The Effects of New Technology on Learning
Learning On Screen versus on Paper: Which Media Enables More Effective Learning and Why?

Rakefet Ackerman

Although individuals use computers extensively in daily life they still prefer hardcopy when it comes to in-depth study of articles. Why? Previous studies examined a variety of technological factors, software and hardware related, but a clear-cut reason was not found. The study described in this paper offers a different approach. It analyzed the on screen and on paper learning process of university social science students based on the metacognitive approach. This approach emphasizes the importance of subjective knowledge level assessment during the learning process. Confirming what most people feel, the study found lower test performance following on screen compared to on paper study. However this difference was only found when study time was fully managed by the participants. Performance level was similar when study time was short and fixed, that is, out of the participants’ control. Under both conditions subjective knowledge assessment was overly high on screen and more accurate on paper. These finding suggest that media does not affect learning itself but rather the effectiveness of learning management.

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Prof. Rakefet Ackerman is an assistant professor at the Faculty of Industrial Engineering and Management, the Technion—Israel Institute of Technology. E-mail: ackerman@technion.ac.il
Introduction: what is the Problem?

Most of us sit opposite the computer screen many hours a day: we read the news and write electronic mail, participate in Internet forums, write documents, analyze data and more. Although we have been doing this for many years, when it comes to seriously studying an article available on the Internet for an exam or a lecture most of us begin the study process by printing the text. The question is: why?

After all, our learning ability is a given, as is the difficulty of the material to be studied, so why do we care on which media it is displayed?

When individuals are asked about their preference to study articles from hardcopy rather than on-screen most indicate reasons related to the technology through which the information is displayed on the screen. These reasons have to do with physical inconvenience, burning eyes or sitting angle, or to the way the information is displayed, for example the amount of information displayed in the computer window or the difficulty of moving between text pages. Another important factor related to in-depth study pertains to the ease with which learning aids such as markup and note-taking can be used. Most of us feel that learning is more effective when we hold a pen in our hand and we can mark the important points on the paper. The ultimate purpose of ongoing extensive research about effective ways to display texts and technological advancements is to create user friendly learning environment. Nonetheless, up-to-date studies show that even young adults still prefer on-paper learning, even with respect to the modern e-book that addresses some of the above mentioned technological difficulties (Jamali, Nicholas & Rowlands, 2009; Woody, Daniel & Baker, 2010).

In this paper I put forth the thesis that technological differences are not at the root of the disparity between studying texts on screen and on paper, but rather the different study process applied by the learner with respect to each medium.
Research of the Learning Process

Liu (2005) conducted a survey among individuals 30-45 years of age regarding changes in their reading habits during the decade preceding the study. The participants reported that they read more texts on-screen in recent years, but that this reading has different patterns than on-paper reading. They reported, for example, that their on-screen reading is characterized by browsing, finding key words, reading non-continuous text segments, one-time rather than repeated reading of the text and in general reading that is less thorough and focused. Writing notes and marking important text is characteristic of on-paper reading and less typical of on-screen reading. The survey provided information about the on screen versus on paper study process as described by the survey participants.

The metacognitive approach to the study of learning processes stresses the subjective feeling accompanying learning, viewing it as a crucial factor in the way learners manage the learning (Nelson & Narens, 1990). According to this approach, a distinction needs to be made between the effectiveness of knowledge acquisition – storing the information into memory, which is the cognitive process, and the learning management process, which is the metacognitive process. The latter includes, for example, the use of learning strategies and the decision, at every point in the process, whether to continue or stop studying. This approach maintains that individuals manage their learning process based on a subjective assessment of their knowledge level that takes place continuously, parallel to the learning itself. This assessment is separate from the knowledge acquisition process and does not necessarily reliably reflect the actual knowledge level. When this assessment is biased, it biases learning management. For example, when individuals think they know more than they actually do, they are over-confident. This may
mislead them to think that they have enough knowledge of the material when in fact their real knowledge level may not be sufficient in order to achieve their goals. Let’s imagine a student that must give a lecture based on an article (he or she) reads. In the afternoon hours on the day before the lecture he assesses his current knowledge level to be 90%, which is indeed a sufficient level, and that he can therefore stop studying and go to a movie. If in reality he only knows 70% of the material, and his lack of knowledge is revealed in the lecture, his grade may be significantly lower than he expected. If the purpose of his study was a presentation to managers of a commercial company or a required step in a job selection process, the ramifications may be even more consequential. By comparison, a learner who reliably distinguishes between material he knows well and material in which he is less knowledgeable can review the material in which he is less proficient, ask for help, or decide that he does not have enough time to delve deeper into this material and that it would be preferable to devote most of his learning time to material in which he has an intermediate level of knowledge (Metcalf & Kornell, 2005). These decisions are all part of the learning management process.

