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WIP: Reflection and Elaboration Task as Spaced Retrieval Practice: Impact on Exam Performance in a Laser Technology Undergraduate Elective

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1. Introduction

In a teaching and learning environment, retrieving what has been thought and learnt is a beneficial learning strategy and even better for long-term learning, future recall, and transfer compared to restudying the learning content [1]. Therefore, lecturers should provide retrieval activities to their students as learning opportunities [2]. Although tests and quizzes that focus on recalling facts are a suitable learning opportunity, tasks that require a higher order thinking, such as elaboration and reflection, are also possible variants of retrieval practice [3].

1.1. Background and motivation

At Hochschule Bonn-Rhein-Sieg, University of Applied Sciences (H-BRS), Germany, engineering undergraduate programs include two elective courses totaling 5 ECTS, which are graded as pass/fail. As in case of a fail, the course can be repeated an unlimited number of times or be replaced by another elective, the grading itself has only minor regulatory effect on the efforts students invest in the course content. For motivational reasons, e.g., [4], instead of using tests focusing on factual content as retrieval task, items focusing on reflection, elaboration, and participation were developed and distributed as spaced task after each session of an applied laser technology elective. With this contribution, we aim to answer the question of whether a spaced retrieval practice is positively correlated with the final exam performance of an elective with (from a student perspective) low consequences (i.e., pass/fail, unlimited retakes).

1.2. Description Laser Technology elective course

1.2.1. Importance of Laser Technology for engineering students at Universities of Applied Sciences

Laser technology is indispensable in many areas of modern engineering and is considered a cross-cutting technology with broad applications in industrial manufacturing, measurement technology, communication, and medical engineering. For engineering students at Universities of Applied Sciences (UAS), engaging with laser technology provides a valuable opportunity to combine scientific foundations with engineering practice. From a university's perspective, integrating laser technology into the curriculum makes an important contribution to the profile of UAS. Students learn, on the one hand, how indispensable solid theoretical foundations are for understanding modern key technologies and, on the other hand, how directly these foundations become relevant in practice-oriented applications. At the same time, it becomes clear that innovative didactic formats such as continuous online learning assessments not only secure learning success but also increase motivation and promote a more sustainable engagement with complex technical content. In this way, the course discussed in this contribution exemplifies the mission of a UAS: systematically combining theory and practice and preparing students specifically for the demands of professional engineering practice.

1.2.2. Didactic embedding and objectives

The course was designed to support students in three dimensions:

1. Subject-related competence: Teaching basic knowledge of geometrical optics, wave optics, and quantum optics as a foundation for understanding laser physics. Introducing the principles of stimulated emission and the specific properties of different laser types.
2. Application orientation: Establishing a clear link between theoretical foundations and engineering applications (e.g., lasers in material processing, optical metrology, data transmission).
3. Self-regulated learning: Encouraging independent engagement through continuous learning assessments provided via the university's learning management system (LMS).

The combination of these goals follows the higher education didactic principle of competence orientation: students should not only reproduce knowledge but also apply and reflect on it within complex technical contexts.

1.2.3. Learning content between theory and application

A special didactic potential arises from the structured composition of the course content:

- Optical fundamentals (geometrical optics, wave optics, quantum optics) provide not only theoretical basics but also create bridges between classical and modern physical concepts.
- Fundamentals of laser technology (stimulated emission, resonator design, amplification mechanisms) illustrate the relevance of abstract quantum physics concepts for technical applications.
- Different types of lasers (gas lasers, solid-state lasers, semiconductor lasers, fiber lasers) demonstrate to students the wide range of technological solutions and their specific advantages and limitations for various engineering applications.
- Application fields of laser technology: Engineering-oriented examples were discussed to emphasize the practical relevance of lasers in industry and research. These include:
    - Material processing such as laser cutting, welding, and drilling, which are central processes in modern manufacturing.
    - Medical technology, for instance in dermatology, ophthalmology (e.g., LASIK surgery), lithotripsy (fragmentation of gallstones), and other minimally invasive procedures.
    - Metrology and combustion diagnostics, including laser-based velocity measurements (e.g., Laser Doppler Velocimetry), laser-induced fluorescence for chemical species detection, and advanced measurements of flow and combustion processes.

