e.g. 16] has revealed that there is a positive relationship between self-efficacy and frequency of tool use, also known as quantity of tool use. This positive relationship has been extended to time spent on the tool (another aspect of quantity of tool use) [17]. However, research suggests that that high levels of self-efficacy also seem to be negatively related to quality of tool use [17]. Therefore it is important to clarify the effects self-efficacy can have on tool use. Furthermore, literature has implied that self-efficacy is also crucial in the relation to learning outcomes (performance) [18] as it predicts performance [18]. Therefore, the impact of self-efficacy should be investigated both in relation to tool use and performance.

4. The present study

Given the mixed results regarding tool and learner characteristics on tool use, this study aims at gaining more insight into the effects of tool presentation (embedded vs. non-embedded tool), tool interventions (explanation of tool functionality vs. no explanation of tool functionality), and self-efficacy on tool use. Moreover based on the theoretical framework, tool use will be explored in two different ways: quantitatively (time spent on tool and frequency of tool use) and qualitatively. Finally the effects of tool use and the influence of self-efficacy on performance will be analyzed. The following questions are then addressed:

1. What is the effect of tool presentation (non-/embedded) on quantity and quality of tool use?
2. Does non-/explained tool functionality influence quantity and quality of tool use?
3. How does self-efficacy affect quantity and quality of tool use?
4. Do tool use and self-efficacy affect performance?

5. Method

5.1 Participants and Design

There were a total of 140 university students. In average they were 18 years old (*SD* = 2.59) and the majority were female (94.3%). This was a quasi-experimental pre- post-test study with a 2 (non-/embedded tool) × 2 (non-/ explained of tool functionality) design (Table 1). Based on the design of the study, participants in the study were randomly and equally assigned to one of four conditions (35 participants per condition).

Table 1. 2x2 design for present study and conditions. Boxes in darker shade were the conditions.

	Tool presentation	
Tool intervention	Embedded	Non-embedded
Explained tool functionality	Embedded, explained	Non-embedded, explained
Non-explained tool functionality	Embedded, non-explained	Non-embedded, non-explained

5.2 Instruments

5.2.1 Interactive Learning Environment. The ILE had two introductory pages. In the first page, the participants had to write down their name. In the second page there were the instructions and the conditions with the explanation on the functionality of the tool, had the explained tool functionality (Figure 1). The explanation read as follows: "Each question will explore a part of your knowledge. If you answer each of the questions, you will be able to find a clearer connection between the topic of the text and everyday life situations. By establishing this link, your knowledge will become more meaningful. If your knowledge is more meaningful, you will have more sources to answer the post-test in a more effective way." After the second page, there was a hypertext titled: *Waarom water broodnodig is* (Why water is essential) which comprised 1,544 words and was divided into five paragraphs. After each paragraph, in the embedded conditions, the tool was automatically attached (Figure 2) making a total of five tools, namely adjunct questions. In the non-embedded conditions, after each paragraph, learners had the option to access the tool by clicking on a button located in the upper right of the screen (Figure 3).

As aforementioned, the tools were five adjunct questions which are considered a cognitive tool. Adjunct questions were chosen based on the attention they have received on studies on tool use in hypertexts [19], also because they aim to influence what it is learned from a text [19]. Moreover, research has indicated that adjunct questions enhance text comprehension by helping learners attend and focus on specific relevant portions of the text [20].

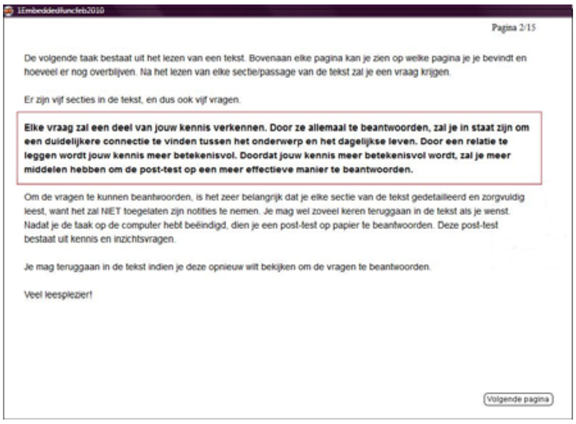

Figure 1. Second introductory page with explained functionality. Explained tool functionality is in the square box. Conditions with non-explained functionality did not have any detail from the explained functionality in box.

