"Write it Down!"—a Learning-Psychology-Based Analysis of the Use of Written Work in Economics Lessons

Björn Paape, Christoph Maus, Iwona Kiereta, Anja Gebing, Anne Meurer, Kathrin Schneider-Zöller & Arne Schön

RWTH Aachen University, Faculty of Business and Economics, Templergraben 64, 52056 Aachen, Germany, e-mail: paape@wiwi.rwth-aachen.de.

Abstract To date, the use of written work in economics lessons at vocational colleges has been insufficiently researched. Relevant studies on this topic may be found primarily at primary or secondary school level. These studies demonstrate among other things that written work can have great significance for learning, retentiveness, and cognitive development. However, particularly because of the process of digitalization in schools, the amount of written work or writing tasks has dropped. The study at hand will examine the benefit of writing as a teaching method. Using learning-psychology-based findings on the processing of learning incentives by information models, the study focuses on the impact of writing by hand on the retention processes of the learners in economics lessons. To this end, two groups of learners are formed who will learn and repeat the material of a standardized lesson via different methods. One group writes the learned material down; the other group receives a handout containing the material. By means of short-term and long-term written learning outcome tests in the form of multiple choice, we obtain information about the knowledge retention effectiveness of written work in classroom teaching. We show that writing down, as a teaching method, does not lead to better absolute results in the learning outcome tests. However, in the long term, writing down does lead to fewer variances in the results of the learning outcome tests and thus to a more stable anchoring of knowledge in the learners' long-term memory.

Keywords: vocational college, learning, writing down, psychology of memory, knowledge retention.

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1 Current state of research

In schools, digital media are gaining increasing significance. Already in 2005, the EU Commission defined the so-called computer competence as a "key competence", and the German *Kultusministerkonferenz* (Standing Conference of the Ministers of Education and Cultural Affairs (KMK)), in its own resolution of 8 March 2012, called for media education in schools (KMK, 2012, S. 3). Digital media such as tablets, smart phones, or whiteboards are thus becoming an integral part of the classroom. The use of digital media makes particular sense, and is particularly necessary, for vocational schooling, since "due to their proximity to the employment system and their role of partner in the dual vocational education system, vocational colleges are particularly and directly affected by the technological and economic change stemming from the digitalization process […]. Following the didactic principle of practice relevance, future developments in the working environment that are caused by progressing digital transformation must be introduced into vocational education in a timely manner"[1] (KMK, 2016, p. 20).The meaningful use of digital media in the classroom needs to be repeatedly addressed regarding its benefits, since the increasing use of digital technologies and methods in the classroom will also lead to changes in the teaching/learning process. In their 2016 strategy paper "Bildung in der digitalen Welt" (Education in the Digital World)[2], the KMK writes "Owing to the digitalization process, a new cultural skill is developing, a skill which both supplements the tradition cultural skills of reading, writing, and arithmetic: competent usage of digital media"[3] (KMK, 2016, p. 13). The change in the cultural skill of writing—particularly copying down by hand—will, in addition to its impacts on the learning process, be the focus of the research at hand. Due to the usage of digital media in schools, there is apparently a diminishing share of situations and tasks where learners write things down by hand. Moreover, school students are increasingly lacking empathy for the meaningfulness of writing. At the same time, there is scientific evidence that handwriting is highly significant "for learning, for retentiveness, and for cognitive development" (Diaz Meyer, 2017, p. 7)[4]. However, it is difficult to assign the learning method "writing down by hand" to a pedagogical-psychological research environment.

[1] Authors' own translation from the German.
[2] Authors' own translation from the German.
[3] Authors' own translation from the German.
[4] Authors' own translation from the German.

2 Research gap

Previous studies on the topic of copying down/handwriting/learning through writing can primarily be attributed to the field of writing- and speech-acquisition and fine motor skills in the primary and secondary school sectors (Diaz Meyer et al., 2017, p. 33 ff., Lessmann 2008, p. 46 ff., Vinter & Chartel, 2010, p. 476 ff.). There are also studies which compare machine writing and handwriting (Müller & Oppenheimer, 2014, p. 1.159 ff.). Other studies research learning, where the learning process of learners is fostered by "independent writing of technical texts" or "material-based writing"[5] (Sturm, 217, p. 19ff., Bergeler, 2009, p. 21 ff.)

