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The complexity of tool use in computer-based learning environments

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Abstract Starting from Perkins' (1985) framework, this study addresses tool use in a computerbased learning environment. In line with Perkins, first the effects of tool use on performance were investigated to gain insight into the functionality of the tools. Next, the influence of advice was studied to identify whether this advice could make students more knowledgeable with respect to the tools, and hence encourage them to make more (adequate) use of the tools. A third research question addressed learner related variables. The influence of metacognitive skills, goal orientation, and instructional conceptions on students' tool use was investigated. An experimental design was used to address these research questions with one control group and two experimental groups, one with advice and one without advice. Results reveal that the tools were functional, the two experimental groups outperformed the control group. With respect to advice, the group of students receiving advice used tools more frequently and spent more time on their use. Finally, the study reveals mastery orientation to be an important variable. The more students are mastery oriented, the less they use tools.

Keywords Learning opportunities · Instructional design · Advice · Computer-based learning environment · Learner characteristics

Already in 1985 Perkins pointed out that students do not always grasp opportunities offered in learning environments. While initially Perkins mainly referred to opportunities presented by information-processing technologies, research since then has clearly shown this is also the case for a wide set of different types of instructional interventions (e.g., adjunct aids in texts: Greene and Land 2000; student counseling at universities: Newman and Goldin 1990; Ryan et al. 1998). With the advent of more open learning environments the problem of students not grasping learning opportunities becomes even more apparent. These open learning environments typically allow for ample learner control and contain a

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large and divergent set of support tools (Hannafin et al. 1994). If students do not use the tools (adequately), they restrain themselves from learning support, since each of these tools presents an opportunity to receive support in their learning process. In line with Perkins (1985), research indeed reveals that instructional interventions, and in particular tools, are seldom used, and if used often in an inadequate way, or at least not as intended by the designers (Aleven et al. 2003; Clarebout and Elen 2006). While various explanations have been provided, researchers seem to agree that learners are not always capable of making adequate decisions with respect to their own learning processes (Clark 1990; Hill and Hannafin 2001; Land 2000). It may be that they do not recognize the opportunities, do not know how to handle the opportunities, or are not motivated to use them (appropriately).

Perkins (1985) indicates that three conditions have to be met to increase the probability that opportunities are taken, or in this case that tools will be (adequately) used, namely (1) the opportunity is there; (2) the opportunity is recognized by the learners, and (3) learners are motivated.

(1) The opportunity is there: this means that the tools provided are indeed functional to students' learning process. Clark and Estes (2002) for instance, indicate that different kinds of support made available to students are not always effective or beneficial for students' learning processes. In order for tools to be beneficial they need at least to be functional for the learning process. In case of doubts about the functionally of the tool, the lack of (adequate) use can hardly be regarded as a problem (Elen and Clarebout 2006).
(2) Learners recognize the opportunity: the tools provided to the learners are indeed recognized by the learners as functional. This implies that students are knowledgeable with respect to the relation between the tools and their learning, and know how to handle the tools to foster their learning (Elen et al. 1996). This knowledgeability entails students' self-regulating skills as well as adequate instructional conceptions. These conceptions refer to students' ideas about instruction in general or to their ideas about specific instructional interventions, for instance conceptions on the tools' functionalities (Lowyck et al. 2004). The probability that students will (adequately) use the tools increases when their instructional conceptions and the specific function of the tools are calibrated. Problems may occur, for instance, when students misinterpret the intentions behind the instructional tools (Winne 1985, 2004). However, recognizing opportunities, does not only relate to recognizing a tool's functionality, it also relates to knowing when using a tool would be beneficial for one's own learning process. In other words, it also relates to a student's self-regulating skills, to the extent a student is capable of monitoring and regulating his/her learning process (Clark 1990).
(3) Learners are sufficiently motivated to use the tools: In line with the self-efficacy theory of Bandura (1977), it can be expected that tools will only be used when learners are willing to invest effort in the task. Added to this, Ryan et al. (2001), as well as Newman (1998) found that a mastery goal orientation increases the probability of requesting help, whereas a performance goal orientation seems to be linked to asking for the right answer. Since, using tools can be seen as a form of help seeking, it is hypothesized that tool use will be influenced by students' goal orientation.