This interplay of theory, technology, and real-world applications corresponds to the didactic concept of situated learning: knowledge is not conveyed in isolation but in the context of real-world situations, thereby fostering transfer and applicability.

1.2.4. Didactic setting: spaced retrieval practice

The course was supported by a blended learning format using the LMS. After each lecture, students were required to answer questions on the topics currently being covered. This setting was based on two core didactic approaches:

- Activation principle: By working on tasks independently right after the lecture, cognitive processing goes beyond passive listening.
- Formative evaluation: Feedback on the answers gave students the chance to assess their learning progress and to identify gaps at an early stage.

The incentive system, which allowed students to earn up to 15 % of the final exam grade through continuous participation in the online questions, was added as an additional motivation. From the perspective of Self-Determination Theory [4], [5], this effect can be explained by the combination of extrinsic incentives (exam bonus) and intrinsic motivation (interest in a highly relevant technology).

2. Research question

Is a spaced retrieval practice based on a regular reflection and elaboration task positively associated with the final exam performance in a laser technology undergraduate elective?

3. Methodology

To answer the research question, the individual participation of each student in the spaced retrieval practice was quantified and correlated with their final exam performance measured in exam raw points.

3.1. Description of spaced retrieval practice

The course consisted of 10 lecture-sessions held each on Thursday morning from 08:45 a.m. to 12:00 p.m.. After each session the students were issued a retrieval practice based on six items focusing on reflection and elaboration of the content discussed prior as well as participation in the course itself. Using the university's LMS, students had to enter their individual answers within a time frame of 45 minutes to two days 6:00 p.m. after the end of the session.

The LMS showed following instructions and items followed by a free text field each:

> "Please complete the corresponding reflection questions after each course. Access is always possible 45 minutes after the lecture until 6:00 p.m. on the following Saturday.
>
> > 1a Which aspect of today's content was particularly important or surprising to you?
> >
> > 1b Why?

2 Can you give an example from your own engineering practice for the content discussed today?

3 Write an open-ended practice question (including a suitable answer) that I can ask the rest of the class.

4a What questions do you have that you would like to discuss in class?

4b What do you hope to learn from the discussion?"

3.2. Sample description

In total $N = 28$ students enrolled in the elective (one female). 18 % ($n = 5$) dropped out during semester or did not attend the final exam. For data protection reasons, no additional sample variables were collected, as the students' responses to the retrieval practice and exam results were linked to their full names.

3.3. Data analysis strategy

Each open-ended response to the six items of the 10 retrieval practices were checked and quantified as 0 = missing response, response is unrelated to, or did not show elaboration of the course content (e.g., 4a: "I'm slowly starting to wonder what the exam will be like.") or 1 = response shows elaboration of the course content (e.g., 3: Name one advantage and one application of a He-Ne laser. - long coherence length - holography).

In a second step the quantified item responses were summed up per participant over the whole semester, resulting in a single number value representing participation in the retrieval practice. A high number, up to the maximum of 60, represents high participation, while low numbers represent lack of engagement in the retrieval practice. This quantification allows to correlate the participation in the spaced retrieval tasks across the semester with the final exam results to test the hypothesized association statistically. Statistical analyses were performed in jamovi [6].

4. Results

4.1. Course participation

From $N = 28$ enrolled students, 14 % ($n = 4$) dropped out during semester prior the final exam, $n = 1$ (4 %) student did not attend the exam, and $n = 3$ students (11 %) attended the exam without ever participating in the retrieval practice. In result, 20 data pairs (71 %) of quantified retrieval practice participation and exam results are available for the statistical analysis (Figure 1).

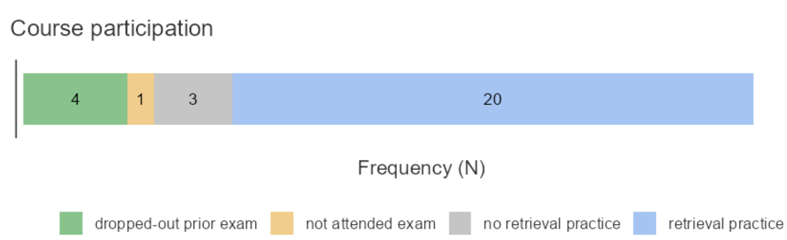

Figure 1. Course participation across semester duration

4.2. Final exam results

Based on the low sample size ($N = 23$) and size-ratio of sub-groups (6.67:1), the comparison of the final exam performance between the students who participated in the retrieval practice ($n = 20$) and those who took the exam without participating in the retrieval practice ($n = 3$) was performed exploratory based on descriptive values only.