In the literature, there is a scarcity of explicit analyses of the cognitive processes involved in writing. However, what does exist are numerous calls from various actors for texts to be written by hand rather than only digitally (van der Ley, 2010, p. 31 ff., James & Engelhardt, 2012, p. 32 ff.). In two surveys, the "Schreibmotorik Institut" interviewed teachers on "problems with handwriting development" and parents on "the importance of handwriting"[6]. The interviewees were convinced that handwriting is important and are in favor of its being promoted (Schreibmotorik Institut, 2015, Schreibmotorik Institut, 2016). In their study of 2012, James and Engelhardt examined the benefit of handwriting skills in the digital age by evaluating via MRT examinations the brain activity of 5-year olds when recognizing letters of the alphabet (James & Engelhardt, 2012, p. 32 ff.). However, such studies usually take neuro-psychological approaches rather than a cognitive learning psychology approach which would help to explain these phenomena in the sense of our research question.

The quantitative analysis at hand aspires to explain and to measure what added value writing down by hand, as a teaching method, has on the learning process of learners. The analysis targets learning-psychological findings on the processing of knowledge through information processing models, even though the latter have yet rarely examined the connection between cognitive and motor systems. This research work therefore focuses on the impact that writing down by hand has on the retention of lesson content by learners in economics lessons.

[5] Authors' own translation from the German.
[6] Authors' own translation from the German.

3 Derivation of hypotheses

Handwriting/writing down still play a very important role at school and in daily life, despite the increasing presence of digital media. But where exactly is the relevance of this "cultural skill"? Mostly, notes, texts, or other written products represent more or less a structured piece of information which informs a person about a factual issue. But how does the processing of this information work, particularly when it is new knowledge that is being processed? Traditional behaviorist theories are not very helpful because they examine and explain the learning of new types of behavior. Within the framework of an analysis of learning processes concerning "writing", a look at cognitivist approaches would seem more appropriate, since we are focusing on learning through the processing of information. Memory psychology – which belongs to this tradition – examines information-processing processes with the help of models which examine stimuli particularly regarding the procedure and the form of information processing.

This type of presentation enables the coding (encoding), the storage, and the retrieval of information passing chronologically through the different memory systems to be explained (Schermer, 2014, p. 142).

The possibly best known model in memory psychology is the so called multi-store model which can be traced back to the authors Atkinson & Shiffrin (1968), who established the so-called three-store model and extended the existing two-store model (short-term and long-term memory) by the so-called sensory register or sensory memory (see Fig. 1). The primary role of the sensory memory is to process external stimuli received by the sensory organs. The existence of such a sensory memory has been thoroughly confirmed by scientific research in the case of visual and acoustic stimuli; however, some researchers believe that "each sensory modality has its own sensory memory, even if the relevant empirical findings are still sparse and not at all conclusive"[7] (Schermer, 2014, p. 144).

[7] Authors' own translation from the German.

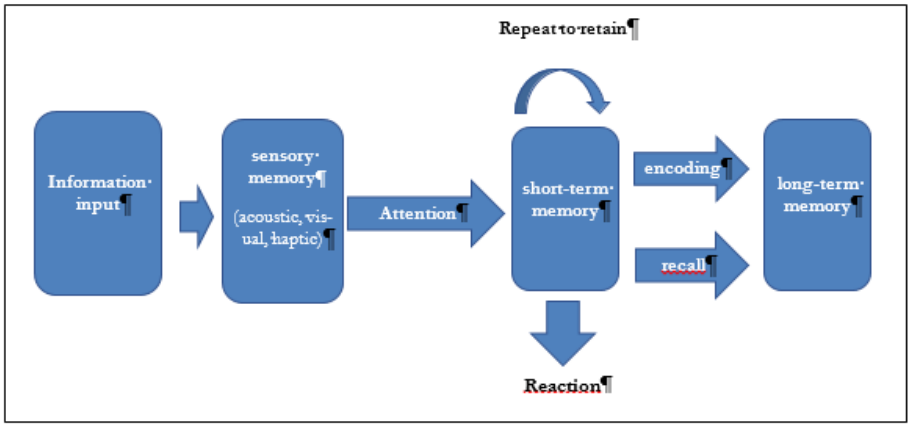

Figure 1: Early model of memory as an information processing system (own representation after Woolfolk, 2014, p. 279)