These three conditions reveal the complexity involved in tool use. Not only the design of the tool matters, also different learner related variables such as goal orientation and prior knowledge (see for instance, Clarebout and Elen 2006) play a role.

Additionally, some evidence has been found that tool use may be influenced by specific instructional interventions. For instance, some evidence has been found that training may affect tool use. Gräsel et al. (2001), found that students receiving strategy training made more adequate use of additional information (a glossary), a diagnostic help tool and a database than students who did not receive strategy training. Relan (1995) on the other hand, found that trained students used the available tools more before practice than during practice, in contrast to the students who did not receive training. In other words, the trained students used the tools less adequately than the other students. Carrier et al. (1986) found that when adding an encouragement to perform another exercise, students selected this additional exercise more than when not offered an encouragement. This encouragement was given when students were asked by the system whether they wanted an additional practice item, stating that more practice may help the student's learning. Similarly, Lee and Lehman (1993), provided students with an instructional cue when they wanted to progress in the program, but had not yet accessed all information. They found a positive effect for the instructional cues, but only for learners with a 'regularly active' learning style, not for students who had a passive or active learning style.

In this contribution the influence of advice is further investigated since it seems that this may encourage students to use tools. Starting from Perkins' (1985) framework, the influence of advice is studied as a mean to inform students about the functionalities of the different tools. Providing advice on tool use may help in making students knowledgeable about the tools (see issue 2). In other words, it is hypothesized that this advice helps learners to recognize the opportunity offered by this tool, and hence that learners will use more frequently tools. Additionally some learner related variables are studied: students' goal orientation (in line with Ryan et al. 2001), instructional conceptions (in line with Winne 1985), and self regulating skills (in line with Clark 1990).

Consequently, the following research questions are addressed:

(a) Do tools contribute to students' learning performance?
(b) Does providing advice on tools increases tool use?
(c) Do students' metacognitive skills, goal orientation and instructional conceptions influence tool use?

Method

Participants

Two hundred and sixteen first year educational sciences bachelor students participated. Students received two credit points for a course on learning and instruction. On average students were 19 years old. The large majority of the population was female (97%).

Instruments

Learning environment

A text[1] on obesity was selected and adapted for a macromedia Director program. Three program versions were built. In all versions different computer screens offered the same

[1] Nederkoorn et al. (2006).

text. This text formed the basic version that was used by the control group (C group). The same text was used in the two experimental versions. In the experimental versions different tools were included in the environment, namely a dictionary, instructional goals, example questions, and help with interpreting figures and text. Additionally, in one experimental version students received advice on the different tools and what the tools' functions were (TA group) before seeing the actual text. For instance, for the 'goal-tool' an advice reads as: "*By clicking on this tool you receive an explanation of the goals that you should achieve by reading this text. By reading these goals you will be able to gain more insight in what is expected from you*". This was not the case for the other experimental version (T group). In Fig. 1a, b two screen dumps are presented; one of the T group and one of the C group.