In total the students could achieve 50 points in the exam, not including the potential 15 % incentive described above. As Figure 2 shows, the performance between the students who performed at least one retrieval task ($M = 32.17$ points, $SD = 6.71$, $Min = 16$, $Max = 41$) descriptively was in mean 2.34 points higher compared to students who took the final exam without participating in the retrieval practice ($M = 29.83$ points, $SD = 2.57$, $Min = 27$, $Max = 32$).

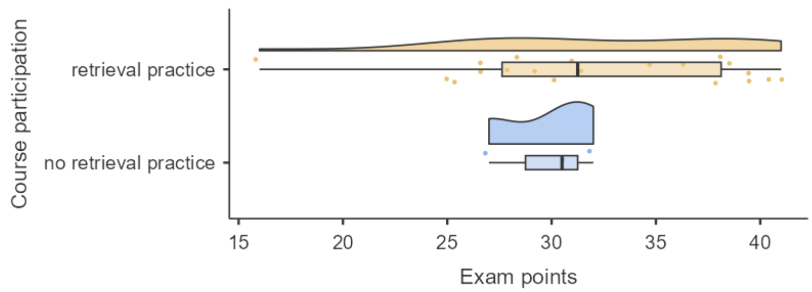

Figure 2. Achieved exam points

However, based on the low test-power ($1\text{-}\beta = .11$) for a two-tailed independent t-test and the observed small effect of Cohen's $d = 0.46$ [7] this descriptive difference could not be analyzed by statistical tests.

4.3. Retrieval task participation

On average, the $n = 20$ students responded to $M = 34.00$ of the maximum 60 items across the 10 retrieval tasks ($SD = 19.95$, $Min = 4$, $Max = 60$). Figure 3 shows the histogram with density plot.

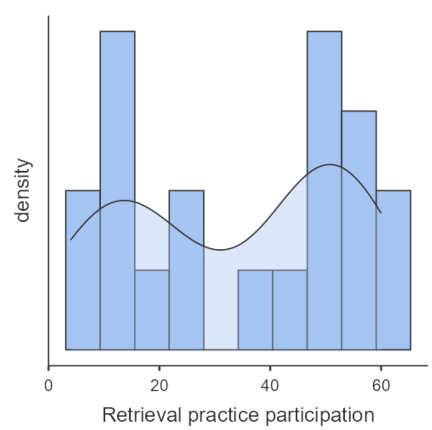

Figure 3. Retrieval task participation measured in responded items

4.4. Correlation between retrieval practice and exam performance

To test the hypothesized positive correlation between the regular participation in the spaced retrieval practice and the performance in the final exam, a one-tailed Pearson correlation between both variables was calculated. Statistically, no significant association ($r = .23$, $p = .165$, $n = 20$) between the variables could be observed (Figure 4).