Information is processed as follows: information that affects an individual in the sense of external stimuli is "encoded" in the sensory memory (to use the term used in memory and cognitive psychology). One definitive factor at the end of this part of the process is that of attention allocation, which determines which information should be transmitted to the short-term memory. There, it is combined with stored knowledge, processed, and transmitted to the long-term memory as networked information. From there, it can be activated for re-use in the short-term memory (Woolfolk, 2014, p. 279). The actual encoding in the short-term memory can primarily take place in a meaningful articulatory-acoustic (semantic) or in a sensory (visual, olfactory) form of representation (Schermer, 2014, p. 151 f.). In which format ("forms of representation") knowledge is stored is not quite clear; however, a differentiation is made between declarative knowledge (represented facts and events) and procedural knowledge (motor tasks and procedures) (Hasselhorn & Gold, 2017, p. 51ff.).

Current memory models have a higher degree of differentiation but are particularly notable for having reformulated the short-term memory as the so-called working memory. This increased differentiation of the short-term memory can be primarily traced back to A. D. Baddeley (1997). His model is characterized by a central executive system and two related auxiliary systems: the phonological loop and the visuo-spatial sketchpad. The central executive is responsible for attention control as well as for control, coordination, and integration of information from the two auxiliary systems. The phonological loop has the role

of storing phonological or sound information, while the visuo-spatial sketchpad processes and stores visual information from perception processes or the long-term memory (Schermer, 2014, p. 154 f.). "In the […] working memory, information is "held" for a short and, via manifold control processes, is compared with existing information in the long-term memory, evaluated and organized, and subsequently transformed into current information"[8] (Hasselhorn & Gold, 2017, p. 50).

3.1 Hypothesis 1: Learners who write down learning content perform better in learning outcome tests in the short term than learners who do not write down learning content

If we transfer findings from memory psychology into information processing during a "writing" task, the following understanding arises: When information (learning content) together with a visual presentation, e.g. in the form of a text, or an acoustic presentation such as a teaching dialogue, is noted down by hand, there is an additional motor stimulus which has to be processed by each of the memory systems. This coupling of an additional motor stimulus with basic visual/acoustic stimulus provides a more intense linkage in the memory.

Apart from the processing of the visual information, there is, then, also a repetition and a focusing on attention, since a good reproduction of information is given through concentrated writing. At the same time, attention is paid to the meaning of the information (learning content) if it is noted down by hand. The working storage (short-term memory) interacts with the learning content on various levels, whereby the learning content can be held more extensively in the short-term memory. Through the above-mentioned coupling of stimuli, more memory levels are addressed, and it can be assumed that learning content can be better retained. Further, it can be assumed that, through a focusing of attention in a writing-down situation, an increase in the retention performance can take place. On account of this argumentation, the following hypothesis can be formulated:

> **Hypothesis 1:** Learners who write down learning content perform better in learning outcome tests *in the short term* than learners who do not write down learning content

[8]Authors' own translation from the German.

3.2 Hypothesis 2: Learners who write down learning content perform better in learning outcome tests in the long term than learners who do not write down learning content

As learning in the classroom and, fundamentally, life-long learning, target a longer-term processing of information and activation of information, it is particularly relevant for consideration in this analysis. Therefore, the long-term memory is specifically addressed in the following section.