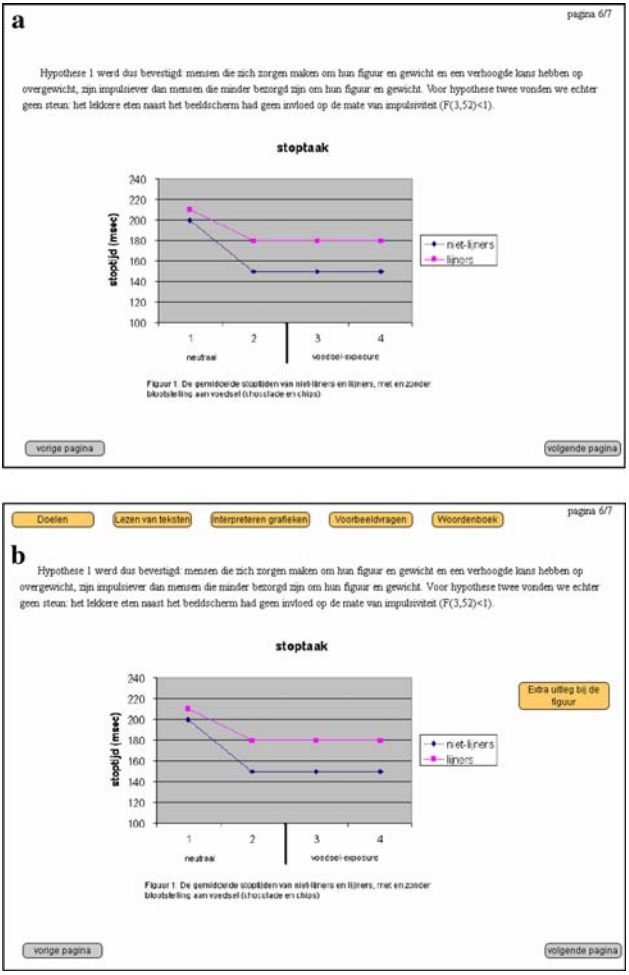

Fig. 1 (**a**) Screen dump of the C-group. (**b**) Screen dump of the T-group

Knowledge test

Based on the text a pre and post knowledge test were constructed. These knowledge tests consisted of factual questions, insight questions and transfer questions.

Metacognitive variables

A widely used existing instrument, namely part of the Learning Style Inventory of Vermunt (1992) was used to measure students' regulation skills. Given low reliabilities in previous studies for the external and no regulation scale, only items measuring students' self-regulation activities were included (Clarebout and Elen 2008). The instructional conceptions, or more precisely, students' conceived functionalities of tools were measured through the ICON-questionnaire (Clarebout et al. 2004). For both instruments, students answered each item on a six point Likert-type scale from 1 equaling 'totally disagree' to 6 equaling, 'totally agree'.

Motivation

Students' task versus performance orientation was measured through a Dutch version of Elliot's instrument (Elliot 1999). Similar to the metacognitive scales, also here a 6 point Likert type scale was used from 1 equaling 'totally disagree' to 6 equaling, 'totally agree'.

Log files

To keep track of students' tool use, log files were kept of all students' activities performed on the computer. Log files allowed registering the frequency of tool use and time students' spent on the tools.

Procedure

During the first session of the course 'Learning and Instruction', students filled out the questionnaire with the metacognitive and motivational items. They were asked to register for a session in the computer room. Students were randomly assigned to one of the three conditions (C-group, T-group, or TA-group). During the 'computer' session, students (20 at a time), entered the room and were given a short computer-based text on obesity.[2] This text was given to make sure students' prior knowledge about the subject was standardized as much as possible. All students were instructed to carefully read the text because a test containing knowledge, insight and transfer questions would be administered. They got 10 min to read the text. An intermediate task (making a drawing) was offered before the test was given. After completing the test, the actual text was presented. They got 20 min to read the text. Again an intermediate task was given before the test was handed out.

For data analysis, first reliabilities for the different scales measuring learner related variables were checked, second some descriptive statistics were calculated to get an idea of how students are positioned on the different scales, and third, a check was performed on the equality of the different groups on metacognition, instructional conceptions, goal

[2] Frankrijk bindt strijd aan tegen obesitas. Zwaarlijvigheid is geen Frans taboe meer. [France fights obesity: Corpulence is no longer a French taboo]: (2006, January 27). *De Morgen*.

orientation and prior knowledge. For the pre- and post-test students received a point for each correct answer. If the groups differed on these variables, these variables would be included as co-variates in further analyses. Next, an ANOVA was performed with the different groups as independent variables and learning results as dependent variable. This allowed answering the first research question. For the second research question, only the two experimental groups were compared. First the correlation between time spent on tools and frequency of tool use were checked. Time spent on tools refers to the time spent on tools relative to the total amount of time spent on working with the program. The frequency of tool use was measured through every click students made to access a tool. Depending on the correlation an ANOVA or MANOVA would be performed with frequency and time spent on tools as dependent variables and experimental condition as independent variable.

For the third research question, the two experimental groups were analyzed separately in order to gain more insight into the relations between the variables for each group separately, without averaging for the advice conditions. First a Pearson correlation coefficient was calculated between the different learner related variables, and the frequency and time spent on tools. Next regression analyses were performed with frequency and time spent on tools as dependent variables and the learner related variables correlating significantly with these dependent variables, as independent variables.

Results

Reliabilities of the different instruments are overall good (Cronbach alpha between .768 and .932). Consequently, the scales are further included in the analyses.