It is noteworthy that metacognitive processes accompany and guide us every minute of our daily life, beyond their role in the conscious and deliberate learning process. For example, during a conversation we must assess our knowledge level about the topic being discussed and decide how to formulate the answer we give to the person we are talking to so that we feel confident enough regarding the veracity of the information we provide. The confidence level we deem sufficient will differ whether we are responding to a friend or testifying in court. For example, the decision to answer ‘I don’t know’ is based on metacognitive judgment. The "I don't know" answer does not necessarily mean that we do not have knowledge in the field, but rather that our knowledge level is insufficient in light of the inquirer’s expectations regarding our reliability.
and the relevant information we can contribute beyond what he already knows (Ackerman & Goldsmith, 2008). When we encounter a medical problem or a problem at work for which expert help is required we must determine whether we know enough to ascertain which specialist to go to and what to ask. Furthermore, when we receive an answer we must determine whether our understanding is satisfactory or perhaps we need more information.

**Studying the Effect of Media on the Learning Process**

A question of interest is which elements of the learning management process are impacted by the media, screen versus paper. Every element of the process may be affected by differences in our subjective feeling about the learning conditions. For example, if individuals expect lower results from on-screen learning they may set a lower goal for themselves. Consequently, they will stop studying when they feel that they reached an adequate level, and this level will be lower than on-paper learning. If this is the case, even if knowledge acquisition and assessment are identical, these individuals will stop studying earlier in the case of on-screen learning and their achievements will be lower compared to on-paper learning. Similarly, if the media used to study affects subjective assessment differently than it does knowledge acquisition, then there may be a gap between self-assessment and actual knowledge, leading to mistakes in learning management.

A study conducted at the University of Haifa (Ackerman & Goldsmith, 2011) proposed a method for comparing learning situations in terms of the cognitive aspect, that is knowledge acquisition effectiveness, and the metacognitive aspect, that is learning management. Learning situations are characterized, among other things, by learner traits, study material
and learning environment. The study participants were undergraduate students of social sciences. The study materials included the same collection of articles for all participants and the learning environment was a small computer room on the university campus. The only difference between the learning situations examined was the media used to study the material—one group studied the articles on screen while the other group studied them from hardcopy.

A survey was conducted at the beginning of the study among a sample of the research population which showed that, in line with widespread opinion, about 90% of the participants think that they comprehend and remember study material better when studied on paper rather than on screen. This was followed by the study in which 144 students were randomly divided between on-screen and on-paper learning. The study materials included a short 200-word practice article and six 1,000 word articles (2-4 pages each). The articles were about a variety of topics such as rites of passage in different cultures (such as the bar-mitzvah in Judaism) and reasons for preferring a power station operating on coal over other energy sources. All articles were taken from websites intended for on-screen reading and were converted into Microsoft Word documents. The articles that were printed for on-paper learning were identical to those displayed on-screen. The computerized learning was done by presenting the articles using Microsoft Word, that is well known to all students and has text marking and note writing features. On-paper learners were given a pen and a yellow marker and could use them as they wished. Each participant studied all the articles on the same medium, in other words either all on screen or all on paper. A test with ten multiple-choice questions with four possible answers was prepared for every article. Half the questions tested memory of details and half examined higher order comprehension. The work process on each article included learning, predicting test performance and answering
test questions. The participants predicted their test performance by indicating the expected success rate in percentages on a horizontal scale. Marking 25%, the lowest point on the scale, meant that the participant did not expect succeeding beyond random guessing, which reflects no knowledge despite learning the article. Marking 100% meant that the participant expected to answer correctly every question about the article studied. In most cases the participants marked intermediate levels of expected success. The test was conducted on the same medium on which the article was studied. Since the entire research procedure was conducted either on screen or on paper, the participants were not aware of the comparison being researched between the two media types.

The participants were divided into four groups. Half worked on screen and half on paper. Furthermore, half the participants in each media type studied under fixed time constraint. In other words, these participants had no control over their study time. The set time (7 minutes) was too short – such that the participants would have preferred to study more in order to realize their potential knowledge level. The goal was to measure the effectiveness of acquiring information in a predetermined period of time. Under this condition participants were relieved of the responsibility to manage their study time such that their cognitive process could be examined while the contribution of the metacognitive regulatory process to the learning outcome is reduced. The procedure was very similar for the second half of the participants. The only difference was that now the participants could manage their study time freely within the overall 90 minute timeframe (an average 15 minutes for every article, including study and taking the test). By comparing learning under the two time conditions it was possible to examine the benefit gained by participants from free control over their study time. Under both time conditions however, fixed time and free time, the participants were required to work on the articles sequentially, such that they could not return to an article
they already studied. The objective measure was the test score. Learning duration was measured and taken into consideration in the free time condition. The subjective measure was the predicted test performance level. Prediction accuracy was measured as the difference between predicted and actual test performance. A difference is not expected if the subjective performance assessment reliably reflects the test score. Additionally, because many people attribute their on-paper preference to the use of markup and note-taking tools, frequency of using these tools was documented.

What findings could be expected? If technological factors such as those specified above hinder knowledge acquisition when studying directly on screen, they should impact the learning process irrespective of the ability to control their study time. If this is the case, we would expect lower test performance on screen compared to on-paper reading under both time conditions, fixed and free control of study time. If, on the other hand, learning management is less effective on screen compared to on-paper study, we would expect lower test performance on screen compared to on-paper reading only when participants were permitted to manage their study time.