5.2.2. Self-efficacy. This was an eight-question questionnaire that learners had to respond in a six-point Likert scale (1= totally disagree 6= totally agree). This questionnaire was a Dutch adaptation that has been previously used in other studies [17] with Cronbach α reliabilities above .80. The reliability obtained in this study was α = .89.

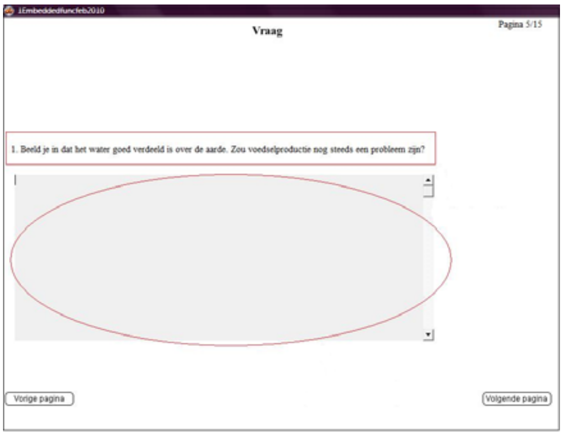

Figure 2. Screenshot of tool. Embedded conditions had access to this screen right after a section from the text. The adjunct question is in the square box. Students were supposed to respond in the darkened circled area. The non-embedded conditions had the option to access it as shown in Figure 3.

5.2.3 Pre- and post-test. To see if learners differed in their prior knowledge among conditions, a pre-test was conducted. It consisted of nine multiple-choice questions (with four choices each) and each correct answer was worth one point. Learners could obtain maximum nine points. The nine pre-test questions explored learners' factual knowledge related to the topic of the hypertext.

To measure performance, a post-test was conducted. This consisted of four multiple-choice questions (with four choices each), three fill-in the blanks questions, one question where learners should pick three out of six correct statements and three open questions. All correct answers were worth a point, except for the open questions. In the open questions, learners could obtain from zero to two points (zero points for no rationale or no answer, one point for a weak rationale answer or two points for a deep rationale answer). Thus, learners could obtain a maximum of 16 points in the post-test. The open questions were revised by three different raters (one of them author of this paper) and the inter-rater reliability for the scoring procedure of the open questions was found to be outstanding (ICC= .97, p <.001).

Both pre- and post-tests were designed by three different researchers, authors of this paper, two of which had experienced in the design of this type of materials. Consequently, the design of the pre- and post-test followed similar criteria used in previous studies [8].

Figure 3. Screenshot of non-embedded condition. In the square box, learners could click and access the tool. The Embedded conditions did not have this option. They accessed the tool right after the text.

5.2.4 Quantity and quality of tool use. Tool use was analyzed through log and text files. For quantity of tool use, frequency of tool use (clicks made by learners into the tool in non-embedded conditions only) and time spent on the tool (in seconds, all conditions) were kept in an individual log file per learner. For quality of tool use, the correctness of the answers on the tool: adjunct questions were individually logged as text files and later analyzed. Participants could obtain from zero to three points per answer on each adjunct question. Zero indicated no answer, or a superficial answer without any rationale. Three reflected a high rationale and well thoroughly provided answer. Participants could obtain a maximum of 15 points. Their answers were scored by the same raters from the open question in the post-test. The intraclass correlation for grading the adjunct questions showed outstanding agreement among the three raters (*ICC*= .99, p <.001).