The descriptive statistics are presented in Table 1 The means for the different scales lie between 3.5 and 4.3, indicating that on average—and considering the standard deviations—students are not pronounced on one of the scales (1 = low; 6 = high).

An ANOVA with condition and score on the pre-test reveals no significant differences between the three groups on the pre-test, $F(2, 178) = 2.75$; $p = .08$; $\eta^2 = .03$. Although a non significant effect is found, it is opted to do an ANCOVA for the analysis that also includes the control group, given that the significance level and the effect size indicate that there may be some difference, and that a Waller–Duncan post hoc test reveals that the control group belongs to a separate subset, while the two experimental groups belong to the same subset. With respect to the first research questions, a significant moderate to high effect is found of condition on the post-test score, $F(2, 175) = 6.79$; $p \leq .01$; $\eta^2 = .072$. The results reveal that the two experimental groups outperform ($M_{TA} = .63$; $SD_{TA} = .16$; $M_T = .67$; $SD_T = .16$) the control group ($M_c = .50$, $SD_c = .19$) (see Fig. 2). Consequently, it can be concluded that the tools are functional. They help students to achieve better learning results.

Table 1 Descriptive statistics

	N	Mean	*SD*
Performance orientation	203	3.84	.80
Task orientation	202	4.33	.67
Conceived functionality	201	4.20	.45
Self regulation	202	3.55	.54

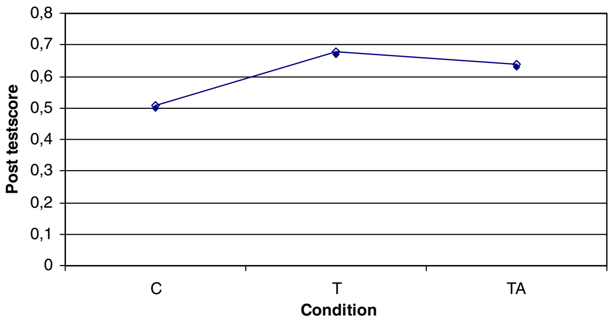

Fig. 2 Differences between conditions on the post test

The Pearson correlation between the frequency of tool use and the time spent on tools is significant ($r = .674; p \leq .05$), hence a MANOVA is performed with the two experimental conditions as independent variable. A significant effect is found of experimental condition, Wilk's $\lambda = .937; F(2, 130) = 4.41; p \leq .01; \eta^2 = .06$. The test of between subjects effects shows that this effect is significant for both dependent variables, i.e. for frequency of tool use, F(1, 132) = 7.61, $p \leq .01$; $\eta^2 = .06$, and time spent on tools, $F(1, 132) = 7.07$, $p \leq .01$; $\eta^2 = .05$. Figure 3a, b illustrate that in both cases students in the advice group use tools more often and spend more time on tools (Frequency: $M_{TA} = 5.68$; $SD_{TA} = 3.91$; $M_T = 3.98$; $SD_T = 3.04$/Time: $M_{TA} = 11.10$; $SD_{TA} = 8.32$; $M_T = 7.73$; $SD_T = 5.70$).

Looking at the means of frequency of use, and knowing that there are six tools available, one can see that not all students consult or look at the different tools. In the TA group students spent 11% of their time on consulting tools, while this is about 8% for the T group.

The third research question addresses the impact of learner related variables. The correlations between the learner related variables and tool use are investigated. This is done separately for the two experimental groups. For the T group, the correlation matrix (Table 2) reveals that only mastery orientation correlates significantly with time spent on tools ($r = -.38$; $p \leq .05$); meaning that all other variables do not correlate with tool use. For the TA group, no significant correlations are found for any of the learner related variables with tool use. Consequently, no further analysis is done for this group.

However, before going into the regression analysis for the T-group, a further look into the correlation matrices is interesting (Table 2). In both groups, students' mastery orientation correlates significantly positive with performance orientation. The more students are mastery oriented, the more they are also performance oriented, and vice versa. In both groups self regulation seems also to correlate significantly with conceived functionality of the tools, meaning that students who are more self regulated conceive tools as more functional for their learning, and vice versa.

