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What are suitable positions for blanks in guided notes? – An investigation of students' perspectives

Frank Feudel¹ and Anja Panse²

¹Humboldt-Universität zu Berlin, feudel@math.hu-berlin.de; ²University of Paderborn, apanse@math.upb.de

One approach to address the problem that in mathematics lectures students are often busy writing, and cannot pay attention to the instructor's oral explanations might be the use of guided notes. These are a modified version of the instructor's notes that contain blanks the students have to fill in during the lecture. However, the extent to which the use of guided notes actually supports students during their note-taking probably depends on the positions of the blanks. We investigated students' perspectives on where to put the blanks by exploring in which elements of a mathematics lecture they appreciate blanks and why. The results yield some suggestions on where to put blanks and preprinted parts in a guided notes script, so that many students might benefit from guided notes for their note-taking in mathematics lectures.

Keywords: students' practices, novel approaches to teaching, note-taking, guided notes, mathematics lectures.

INTRODUCTION AND EMBEDDING OF THE RESEARCH

In traditional mathematics lectures, the instructor usually writes the definitions, theorems, and proofs on the board, and provides additional oral explanations (Artemeva & Fox, 2011). In such lectures, students are often busy copying everything correctly, and have trouble paying attention to the instructor's explanations (Freitag, 2020). This could make it hard for them to gain an understanding of the content during the lecture. However, making sense of the content after class solely on the basis of the notes taken is also a hurdle for many students, because they often only note down the definitions, theorems, and proofs the lecturer has written on the board, and not the additional oral explanations that are especially important for making sense of the content (Fukawa-Connelly et al., 2017), e.g., ideas behind the formal proofs.

One approach to address these problems might be the use of *guided notes*. These are preprinted lecture notes with blanks at certain places that the students are required to fill in as the lecture progresses (Austin et al., 2004). There are some contributions in the mathematics education literature on the effect of guided notes on students' note-taking and their learning. Cardetti et al. (2010), for instance, investigated the effect of guided notes on students' learning in a calculus course by comparing the exam results of the years 2006 and 2007. In 2006, the students had to take notes solely by themselves, while in 2007, they received parts of the instructor's notes as a script, and only had to fill in blanks (the instructor was the same in both years). Cardetti et al. (2010) then found that the students in the guided notes group attained better results although they scored lower in the SAT entry test. Furthermore, students in this group particularly liked about the guided notes that they could follow the lecturer better, and

did not have to concentrate on writing exclusively. Similar results were found by Iannone and Miller (2019) who investigated students' attitudes towards guided notes in a qualitative study. Furthermore, Iannone and Miller (2019) found that some students also noted down the instructor's oral comments or added own comments, which can particularly help to recall and to make sense of the content covered later on the basis of the notes taken. We also confirmed these findings in a course with a larger sample in a study using a mixed-methods design (Feudel & Panse, 2022). Hence, overall, the literature suggests that guided notes can be on the one hand an aid for processing the information noted – the so-called *encoding function* of note-taking (Di Vesta & Gray, 1972; Kiewra, 1989) – and for creating notes that are useful in a later review phase (the so-called *storage function*).

The extent to which guided notes actually support students during their note-taking, however, possibly depends on the positions of blanks and preprinted parts. Instructors using guided notes, for instance, often leave blanks in examples or in problems students might be able to solve by themselves or with the help of a discussion in class (Alcock, 2018; Cardetti et al., 2010; Feudel & Panse, 2022; Tonkes et al., 2009). This can foster students' active engagement with the corresponding content, and help them process the information presented already during the lecture.