The long-term memory basically has the function of guaranteeing a longer-term, failure-resistant retention of information. Following Klix (1980), the long-term memory has three key aspects: identifying, reproducing, and producing. "Identifying" can also be described as recognizing information which flows into the memory system as external stimuli. "Reproducing" information is, in this context, the retrieval of memory content, whereby the "producing" represents the transforming of old memory content or the producing of new content (Schermer, 2014, p. 155). Following Schermer, the long-term memory is broken down into further parts such as the episodic and the semantic part and, based on the demands of other authors, extended by the procedural memory (Schermer, 2014, p. 155, Gudehus, Eichenberg & Welzer, 2010, p. 11). Without a "sustaining repetition" the holding period of information in the working memory is very brief. For a long-term storage of information in the long-term memory, information has to be processed via elaborate repetition, whereby the way in which a "deeper processing" takes place in the sense of a networking of the semantic content of the learning material is relevant, rather than the number of repetitive acts. (Schermer, 2014, p. 149, Hasselhorn & Gold, 2017, p. 59).

Regarding the forgetting curve of Ebbinghaus (1885), memory content seems to be forgotten relatively quickly because the retention ability drops. Therefore, it would seem of value to examine whether knowledge can be transferred more effectively into the long-term memory via writing information down, since a long-term retention of knowledge is a key intention of learning. This leads us to our second hypothesis, which we will test in this study:

Hypothesis 2: Learners who write learning content down perform better in learning outcome tests *in the long term* than learners who do not write down learning content.

4 Research design

4.1 Conducting of research

In order to collect data and examine the effects of writing [copying down] on learners, we implement a teaching unit that is as standardized as possible at three different German vocational colleges in four different classes. The classes are assigned to either the Experimental Group or to the Control Group and are taught identically until the learning consolidation phase. The Experimental Group consists of all learners who are writing content down and the Control Group consists of all learners who are not doing this. During this phase, the learning parameters "writing down" and "not writing down" and "handout" are varied (in two classes respectively). The four classes have been chosen based on their having the same educational level in accordance with the DQR (German Qualifications Framework) in order to have a uniform foundation with regard to the test subjects' prior knowledge. The DQR enables a standardization of vocational qualification levels and types. The starting point in our context is that of the academic requirements for a specific vocational training course.

At the beginning of the study, a single choice learning outcome test is implemented in all four classes on a previously set learning topic "The sales contract". This first learning outcome test is intended to establish the prior knowledge of the learners. The test comprises ten questions, each with three possible answers, only one of which is the correct answer. During the course of the learning outcome tests, the order of the questions and the answers was changed around. All tests were anonymous. However, in order to be able to associate the test outcomes with the respective learners, the tests were encrypted by means of an individual letter-number combination.

The actual teaching unit followed during a school lesson (45 minutes) one week after the pre-test. In this lesson, the learners are presented with an introductory case which they are to solve with the help of an informational text and the think-pair-share strategy. In all four classes, the lesson is identical up to the learning consolidation phase. In two classes (Group A, Experimental Group), the consolidation phase is characterized by a high degree of hand-written work. This entails learners having to write down by hand content from the blackboard. In the other two classes (Group B, Control Group), this phase is completed with the distribution of a handout.

At the end of the lesson, the same learning objectives test that was taken a week earlier was given to the students of all four classes after a distraction-break of 20 minutes. The order of the questions was, however, a different one. The break served to prevent learners from internally repeating the learning content and keeping it in their short-term memory. This learning outcome test is therefore intended to check our first hypothesis.

Four weeks later, another learning outcome test takes place in order to test our second hypothesis. For the statistical evaluation, those learners who have not taken part in all three tests are eliminated. By doing this, we increase the meaningfulness of our results and avoid the distortion of the mean value and variance. We then have a total sample of n=54, which is split into Writing Down n=32 und Handout n=22.

4.2 Method of evaluation

It is expected that the Experimental Group, which writes down learning content, will have a higher mean score in both learning outcome tests than the Control Group. We also expect that the mean value of the Experiment Group will be above that of the Control Group.