Given these correlations it is further investigated through regression analysis whether mastery orientation influences tool use, more specifically time spent on tools. The regression analysis reveals a significant effect ($R^2 = .15$; $\beta = -.384$; $t = -2.528$; $p \leq .05$). This means that—in the absence of advice- the more students are mastery oriented the less time they spend on tool use.

Discussion and conclusion

In this study, Perkins' (1985) basic conditions on grasping learning opportunities were taken as starting points. First, the functionality of tools for students' learning was checked.

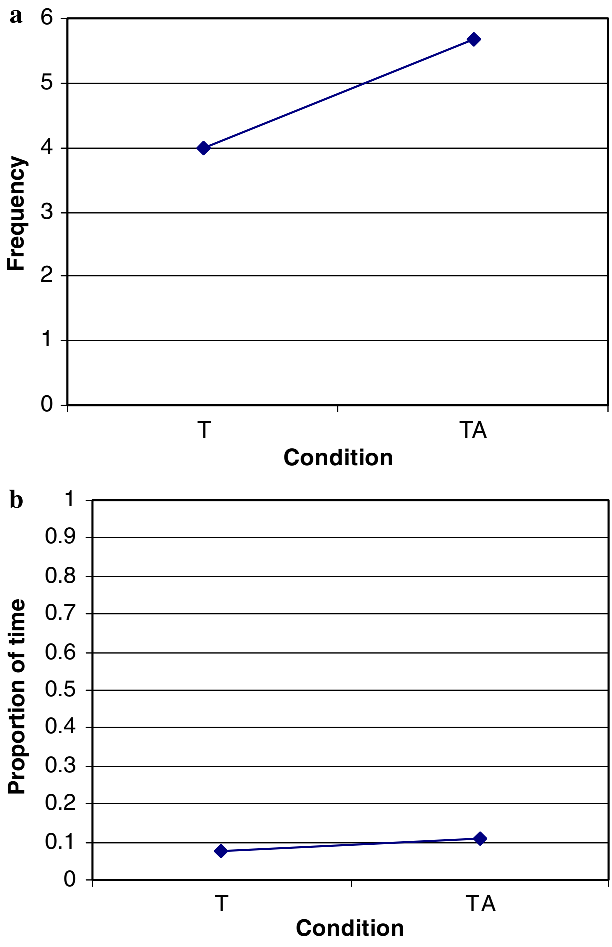

Fig. 3 (**a**) Frequency of tool use. (**b**) Proportion of time spent on tools

Table 2 Pearson correlation matrix

	T-group					TA-group				
	Tool T	SR	PO	MO	IC	Tool T	SR	PO	MO	IC
Tool #	.594**	.217	−.170	−.225	.104	.686**	.081	−.123	−.106	−.141
Tool T	–	.071	−.171	−384*	.049	–	.003	−.123	−.243	−.140
SR	–	–	.121	.397**	.489**	–	–	.401**	.427**	.365**
PO	–	–	–	.411**	.217	–	–	–	.623**	.387**
MO	–	–	–	–	.330**	–	–	–	–	.311**

Tool #, Frequency of tool use; Tool T, time spent on tools; SR, self regulation; PO, performance orientation; MO, mastery orientation; IC, instructional conceptions

* $p < .05$, ** $p < .01$

The analysis revealed that tools were actually functional: the experimental groups outperformed the control group. Given this finding, additional analyses were appropriate.

A first issue addressed was whether an external factor, i.e. advice, contributes to enhance tool use. The results were positive. Students consulted more frequently the tools and spent more time on consulting the tools when they first received advice. One may question, though, whether the advice was sufficiently strong given the rather limited frequency of tool consultation and, given the fact that only a small to moderate effect size was found. Further research is needed to study the design of the advice, including when in the learning process it should be offered. In this study advice was provided prior to accessing the text by mentioning the different functionalities of the tools. Perhaps students need also advice while reading the text. The advice on tool use can be seen as procedural information. Kester (2003) points to the importance of just-in-time information; and that for procedural information this means giving students this information while working on the task and not prior to.

For performance this study reveals no difference between the two experimental groups. Although the advice resulted in more tool use, this increase in use did not result in better learning results. As suggested the advice might not have been strong enough, hence the difference in tool use may not have been large enough to affect performance. It could be possible that a certain threshold has to be reached before using tools affects the learning results, and that the advice provided in this study did not lead students to reaching that threshold.