But at which text modules of a guided notes script do *students* consider blanks as useful and why? Their opinions on this matter add an important further perspective on where to put blanks in a guided notes script, which can especially help to derive empirically grounded recommendations for the design of such a script. Research on this issue is, however, currently limited. In the study by Cardetti et al. (2010) mentioned above, one student appreciated that definitions had already been preprinted, and did not have to be written down. Further results on the question of where to put blanks were found by Tonkes et al. (2009). They explored to what extent students of a large first-year mathematics course appreciated blanks within a distributed script, by surveying them about the perceived usefulness of the blanks and about the extent to which the students actually filled in the blanks by themselves. The corresponding questionnaire especially contained Likert items asking whether blanks should be left in examples, definitions, or when introducing new mathematical techniques. While there was no clear preference about whether blanks should be left at the latter two positions, many students strongly agreed that blanks should be left in examples. However, the studies by Cardetti et al. (2010) and Tonkes et al. (2009) did not systematically investigate which parts of a mathematics lecture should be preprinted or left blank within a guided notes script. Furthermore, these studies did not provide reasons for students' preferences that might help to find out why students consider blanks as helpful at certain positions for their note-taking. The research we present here attempts to fill these gaps.

THEORETICAL FRAMEWORK

For investigating why students might consider blanks or preprinted material at certain positions in a guided notes script as helpful for their note-taking, we used for our data analysis a theoretical framework that particularly considers students' goals of note-

taking: the college students' theory of note-taking by Van Meter et al. (1994). On the basis of interviews with 252 students from different disciplines about their perceptions of the functions of note-taking, their regulations of note-taking, and their beliefs regarding factors that influence their note-taking, Van Meter et al. (1994) developed a framework describing different aspects of students' note-taking behavior. According to them, students have the following goals of note-taking (p. 338):

- 1) Increase attention,
- 2) Increase comprehension and memory of the lecture content,
- 3) Organize the material presented,
- 4) Inform about the content of the exam, and
- 5) Inform about solutions to practice problems and provide information relevant for written assignments.

Although Van Meter et al. (1994) restricted the last point to homework assignments in their framework (they called it “homework aid”), we want to view the term “written assignment” broader as any assignment students are required to work on in a course – also in the exam. This also fits to the data Van Meter et al. (1994) presented to goal 5, as the students they cited only mentioned that writing down worked examples helps to find solutions to similar problems, and did not refer to homework explicitly.

Besides the goals of note-taking, Van Meter et al. (1994) describe further aspects of students' note-taking in their framework: content-structure of students' notes, contextual factors affecting students' note-taking, and students' post-class processing of the notes. Since in the study presented here, we wanted to investigate at which positions of a lecture students appreciate blanks or preprinted parts in a guided notes script, and tried to explore reasons for their choices, we particularly referred to the goals of note-taking when analyzing our data. Therefore, we refrain from describing the other three aspects of students' note-taking in the framework by Van Meter et al. (1994) in detail here (for details, see Van Meter et al. (1994), p. 337).

EXTERNAL SETTING OF THE STUDY

The study took place in an introductory mathematics course called “Introduction to mathematical thinking and working” for teacher students in Germany, who will teach mathematics up to the end of secondary level. The course consisted of one 90-minute lecture and one 90-minute tutorial per week, and the students had to complete written assignments each week. The topics were elementary number theory (divisibility, prime factorization, residue classes, Euclidean algorithm), sets and relations, basic algebraic structures (groups, rings, fields), and the construction of the number systems.

The instructor taught the course on the basis of a guided notes script following the idea of Alcock (2018). Before each session, she distributed a paper script with blanks at certain positions. A sample page can be seen in Fig. 1.

7.2 Rings

Definition 7.3 (Commutative ring). A set $R \neq \emptyset$ with an addition $+$: $R \times R \rightarrow R$ and a multiplication \cdot : $R \times R \rightarrow R$ is called *commutative ring*, if

- $(R, +)$ is
- (R, \cdot) is
- (D) Distributive property:

If (R, \cdot) furthermore has a neutral element e , $(R, +, \cdot, e)$ is called commutative ring with *one*.