6. Procedure

The study was divided in two sessions. In the first session, the questionnaire of self-efficacy was administered to all participants at the same time in one of their classes of Learning and Instruction. Afterwards participants got enrolled for the second session by means of an electronic learning platform. In the second session, participants attended by groups of maximum 20. First they were given the instructions, next they answered the pre-test, after they were confronted to the hypertext. Once they finished reading the hypertext, they were given the post-tests.

For the data analyses, we conducted descriptive statistics with each condition and the quantity and quality of tool. Next, to possibly observe differences among conditions, a MANOVA was run with condition as independent variable and self-efficacy and the pre-test (prior knowledge), as dependent variables. If groups were not equal, then these variables were to be considered covariates in the further analyses.

To answer question 1 and 2, hence to see effect of tool presentation and tool intervention on tool use, a second MANOVA was conducted with same independent variable (condition) and quantity of tool use (time) and quality of tool use as dependent variables. An ANOVA was conducted, to answer the same questions 1 and 2 but in relation to frequency of tool use (quantity) which was only in the non-embedded condition. Non-embedded conditions were the independent variable and quantity of tool use (frequency) the dependent variable.

For the effects of self-efficacy on tool use (third question), we conducted regression analyses with self-efficacy as independent variable and quantity and quality of tool use as dependent variables.

Finally to see the effects of self-efficacy and tool use on performance, thus answer the last question, regressions were also conducted. One regression was done with self-efficacy and quantity (time) and quality of tool use as independent variables and performance as dependent variable, another regression was done only with frequency as independent variable.

7. Results

The first MANOVA analysis pointed out that using Wilks's statistics there was no difference in self-efficacy nor prior knowledge among conditions λ=.94, F (6,270)=1.47, p=.19, η_p^2 = .03. The separate ANOVA's confirmed this finding: prior knowledge F (3,136)=1.87, p=.14, η_p^2 = .04 and self-efficacy F (3,136)=1.08, p=.36, η_p^2 = .02. Therefore, neither prior knowledge nor self-efficacy were considered as covariates in further analysis.

7.1 Research question 1 & 2: What is the effect of tool presentation (non-/embedded) on quantity and quality of tool use? Does non-/explained tool functionality influence quantity and quality of tool use?

Descriptive statistics illustrated in Table 2 show that all students in all conditions used the tools as well as the differences among conditions.

Table 2. Descriptive statistics with every condition and quantity and quality of tool use. Only frequency of tool use is reported in the non-embedded conditions due to the fact that in these conditions the tool access was optional.

Condition	Tool use	*N*	Mean	*SD*
Embedded, explained	Quality (max. 16 points)	34*	9.12	2.17
	Quantity: Time (seconds)	35	793.03	370.85
Embedded, non-explained	Quality (max. 16 points)	35	8.43	1.82
	Quantity: Time (seconds)	35	583.31	235.23
Non-embedded, explained	Quality (max. 16 points)	35	9.77	2.30
	Quantity: Time (seconds)	35	402.17	143.04
	Quantity: Frequency (clicks)	35	16.77	9.38
Non-embedded, non-explained	Quality (max. 16 points)	35	9.94	1.51
	Quantity: Time (seconds)	35	398.11	175.95
	Quantity: Frequency (clicks)	35	18.09	10.77

* Data from one participant was lost

The MANOVA confirmed the differences among conditions found in the descriptive statistics. Using Wilks's statistics, there was a significant effect of condition on quality and quantity of tool use (time spent on tool) λ=.63, F (6,268)=11.73, p<0.001, η_p^2 = .21. The separate ANOVA's on the outcome variables confirmed this significance, quality tool use F(3,135)= 4.27, p<.01, η_p^2=.09 and quantity F (3,135)= 19.98, p<.001, η_p^2=.31. The pos hoc Tukey analyses revealed that the embedded condition with explained functionality and with non-explained functionality spent more time on tools than both non-embedded conditions (p<.001, p<.01, respectively). Additionally, both non-embedded conditions with explained functionality and with non-explained functionality used tools more qualitatively (answer questions more thoroughly) than the embedded condition with non-explained functionality (p<.05, p<.01, respectively). This effect, however, could not be observed in relation to the embedded condition with explained functionality.