While some evidence has been found that tool use can be externally enhanced, also learner related variables were looked at. To gain insight in the effect of these variables the two experimental groups were analyzed separately. Interestingly enough, when students did not receive advice, their mastery orientation negatively affected tool use (time spent), while this effect was not found in the TA group. This raises at least two issues. A first one relates to the negative effect of mastery orientation. Students who are more mastery oriented use less tools. This seems to mean that the more students are mastery oriented the less they see using tools as belonging to the task. It may imply that for them mastering the task means completing the task with as less tools as possible. Or it may be that students perceive the task as a performance task rather than a learning task, and hence that this perception interferes with students' mastery orientation. In previous research (Clarebout et al. 2004) it was found that students tend to interpret tasks in a learning environment as performance tasks and see tools as cheating devices, rather than instruments to support or guide their learning process. A second issue pertains to the observation that providing advice mediates the effect of mastery orientation. In this case, this would mean that the advice may have redirected students' perceptions towards viewing the task as a learning task rather than a performance task. The task may then be more calibrated to students' goal orientation. However, further research is needed to determine students' task perceptions and the relation with goal orientation and tool use.

It should be noted however, that Ryan et al. (2001) indicate that mastery orientation increases requesting help, but that they place mastery and performance orientation in an orthogonal relationship. In the study here, a significant high positive correlation was found between performance orientation and mastery orientation in both groups.

While it was expected that the other learner related variables would also influence students' tool use, no effects were found for self regulation skills and students' instructional conceptions. Given the no significant effects for instructional conceptions in other studies using the same instrument for measuring instructional conceptions (Clarebout and Elen 2008; Sarfo and Elen 2008), it can be wondered whether instructional conceptions do really matter. The questions are formulated in a general way, referring to the effectiveness of the tools for learning in general and not the learning of the individual student. Given the generality of these items, they may no longer predict students' individual learning behavior.

With respect to self regulation, previous research revealed mixed results with the influence of self regulation measured by the ILS on tool use (Clarebout and Elen 2008). It may be wondered whether this instrument is actually assessing students' regulation skills (Veenman 2005). It might simply be an instrument to measure students' declarative knowledge about their self regulation skills. Behavioral measures of metacognitive skills would probably have a more predictive value towards learning in general and tool use in specific (e.g. Roll et al. 2005).

On the other hand, the correlation matrix (Table 2) indicated that the different learner related variables correlated differently in the two experimental groups. This may indicate that although these groups may not be differentiated on the scales separately, they may have different profiles that consist of patterns of positions over the different scales. Perhaps future research should focus more on learner profiles rather than separate learner related variables.

A further research program should focus on the relation between mastery orientation, task perception and tool use, it seems that these three variables are intertwined and influence students' tool use. Comparing a group of students that perceives a task as a performance task and a group of students that perceives the task as a learning task would increase insight into the issue of tool use and how this is related to motivation. This would align with research in the field of management information system research. In this field, perceptual variables have been identified as important variables to induce human behavior (Davis et al. 1989). Davis et al.'s Technology Acceptance Model states that a user's behavior in an environment is determined by the user's attitude towards that environment. The user's attitudes are then influenced by the perceived usefulness and the perceived ease of use of a technology-based environment. One could argue that, specified to support devices, learners' perceived usefulness and expectancies will influence learners' intention to use the support device. This will increase the probability of actual using the support device and the mental effort invested to process the information from the support device, hence resulting in better learning. In a second step, if student motivation and perception indeed plays a role, one could investigate how student motivation can be increased. The research of Kim and Keller (2008), for instance, could be inspiring. They studied the effects of motivational and volitional e-messages on students' motivation and achievement.

However, to gain insight in students' task perception, questionnaires may not be the most adequate measurement method. Additional data gathering methods seems to be needed such as interviews or even a thinking aloud method. This may also perhaps resolve issues mentioned above with respect to the measurement of, for instance, self regulation. In a second phase, the design of the advice could be studied, more specifically on which aspect this advice could focus: mastery orientation, functionality of tools, etc., and when the advice should be delivered. Additionally, a more diverse group of participants should be used to gain insight into the role of learner related variables or learner profiles.

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