Example 7.19. $(\mathbb{Z}, +, \cdot, 1)$ is

Example 7.20. $(2\mathbb{Z}, +, \cdot)$ is

Example 7.21. $(\mathbb{Q}, +, \cdot, 1)$ is

Example 7.22. For each $m \in \mathbb{N}$ the set $\mathbb{Z}/m\mathbb{Z}$ of the residue classes modulo m with the corresponding addition and multiplication is

Proposition 7.5. Let $(R, +, \cdot)$ be a commutative ring and 0 the zero of $(R, +)$. Then the following holds:

(i) $\forall x, y, z \in R : (x + y)z =$

(ii) $\forall x, y, z \in R : x(y - z) =$

(iii) $\forall x \in R : 0x =$

(iv) $\forall x, y \in R : (-x)y =$

Proof.
(left blank)

Figure 1: Sample page of the guided notes script used (see also Feudel and Panse, 2022, p. 15)

The instructor made the decisions for the positions of the blanks on the basis of her teaching experience from former years, in which the course was taught traditionally. She especially left blanks at positions,

- 1) at which she assumed that students could complete the blanks by themselves,
- 2) at which she considered statements as particularly important, or
- 3) at which she suspected particular problems in making sense of the content.

During the lecture, she initiated activities at the blanks that involved the students, e.g., discussions about different options for filling the blanks (for further details see Feudel and Panse (2022)). After the lecture, she made the completed script available.

METHODS USED IN THE STUDY

For finding out at which positions students appreciate blanks and why, we surveyed the course participants during a lecture four weeks before the final exam. In this survey, we asked them to complete the following assignment:

The instructor of the course “Introduction to mathematical thinking and working” wants to use guided notes in the next semester. She informs you about this idea and adds that she is not sure about where to put the blanks. A mathematics lecture consists of different elements (definitions, theorems, proofs, explanations, and examples). Please give the instructor an advice on where to put the blanks on the basis of your experience with guided notes. Justify your advice.

61 students took part in the survey. Four of these did not provide answers to the task, i.e., they either did not refer to guided notes at all, or just wrote something general about guided notes. We excluded these four from the further analysis.

Our data analysis consisted of three steps. First, we categorized for each of the lecture elements mentioned above (definitions, theorems, proofs, explanations, and examples) if our participants appreciated blanks in this element or not. In a second step, we categorized the extent to which they appreciated blanks in the different lecture elements inductively. Hereby, we first developed the corresponding category system on the basis of the responses of the first ten cases. It was the same for each lecture element and is shown in Table 1. Then we coded the whole data with this system separately, compared the degree of agreement afterwards, and finally resolved disagreements in a discussion.

Category	Description of the category
Leave the element fully blank	A student mentions explicitly that the whole element (e.g., whole definitions) should be left blank.
Leave blanks at some positions of the element	A student mentions that parts of the lecture element should be left blank while other parts should be printed.
Leave blanks in some elements of this type	A student mentions that blanks should be left in some of the elements of a certain type (e.g., in some definitions).
Print the element	A student mentions that the element should be printed.

Table 1: Categories for the extent the students appreciated blanks in the different lecture elements (definitions, theorems, proofs, explanations, examples)

Finally, we searched within the answers for reasons why blanks in the different lecture elements were considered as helpful by the students for their note-taking. For this, we categorized their responses with content analysis (Mayring, 2015), and used the different parts of our theoretical framework (the different aspects of note-taking in the college students’ theory of note-taking, especially the goals of note-taking) as categories. Whenever a student referred to one of these aspects, e.g. a goal of note-taking, we assigned the corresponding part of the response to the respective category.

RESULTS OF THE STUDY

Table 2 shows for each of the lecture elements mentioned in the survey if our participants appreciated blanks in it or not. The extent to which they appreciated the blanks in these elements (if they mentioned an extent) is shown in Table 3.

Element	Definitions	Theorems	Proofs	Examples	Explanations
Leave blanks	70.2%	66.7%	78.9%	71.9%	24.6%
Print	22.8%	22.8%	10.5%	12,3%	40.4%
No statement	7.0%	10.5%	10.5%	15.8%	35.1%

Table 2: The share of our participants appreciating blanks in the different elements of a mathematics lecture ($N = 57$)

Element	Definitions	Theorems	Proofs	Examples	Explanations
Leave fully blank	22.8%	8.8%	12.3%	8.8%	3.5%
Leave blanks at some positions	10.5%	24.6%	14.0%	7.0%	3.5%
Leave blanks in some elements of this type	12.3%	15.8%	24.6%	14.0%	-

Table 3: The extent to which our participants appreciated blanks in the different elements of a mathematics lecture – if mentioned ($N = 57$)

We will now discuss the results for each element in detail, including possible reasons why the students appreciated blanks in the corresponding element. Since our focus lay on students' perceptions towards blanks in the different elements of a mathematics lecture, we will especially present those reasons for which the students presented a clear connection to specific facets of the respective element in their responses.