The descriptive statistics (table 2) show that in the non-embedded conditions, participants accessed tools more frequently in the conditions with non-explained functionality (*M*=18.09) than the ones with explained functionality (*M*= 16.77). However, the ANOVA showed no significant effects regarding condition effects on frequency of tool use $F(1,68)=.30$ $p= .58$ $\eta_p^2=.004$.

7.2 Research question 3: How does self-efficacy affect quantity and quality of tool use?

The regression analyses illustrated in Table 3 show that self-efficacy did not significantly influence quality and quantity of tool use, more specifically time spent on tool. An effect of self-efficacy was found in the non-embedded conditions where high levels of self-efficacy had an impact on the frequency of tool use, that is the clicks made to access the tool.

Table 3. Regression analyses. Self-efficacy on tool use.

Embedded conditions					
	Quantity tool use (time)				
	B	**SE B**	**β**	***t***	***p***
(Constant)	465.66	146.12			
Self-efficacy	22.300	40.910	.05	.55	.59
	Quality of tool use				
	B	**SE B**	**β**	***t***	***p***
(Constant)	8.87	1.02			
Self-efficacy	.13	.29	.04	.44	.66
Non-embedded conditions					
	Quantity of tool use (frequency)				
	B	**SE B**	**β**	***t***	***p***
(Constant)	33.05	6.98			
Self-efficacy	-3.78	1.95	-.16	-1.94	.05*

* significant at .05 level

The impact that self-efficacy had on frequency of tool use was, however, negative. The higher the levels of self-efficacy, the less the learners accessed the tools. This effect can be observed in Figure 4.

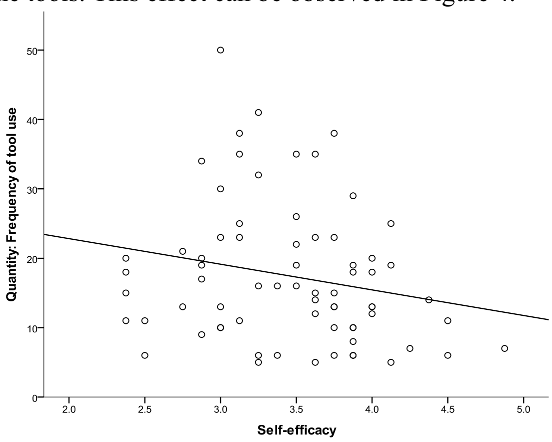

Figure 4. Self-efficacy significant effect frequency of tool use.

7.3 Research question 4: Do tool use and self-efficacy affect performance?

The regression analyses showed that unexpectedly, neither quality of tool use nor frequency affected performance. Only the time spent on tools and self-efficacy influenced performance significantly (Table 4).

Table 4. Regression analyses. Tool use and self-efficacy on performance

All conditions					
	Performance				
	B	**SE B**	**β**	***t***	***p***
(Constant)	9.23	.85			
Quantity (time on tools)	.00	.00	.18	2.28	.02*
Quality tool use	.13	.08	.13	1.69	.09
Self-efficacy	1.00	.26	.31	3.92	.00**
Non-embedded conditions					
	Performance				
	B	**SE B**	**β**	***t***	***p***
(Constant)	11.66	.50			
Quantity (frequency)	-.02	.02	-.08	-.64	.52

* significant at .05 level ** significant at .001 level

Even more surprising was that self-efficacy accounted for 9.61% of the variation in performance more than the time spent on tool use which accounted for 3.24%. This means that the relationship between self-efficacy and performance is stronger than that of time spent of the tools (Figures 5 & 6).