With regard to testing both hypotheses, we select a T-test. In order to choose the correct T-test, we calculate, in addition to the mean value, the variance for all three performed tests. Based on the variance calculation, we implement a two-sample F-test in order to establish whether there is homogeneity of variance for the results (Cramer & Kamps, 2016, p. 314ff.). Based on the results of the two-sample F-test, a two-sample T-test for homogeneous and heterogeneous

variances is carried out (Cramer & Kamps, 2016, p. 308ff.). This is done in order to ascertain whether there are systematic differences between the mean values of both groups. In order to test the hypotheses, the basic population n is split into two groups, depending on the size of the classes.
For the first hypothesis, two T-tests are carried out: "Test results under the influence of copying down by hand" and "Test results without the influence of copying down by hand". The T-test procedure can also be applied for the second hypothesis, because the focus now lies on the long-term retention rate.

5 Analysis of results

To test our hypotheses, an observation of the mean values and standard deviations is carried out.

Table 1: Observation of mean values (points achieved in test)

Mean value	Pre-test	Short-term	Long-term
Variable 1 = Blackboard	7.1875	8.6250	8.5938
Variable 2 = Handout	6.8636	9.5909	9.0909

As can be seen, the Blackboard Group achieves absolutely better results in the pre-test than the Handout Group (Delta + 0.3239 points), whereby the standard error must be taken into consideration, i.e. learners correctly answering the test questions purely by chance. We abstain from a mathematical quantification of the standard error, as the latter's absolute size is not relevant for the further evaluation. When we observe the mean values of the short-term test, we can see that the Handout Group has a larger knowledge gain (Delta + 2.7273 points) than the Blackboard Group (Delta + 1.4375 points). If we compare these two figures with each other, the knowledge gain of the Handout Group outrates that of the Blackboard Group by + 1.2898 points. If we compare the performances from the short-term test and the long-term test, we see that the Blackboard Group drops by - 0.0312 points in the mean value. This means that knowledge in the Blackboard Group remains relatively stable over a longer period. In contrast, the mean value of the Handout Group drops by - 0.5000 points; this group, then, does not retain knowledge as constantly as the Blackboard Group does.

This assumption is confirmed by observation of the variance. The variance describes the distribution of values around the mean value, whereby we can see that the variance of the learners who are copying down decreases in dependence on the time that passes between the short-term and the long-term test. In contrast, the variance of the learners who do not copy down increases.

Table 2: Variance observation

Variance	Pre-test	Short-term	Long-term
Variable 1 = Blackboard	1.5121	2.1129	1.0877
Variable 2 = Handout	3.4567	0.4437	0.9437

4In order to examine the significance of these differences, we carry out a T-test, which establishes whether there is a significant difference between two sample groups. First, the sample variances are tested for homogeneity, which serves as a selection criterion for a correct T-test. To do this, a two-sample F-test is used for variance homogeneity, which allows us to examine whether there is a significant difference between the variances of the two groups.

The null hypothesis shows that there is no difference between the variances of the two groups and that thus homogeneity of variance exists.

Table 3: Two-sample F-test for testing the homogeneity of variance in the pre-test

	Variable 1	*Variable 2*
Mittelwert	6,8636	7,1875
Varianz	3,4567	1,5121
Beobachtungen	22	32
Freiheitsgrade (df)	21	31
Prüfgröße (F)	2,2860	
P(F<=f) einseitig	0,0179	
Kritischer F-Wert bei einseitigem Test	1,9071	

The relevant test value F can be ascertained by dividing the larger variance by the smaller variance. When observing the pre-test, we see that F = 2.2860 > F crit. = 1.9071. F crit. is the critical value, the exceeding of which leads to a rejection of the null hypothesis. The null hypothesis can thus be rejected, and there is heterogeneity of variance.

Similarly, for the short-term test we have F = 4.7618 > F crit. = 2.0045. This allows us to conclude that the null hypothesis can be rejected, as we have heterogeneous variances.

Table 4: Two-sample F-test for examining homogeneity of variance in the short-term test

	Variable 1	*Variable 2*
Mittelwert	8,6250	9,5909
Varianz	2,1129	0,4437
Beobachtungen	32	22
Freiheitsgrade (df)	31	21
Prüfgröße (F)	4,7618	
P(F<=f) einseitig	0,0002	
Kritischer F-Wert bei einseitigem Test	2,0045	

In contrast, when we observe the long-term test, we see that F = 1.1526 < F crit. = 2.0045. The null hypothesis cannot be rejected; thus, we have homogeneity of variance.