Definitions

Table 2 indicates that the majority (over 70%) of our participants appreciated blanks in definitions. Table 3 shows that many of these even wished definitions to be left completely blank. The reason most often mentioned – namely by 14 students – was that blanks in definitions can be helpful for memorizing these (memorization is one of the students' goals of note-taking), as the following quote shows:

Definitions should be written for yourself, as students should memorize these. And if you write something for yourself, it better remains in your memory than if you only read it.

The other aspect of the college students' theory of note-taking many students referred to in their statements related to definitions was the note-taking goal "understanding". Four students, for instance, argued that blanks help to gain an understanding because they are required to think when writing for themselves, as the following quote shows:

Definitions are in my opinion suitable for blanks, because by writing for yourself, you are required to think more than if you only have to listen.

Others argued that blanks in definitions provide opportunities for further explanations:

In my opinion, blanks should be left in definitions, so that these are explained in more detail, and not just passed over.

13 students wished definitions to be fully preprinted. One important reason mentioned was that mistakes may occur during the writing process in the lecture. These might be especially problematic for definitions because definitions are some kind of basis, as the following quote indicates:

Print definitions, because students still need to acquire the knowledge, and mistakes induced by writing can cause a chain reaction.

Theorems

Table 2 indicates that the majority also appreciated blanks in theorems (although the numbers might suggest that these were the same students as for definitions, this was not the case). However, Table 3 indicates that many of our participants (24.6%) wished blanks only in parts of a theorem, for instance in the claim, while the framing and the assumptions should be printed. Concerning reasons why blanks should be left in theorems, some students referred to the note-taking goal of memorization again, but much fewer than in the case of definitions (only 8 versus 14 students). Instead, in the case of theorems, the students more often referred to the goal of understanding. Besides the explanations how blanks might help to gain an understanding of the content that had been already mentioned in the case of the definitions, several students now argued that blanks provide opportunities for working with the theorems covered during the lecture. Six participants, for instance, pointed out that students might be able to deduce the claim of a theorem by themselves or together during the lecture:

You should leave blanks for the core assertion of a theorem (a mathematical formula, a deduction, an equivalence, ...), since with the help of the remaining part of the theorem, students could try to deduce this core, so that the idea behind it becomes tangible.

13 students wanted theorems to be printed (not the same 13 students as for definitions), and these mentioned several reasons. For instance, one reason was again that mistakes might occur when having to write for yourself. Another one was that *not having to write* and being able to listen instead helps to make sense of the theorems covered.

Proofs

Table 2 shows that the majority of our participants also appreciated blanks in proofs. Besides the reason that writing for yourself encourages thinking that had already been mentioned for definitions and theorems, the following reason for blanks in proofs was mentioned by several participants (6 students): having to write proofs for yourself helps to practice or might be helpful for written assignments (informing about solutions relevant for written assignments is also one of the note-taking goals by Van Meter et al. (1994)). This was, for instance, expressed in the following quote:

Perhaps, it [filling in the blanks during the lecture] helps for other assignments. You get used to proving because you never did this at school.

Nevertheless, many students only wished blanks in parts of the proofs or in some proofs (see Table 3). Ten students, for instance, mentioned that long or complicated proofs should be printed or should contain *only some blanks*, as the following quote indicates:

It depends on the situation. Long and complicated proofs should be printed, but with blanks for additional comments. Small proofs that are also useful for practicing, and which are required by the students, should contain blanks/ be left blank. This helps to internalize the proof structure.

The quote above also shows the aspect “writing for practicing” again. Other students argued that complicated proofs should be printed, so that one could work through them step by step during the lecture, or that one does not have to concentrate on writing exclusively. Those answers are again related to the note-taking goal “understanding”.