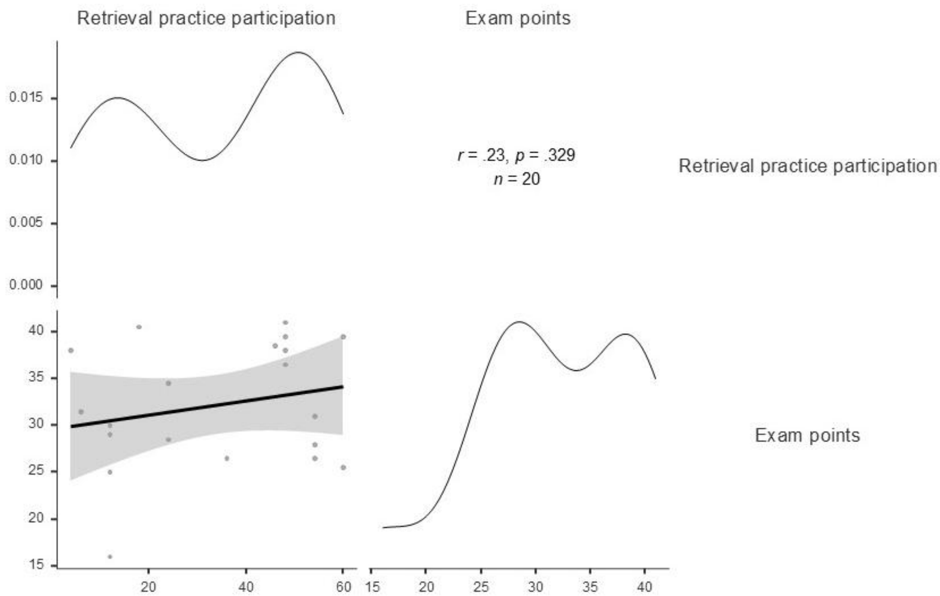

Figure 4 Scatter plot with linear regression line and confidence interval

With an a-priori-power of $1\text{-}\beta = .80$ and the gathered sample size of $n = 20$ data pairs, true effect sizes of $r \geq .53$ would have been probably detected with a one-tailed test. Therefore, any hypothetical positive impact with medium to large effect of participation in the retrieval practice on the final exam performance can be rejected.

5. Discussion and Conclusion

This contribution investigates the effects of spaced retrieval practice on students' performance in a low-stakes elective engineering course. Based on research demonstrating the superiority of retrieval over restudying for long-term learning, the course integrated reflective, elaborative, and participatory retrieval tasks after each of ten lectures. Students were required to submit responses through an LMS, which were coded according to whether the task had been completed to quantify engagement so the hypothesized association with the final exam results could be tested statistically. However, no statistical associations between the variables could be observed ($r = .23$, $p = .165$, $n = 20$). According to the a-priori test power and the gathered sample size this leads to a rejection of any hypothetical positive impact with medium to large effect of participation in the retrieval practice on the final exam performance.

An additional exploratory comparison of the final exam performance showed that descriptively a small sub-group of students ($n = 3$), who did not participate in the retrieval practice, performed in mean 2.34 points (of total 50 points without incentive bonus) lower in the final exam as the majority of the course (n = 20), who actively participated in the spaced retrieval practice across the semester. Based on the small sample size and the resulting low test-power additional data in future course iterations need to be collected to analyze the observed descriptive difference with statistical tests.

Based on these results, future work in this WIP-topic will focus on qualitative analyses of potential benefits of spaced retrieval activities after each course session on factors like reducing drop-out rate (i.e., here 18 %), belonging, elaboration of course content, motivation and feedback for one's own learning process.

References

[1] P. A. Kirschner, C. Hendrick, J. Heal, and O. Caviglioli, *How teaching happens: seminal works in teaching and teacher effectiveness and what they mean in practice*. London New York, NY: Routledge, Taylor & Francis Group, 2022. doi: 10.4324/9781003228165.

[2] P. A. Kirschner and C. Hendrick, *How learning happens: seminal works in educational psychology and what they mean in practice*, Second edition. London ; New York, NY: Routledge, Taylor & Francis Group, 2024.

[3] F. Rahman, "Reflecting on Retrieval Practice," Class Teaching: Find the bright spots. Accessed: Oct. 06, 2025. [Online]. Available: https://classteaching.wordpress.com/2022/04/08/reflecting-on-retrieval-practice/

[4] R. M. Ryan and E. L. Deci, "Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being.," *Am. Psychol.*, vol. 55, no. 1, pp. 68–78, 2000, doi: 10.1037/0003-066X.55.1.68.

[5] E. L. Deci and R. M. Ryan, "The 'What' and 'Why' of Goal Pursuits: Human Needs and the Self-Determination of Behavior," *Psychol. Inq.*, vol. 11, no. 4, pp. 227–268, Oct. 2000, doi: 10.1207/S15327965PLI1104_01.

[6] The jamovi project, *jamovi (Version 2.7.17)*. (2026). [Computer Software]. Available: https://www.jamovi.org

[7] J. Cohen, *Statistical power analysis for the behavioral sciences*, 2nd ed. Hillsdale, N.J: L. Erlbaum Associates, 1988.