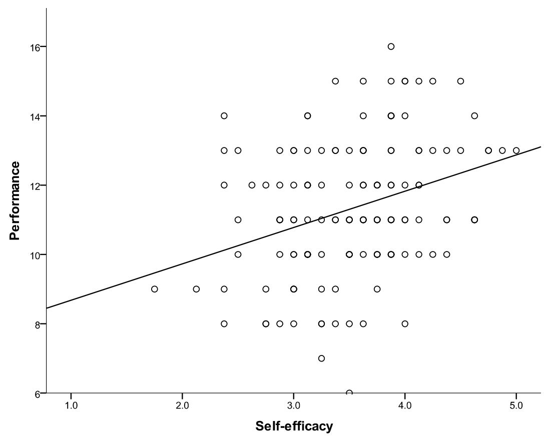

Figure 5. Effects of self-efficacy on performance.

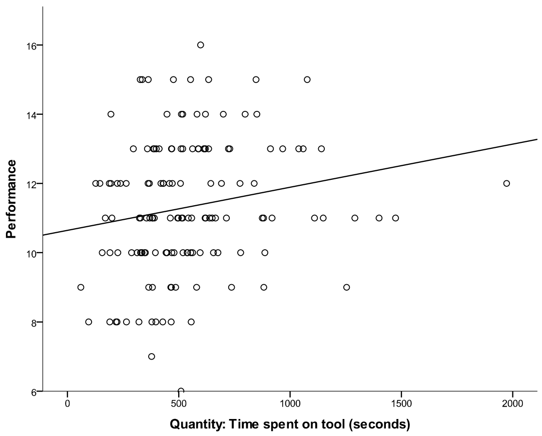

Figure 6. Effects of time spent on tool on performance.

8. Discussion

This paper aimed at gaining more insight into learners' quantitative and qualitative use of tools by exploring the impact of tool presentation (non-/embeddedness), tool intervention (non-/explained of tool functionality) and a motivational learner characteristic (self-efficacy) on performance. Some learners had to answer the questions (embedded conditions) whereas others could choose whether to use the questions or not (non-embedded conditions). Within these conditions the explained tool functionality was added in two of the four conditions (one embedded and one non-embedded condition).

One of the results from this study is that learners in the embedded conditions spent proportionally more time on the tools than the learners in the non-embedded conditions. Additionally, the non-embedded conditions used tools more qualitatively than the embedded conditions. However, based on the Tukey pos hoc analyses, it was also found the quality of tool use was only better than the embedded condition with non-explained functionality. This effect could not be retrieved in the embedded condition with explained functionality. This finding suggests that the condition influenced quantity and quality of tool use. This result is also similar to previous research [8, 17] where participants in the embedded conditions also used tools more, but the conditions that were non-embedded had better quality of tool use. However, based on our results it is still not clear whether or not to embed tools. On the one hand, embedding tools can encourage more time on the tool(s). On the other hand, non-embedding tools can guarantee more quality of tool use. However, if we observe the results on what aspects of tool use influenced performance, in this case, time spent on tool. Then we could suggest that embedding the tool may be in the end the best solution.

No concrete results with respect to the explanation of the tool functionality could be retrieved, however, a slight effect could be observed in relation to quality of tool use. The pos hoc analysis revealed that the non-embedded conditions (with explained and non-explained functionality) used tools more qualitatively than the embedded condition with non-explained functionality. This effect could not be observed in the embedded condition with explained functionality. Hence, the explanation of the tool functionality probably played a significant positive role in relation to quality of tool use. This possible effect, however, could be overpowered by the presentation of the tools (embedded vs. non-embedded). It is possible that the explanation of the tool functionality did not have a strong impact on tool use due to the nature of the explanation. That means, the explanation was only presented once in all the hypertext. Perhaps, adding the explanation more than once or before the learner could access the tool could have stronger effects.