Students who wanted proofs to be fully printed argued, for example, again that *not having to write these* allows them to be attentive towards the instructor’s explanations and to reflect on the proofs, which can help to gain an understanding of these.

Examples

Just like in the study by Tonkes et al. (2009), most of our participants also appreciated blanks in examples (see Table 2). Many of them argued again that the blanks encourage thinking and/or that these offer opportunities for working actively with them during the lecture, which can again help to reach the note-taking goal “understanding”. Furthermore, just as in the case of proofs, there were students who mentioned that blanks in examples provide opportunities for practice.

Also in the case of examples, some students wished these to be already fully printed (7 students). The reasons mentioned in our survey were that examples would not require thorough thinking, that printing them allows the treatment of more examples, or again that having to write for yourself may lead to mistakes. However, one of these seven students wished an additional blank for own examples instead:

Explanations and examples can be given. But afterward, there may be a blank for own examples.

Hence, this student nevertheless wanted blank space for being able to adapt the content-structure of the notes (this wish was also expressed in general by 8 students).

Explanations

40.4% of our participants wanted explanations to be preprinted, and 35.1% did not refer to this lecture element at all in the survey (see Table 2). Since over half of the ones who did not make a statement on the element “explanations” only referred in their survey responses to those lecture elements at which they appreciated blanks, it is probably even the majority who wanted explanations to be preprinted. Reasons mentioned were, for example, that the explanations given in the guided notes script of the course were understandable immediately, that explanations do not need extra attention, that writing them down requires too much time, or that students cannot be attentive towards the explanations if they also need to write these down. Overall, the reasons why our participants wished explanations to be printed were rather diverse.

SUMMARY AND DISCUSSION

We investigated at which elements of a mathematics lecture students appreciate blanks in a guided notes script, and explored why students might consider blanks in these elements as helpful for their note-taking from the perspective of the college students' theory of note-taking by Van Meter et al. (1994). This research especially *specified perceived benefits* of blanks and preprinted material in a guided notes script for students' note-taking in a mathematics lecture (that have also been found in previous research, see section 1) *for different elements of such a mathematics lecture*.

First, our data showed that the extent to which our participants appreciated blanks in a guided notes script differed for different elements of a mathematics lecture. Just like in the study by Tonkes et al. (2009), most of our participants appreciated blanks in examples. Reasons mentioned were that having to write these for yourself encourages thinking about the content, and that blanks provide opportunities for working with them actively during the lecture. Unlike in the study of Tonkes et al. (2009), our participants also mostly appreciated blanks in definitions, especially because having to write these helps to memorize them, as further content often builds upon the definitions.

Our participants were more selective about whether blanks should be left in theorems and proofs. In theorems, several of our participants wished assertions to be printed, while claims should be left blank, as these could be conjectured by the students by themselves, which can help to make deeper sense of the theorems covered. Concerning proofs, our participants appreciated blanks especially in short proofs that they are also required to carry out in an exam, because the blanks provide opportunities for practicing, and because having to write encourages thinking about the proofs. But several students mentioned that long or complicated proofs should be printed, so that one could go through them step by step during the lecture. Finally, concerning explanations, the majority of our participants wished these to be printed. Reasons were, for example, that students could then be more attentive towards these explanations, or that writing these down would require too much time.

Our findings finally also provide some practical consequences for the implementation of guided notes into mathematics lectures. First, our data yield some suggestions on where to put blanks and preprinted parts into a guided notes script, so that many students might benefit from guided notes for their note-taking. They especially suggest that leaving blanks in examples, definitions, partly in theorems, and in short proofs might be beneficial for many students, while it might be advisable to preprint parts of longer or more complicated proofs and additional explanations. But our data also indicate that there are students who prefer those elements of a mathematics lecture to be fully printed in which the majority of our participants appreciated blanks. Reasons found were that having to concentrate on writing can make it difficult to grasp the instructor's explanatory comments, or that mistakes might occur during the writing process in the lecture. Hence, it might be advisable to also offer students the instructor's full notes after the lecture. If one follows these suggestions, many students might benefit from the use of guided notes for their note-taking in mathematics lectures.

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