Table 5: Two-sample F-test for examining homogeneity of variance in the long-term test

	Variable 1	*Variable 2*
Mittelwert	8,5938	9,0909
Varianz	1,0877	0,9437
Beobachtungen	32	22
Freiheitsgrade (df)	31	21
Prüfgröße (F)	1,1526	
P(F<=f) einseitig	0,3729	
Kritischer F-Wert bei einseitigem Test	2,0045	

As both homogeneity and heterogeneity of variance exist, we employ two different T-tests for the evaluation. For the pre-test and the short-term test, the two-sample T-test is applied under the assumption of different variances. In contrast, for the evaluation of the long-term test, the two-sample T-test is applied under the assumption of same variances. For all three tests, the same null hypothesis applies: There is no difference between learners who copy down learning content and those who do not.

The evaluation of the pre-test shows that $p = 0.2394 > 0.05$. The null hypothesis cannot be rejected; therefore, there is no difference between the observed groups in the pre-test. The t-statistic shows the relation between the mean values of the Experimental and the Control Group. As already shown for the mean value observation, the relation is positive, i.e. the mean value for the Experimental Group is higher than that for the Control Group. The critical t-value is the value that the t-statistic must exceed in order to produce reliable results at the 95% significance level selected for the test; however, $|t| < t$ crit. This means that the results may be affected by standard error.

Table 6: Two-sample t-test assuming different variances in pre-test

	Variable 1	*Variable 2*
Mittelwert	7,1875	6,8636
Varianz	1,5121	3,4567
Beobachtungen	32	22
Hypothetische Differenz der Mittelwerte	0	
t-Statistik	0,7164	
P(T<=t) einseitig	0,2394	
Kritischer t-Wert bei einseitigem t-Test	1,6924	

An observation of the short-term test shows, with $p < 0.05$, that the null hypothesis can be rejected. Learners who do not write down content achieve better results.
We can exclude standard error affecting results, since $|t| > t$ crit.

Table 7: Two-sample t-test assuming different variances in short-term test.

	Variable 1	*Variable 2*
Mittelwert	8,6250	9,5909
Varianz	2,1129	0,4437
Beobachtungen	32	22
Hypothetische Differenz der Mittelwerte	0	
t-Statistik	-3,2899	
P(T<=t) einseitig	0,0010	
Kritischer t-Wert bei einseitigem t-Test	1,6787	

Evaluation of the long-term test shows that here, too, the null hypothesis may be rejected, since $p < 0.05$. Learners who do not write content down achieve better results.

Similarly, for the long-term test, we see that there is no influencing of results by standard error, since $|t| > t$ crit.

Table 8: Two-sample t-test assuming same variances in the long-term test.

	Variable 1	*Variable 2*
Mittelwert	8,5938	9,0909
Varianz	1,0877	0,9437
Beobachtungen	32	22
Hypothetische Differenz der Mittelwerte	0	
t-Statistik	-1,7691	
P(T<=t) einseitig	0,0414	
Kritischer t-Wert bei einseitigem t-Test	1,6747	

6 Conclusions

The goal of this analysis was to ascertain whether a short-term and long-term change in learning occurs, particularly regarding retention performance, by varying the processing of information through writing information down and not writing it down. Our statistical evaluation shows that our first hypothesis "Learners who write down learning content perform better in learning outcome tests in the *short term* than learners who do not write down learning content" cannot be confirmed. We have found that learners who do not write learning content down gained on average higher scores in all tests following the unit of

teaching. This result is confirmed by both an observation of the mean values and the analysis by means of a T-test. The results of the pre-test are potentially influenced by standard error and might thus be random. If we observe the variances, we can see that these are larger for learners who write down than they are for those who receive blackboard information as a handout.