**Study Findings**

The main findings are presented in Diagram 1. First, it was found that time allocated under the first condition, 7 minutes, was shorter than the time participants chose to invest in each article when they could manage their study time (9.6 minutes on average). Furthermore, the findings support the second proposed possibility, showing that the ability to manage learning time was less effective on screen compared to on-paper study. The same test score level was achieved under both media when learning time was fixed and short, suggesting that the various
technological factors do not necessarily result in lower test scores in on-screen learning. This finding is reinforced by the fact that no differences were found between the media with respect to use frequency of markup and note-taking tools. On the other hand, when participants were given free control of study time, lower performance was found on screen compared to on-paper learning, despite the fact that under this condition, and contrary to commonly-held belief, on-screen learners used markup and note-taking tools even more than their peers who studied from print. A comparison of participants under the two time conditions indicates that on-paper learners took advantage of their ability to manage learning time and invested the additional time, when it was available, to achieve higher test scores than when study time was fixed. On the other hand, on-screen learners did not succeed in achieving higher scores when they devoted an average 9.1 minutes to every article compared to their score when allowed only 7 minutes. In other words, the additional time they invested did not result in improved test scores.

**Diagram 1**: A comparison between predicted performance level and actual score in on-screen and on-paper learning under the condition of fixed study time (Table A) and under free regulation of study time (Table B).
Diagram 1 shows that the predicted text performance in on-screen learning under both time conditions was higher than actual performance. In other words, the participants were overconfident, while their predictions of performance were more accurate in the case of on-paper learning. This finding contradicts the commonly held notion that people expect their learning to be less efficient on screen relative to on-paper learning. Indeed, in the survey conducted prior to the study, participants who assessed on-screen versus on-paper learning and the learning environment in general, thought that on-screen learning is less efficient than on-paper learning. According to the test scores of participants under the free time condition they were right – performance in on-screen learning was poorer than on-paper study. However, the general notion regarding less efficient on-screen learning that emerged from the survey was not reflected in the participants’ prediction regarding every article separately, when they were unaware of the comparison between the two media. In this case, a substantially different picture emerged – participants’ self-predicted test scores after on-screen learning were exaggerated under both time conditions, when learning time was fixed as well as when study time was self-managed.

It is interesting to analyze the effect of overconfidence on time allocation under self-managed time conditions. When reviewing participants’ predictions in both media under this condition, it appears that on-screen learners stopped studying when they thought they had reached a knowledge level similar to that on-paper learners thought they had reached. This finding enables us to reject the possibility suggested above, that people expect to achieve lower scores in on-screen learning. However, it is important to note that while on-paper learners thought they had reached this level after 10 minutes of study, on-screen learners thought they had already reached this level after 9.1 minutes. At this point in time they stopped studying, however their knowledge level did
not progress as they thought – this is the result of overconfidence, the illusion of knowledge which leads to under-allocation of time and lower performance levels.

Summary

Why are people inclined to print articles they need to study? It seems that this decision is based on a general feeling regarding the media rather than an assessment of actual learning of a particular article. And why do people think that on-screen learning is less effective than on-paper learning? Overconfidence accompanying on-screen learning and the fact that individuals do not utilize the freedom to manage study time suggests that their learning process on screen may be less rigorous, as described at the study by Liu (2005) mentioned above. If individuals feel that they cannot trust their ability to manage study time effectively on screen, there is a good reason for them to prefer study from printed material. Thus, they transfer the learning task to what they consider to be a more reliable learning environment, where they have greater trust in their ability to manage their learning.

As to the benefit to be gained from the used analysis methodology in comparing learning situations, the study conducted by Ackerman and Goldsmith (2011) demonstrates that by using the metacognitive approach for examining learning processes it is possible to systematically delve into knowledge acquisition effectiveness, self-assessment accuracy and study time allocation and to distinguish between them, beyond looking at the final outcome as reflected in test scores. As stated above, this methodology can be used to compare completely different learning situations. For example, we can examine whether progress achieved following cultivation of knowledge or a skill is simply the result of increased knowledge per se, or perhaps stems from the learner’s knowledge
assessment or time allocation efficiency. It also affords comparing populations, for example those with learning difficulties compared to regular learners, in order to determine whether the differences derive from knowledge, self-assessment or time management. In the same way, an in-depth comparison can be conducted among versions of study material and varied teaching methods, just to mention a few possibilities.

This study demonstrates the importance of accurate self-assessment of knowledge as a central component of effective learning regulation. One of the challenges we face as researchers and educators is to find ways to improve self-assessment accuracy. This challenge is relevant to on-screen learning, as shown by this study, but is also relevant to a variety of other fields, since in general people tend to be overconfident (Pressley & Ghatala, 1988). Moreover, this tendency is more characteristic of weaker students (Kruger & Dunning, 1999) – exacerbating their situation because it breeds complacency that hinders their ability to improve their achievements.
Bibliography