Effects of the different non-embedded conditions could not be retrieved in relation to frequency of tool use. The non-embedded condition without explained functionality accessed tools more frequently, in comparison with the non-embedded conditions with explained functionality which reported fewer clicks to access the tools. Even though these effects were not significant, they may be to a certain extent related to the finding regarding self-efficacy.

Self-efficacy had a negative influence on the frequency of tool use in both non-embedded conditions. That means that the higher the self-efficacy the fewer the learners accessed the tools. Possibly the non-embedded conditions interacted with self-efficacy levels in learners. The higher the self-efficacy the lower the tool use access. This effect contradicts previous findings where the frequency of tool use was positively correlated to self-efficacy [16]. However, unlike Waldman [16], who studied tool use by means of a survey, our study explored the use of tools in an experimental setting. Additionally, self-efficacy is related to the belief of one's ability to plan/execute a behavior [14]. Thus, if one believes they have a great ability to organize and execute the course of actions required to succeed and reach a certain goal then one is capable of adapting their use of tools. This adaptation of tool use could be reflected in the frequency of tool use by the learners in our study. They probably adapted their use of tools and instead of accessing the tool 'too' often, they rather spent more time on it which leads us to our next result.

Neither quantity (frequency) nor quality of tool use influenced performance. Only quantity of tool use (time spent on tool) showed a significant effect on performance. Added to this was the effect of self-efficacy which also impacted performance. These findings not only add to literature but also raise questions in relation to research on tool use in ILE's. First our results contradict other findings in which a positive relationship was also found between tool use (quantity and quality) and performance [8]. Second, these results raise a question that goes in line with Perkins's condition (1985) which suggests that if the tool is there, it should be functional. The tool provided in this study was probably not entirely beneficial nor effective for the learning process [21]. Third, these findings also raise a question on whether the time spent on the tool may be indirectly related to the quality of tool use. The time spent on the tool – adjunct question- could also be an indicator of quality of tool use as learners could spend more time thinking on the question than actually writing down a detailed and comprehensive answer. Fourth, even though we aimed to ensure the relevance of the adjunct questions, it is possible that the relationships between the adjunct question and the questions in the post-test were a cause of our results [20].

With respect to the result on self-efficacy, it seems that self-efficacy not only influenced performance but the self-efficacy effects were stronger than quantity of tool use, as they explained more variance. This finding adds to the literature on self-efficacy and its power to predict performance [18]. They also bring to light the question on whether presenting the tools in different ways (non-/embedded) or influencing tool use by means of interventions (explained functionality) is beneficial for learners that are self-efficacious. However, we are far from disentangling the complexity of tool use in ILE's. Therefore further studies could not only give a deeper insight on the role of self-efficacy in ILE's but also on whether or not to embed tools, on the design of an 'effective' explanation of the tool functionality as when and how often the explanation should be provided. Additionally, methodologically speaking, as in previous studies [11] adding a control condition–a condition without tools nor explanation- could provide deeper insight on the effects of tool presentation and explanation of tool functionality on the use of tools as this could provide a baseline for the analyses.

9. Conclusion

Our results reconfirm that embedding tools may increase the time spent on tools and consequently have a positive influence performance, but non-embedding tools may lead to superficial tool use (low quality) which could possibly affect learners' performance. Although in our study the effects of quality of tool use on performance could not be retrieved, previous studies [8] have suggested that there is a relationship between quality of tool use and performance. This paper also provides evidence that tool interventions such as the explanation of the tool functionality may play a role in ILE's. Finally, this research also sheds light to the study of self-efficacy on tool use. The importance of self-efficacy in ILE's is emphasized as effects of self-efficacy on tool use were not only retrieved but also direct effects of self-efficacy on performance. Overall, these results reveal that tool presentation and self-efficacy may affect the quantity and quality of tool use and that quantity of tool use and self-efficacy impact performance.

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