The second hypothesis, "Learners who write down learning content perform better in learning outcome tests in the *long term* than learners who do not write down learning content" cannot be confirmed by the T-test, because learners who do not write information down gain better results in the learning outcomes tests after the short-term and after the long-term test. However, if we compare the development of the mean values in the groups, we see that the mean value observation for the learners who are writing down is more stable than it is for learners who are not writing down. This is also supported by the development of the variance. The variance for learners who are writing down drops in dependence on the time elapsed, whereas it increases for learners who are not writing down. This means that the expected long-term learning success via the writing down of information occurs for the test sample and all members of the learning group achieve a homogenous learning status/knowledge increase. For learners who are not writing information down, individual conditions might be a reason why long-term learning success varies more strongly.

It is not possible to derive from the collected data a precise explanation for why Hypothesis 1, where the learners who are writing information down should perform better in the *short-term* learning outcome tests, was not confirmed. Presumably we have standard error here, i.e. random phenomena and uninfluenceable framework conditions. We will take a close look at these in the next section.

However, the mean value development is more stable for learners who are writing down. Thus, we can conclude that learning growth is more stable, and that knowledge is anchored more firmly in the long-term memory than is the case for the group with the handouts. Presumably, a more intense linkage has taken place in the memory, since writing down involves additional stimulation in the brain. Further, we can assume that writing down involves an elaborated repetition and thus a deeper processing of the learning content.

7 Limitations and need for further research

The analysis is subject to some limitations, particularly regarding the research design and the interpretation of the results.

One limitation is that of the small size of the sample, n=54 learners, which can lead to distortion of the results through standard errors. A larger sample would assuredly lead to a higher robustness of the mean values as well as lower variances, and thus to more valid results. Further, the sample was regarded to be homogeneous, i.e. in conformity with the DQR standards, equivalence of the vocational programs was assumed and thus a homogenous group of students with regard to their prior education and basic understanding of the material. During the course of the analysis, however, the student body was found to be rather heterogenous, with different learning environments and individual learning requirements. The various cognitive skills and different physical constitutions that stem from this heterogeneity can impact the motivation of learners and their learning success.

A further impacting factor is that of the class being taught by four different teachers in the three schools. The lesson that was used for the research at hand was standardized in both content and methodological aspects. This did not apply to the concrete interactions between the four teachers and their respective classes in order to avoid depriving the learners of an authentic lesson and to avoid any negative influencing of the learning process. This correlates with the previously described different learning environments which the participating learners were subject to. In order to achieve more finely grained research findings, lesson implementation by the same teacher might be considered. Further, a greater degree of standardization is required in the sense of the teacher having a more stringent script for how to conduct the lesson.

In a similar vein, the actual writing down process of the learners was not stringently controlled and no help was provided beforehand on how to efficiently note information down. This lack of standardization – which would also have applied to the control group (efficient learning with handouts) in order to avoid any negative impact on research findings – definitely also leads to the learning parameters having an impact on the research question.

The test construction (learning objectives test) should also be viewed critically. It is questionable as to whether the test questions can really reproduce the knowledge that is presented in the lesson. For practical reasons the questions are limited to ten, as only a 45-minute slot was intended. Increasing the number of questions might lead to more meaningful results.

A further influencing of the findings could take place through potential learning processes, e.g. repetitions, new confrontations with the topic, or other learning processes.

In summary, we can say that further analysis should be expanded with regard to the number of classes, i.e. more learners in more classes in the same program of study with comparable prior knowledge (which should be ascertained in a separate study beforehand). A further focus would be on the learning environment on the one hand and on the implementation of the lesson through the teacher. Only the repetition methods and the teaching methods should be differentiated according to the hypotheses so that one class writes down learning content and the other class does not. It could be ascertained via a test whether the learners in the learning objectives tests perform better particularly in the *long term*. Further analysis should also establish in which phase of a learning process, for instance when new knowledge is acquired or when existing knowledge is being deepened, writing information down has a significant impact on retention performance. Also, the role of self-organizing or self-designing of learning processes should be evaluated with regard to a sustainable learning process. Can procedural or declarative knowledge become more sustainable via the writing down process? However, in the context of further analysis, the question of research design is again pertinent, i.e. to what degree is it possible in a school environment to construct laboratory type conditions in order to have learning groups and learning environments that are as homogenous as possible and easy to examine? A more valid, objective, and reliable test construction could be a start.

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