



Refuting student teachers' misconceptions about multimedia learning

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Abstract

Prior research indicates that student teachers frequently have misconceptions about multimedia learning. Our experiment with $N=96$ student teachers revealed that, in contrast to standard texts, refutation texts are effective to address misconceptions about multimedia learning. However, there seems to be no added benefit of making “concessions” to student teachers' prior beliefs (i.e., two-sided argumentation) in refutation texts. Moreover, refutation texts did not promote the selection of appropriate multimedia material. This study suggests that refutation texts addressing multimedia-learning misconceptions should be applied in teacher education. Yet, further support seems needed to aid the application of the corrected knowledge.

Keywords Conceptual change · Knowledge transfer · Misconceptions · Multimedia learning · Refutation texts

Teachers are major players in the educational system. Hence, teachers' professional competence is crucial for effective educational processes (e.g., Baumert & Kunter, 2006). In fact, teachers' pedagogical-psychological knowledge – a central part of their professional competence – was shown to be an important determinant of the quality of their instruction (Voss et al., 2014). Pedagogical-psychological knowledge is subject-unspecific knowledge about instructional methods and behaviors to optimize teaching–learning situations (e.g., Voss et al., 2011). This knowledge includes knowledge about the effective design of multimedia material, that is, material that covers both text (i.e., written or spoken) and one or several pictorial representations (i.e., diagrams, graphs, or photographs; see, e.g., Mayer, 2021; Renkl & Scheiter, 2017). Actually, a large part of instruction is based on multimedia material, and teachers often select and prepare multimedia material for their lessons (e.g., McElvany et al., 2012). Yet, prior research has indicated that student and in-service

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teachers frequently have misconceptions about effective multimedia material (e.g., Dreher et al., 2016; Eitel et al., 2021). Such misconceptions can adversely affect the quality of their instruction and, as a consequence, students' achievement. For instance, when teachers have the misconception that the main purpose of pictures is to motivate learners, they might generally prefer nice-looking decorative pictures over explanatory conceptual pictures, which, however, do not support but can even impair students' learning (see, e.g., Sundararajan & Adesope, 2020). An important goal of teacher education therefore is to address such misconceptions in order to improve teachers' professional competence and thereby students' achievement.

A method that proved effective to reduce misconceptions are refutation texts, which are texts that explicitly describe misconceptions before they dispel them with the correct explanations (see, e.g., Tippett, 2010). However, student teachers might often have strong opinions and ideas about their profession, which, for example, they have formed based on their experiences as a pupil in school or as a student at university (e.g., Holt-Reynolds, 1992; see also Lortie's, 1975, conception of apprenticeship of observation). The adherence to their beliefs about "good teaching" might render the revision of misconceptions in that area a particularly tricky endeavor, and typical refutation texts might be of limited effectiveness. Research on communication and persuasion has shown that people are more likely to change their point of view after two-sided argumentation that provides arguments for and against a position than after one-sided argumentation that only advocates one position (see, e.g., Hovland et al., 1953). Hence, refutation texts that acknowledge correct aspects of a misconception before stating why the misconception is nevertheless wrong might be more helpful for knowledge revision in that area. In the present study, we investigated to what extent student teachers endorse misconceptions about multimedia learning and to what extent refutation texts with and without "concessive" statements are effective in reducing these misconceptions and thus in supporting the selection of beneficial multimedia material.

Misconceptions about multimedia learning

Misconceptions are beliefs that are not in line with the scientific, canonical conceptions. Typically, misconceptions are well embedded in learners' knowledge structures, which makes the revision of misconceptions, known as conceptual change, hard to achieve (see, e.g., Guzzetti et al., 1993; Posner et al., 1982; Vosniadou & Skopeliti, 2014). Many misconceptions exist in the area of educational psychology such as about multimedia learning. Specifically, there are four common multimedia misconceptions. First, the *learning-styles misconception* is that learners achieve higher performance when they receive instructional material that matches their learning style (e.g., visual, auditive). People who hold this misconception incorrectly assume that learners are especially skilled at processing information either visually (i.e., visualizers) or verbally (i.e., verbalizers; see, e.g., Kirschner, 2017; Pashler et al., 2008). Although it has been found that learners tend to prefer visual or verbal information, there is no empirical evidence showing that indeed "visualizers" learn better with pictures and "verbalizers" learn better with texts (e.g., Massa & Mayer, 2006; see, e.g., also An & Carr, 2017; Kirschner, 2017; Pashler et al., 2008).

Second, according to the *hemispheric-isolation misconception*, one should always present learners with textual and pictorial material so that both brain hemispheres are

activated. Presenting textual and pictorial material is considered especially important as one hemisphere is always dominant (i.e., better trained). Hence, its activation leads to better performance. This misconception includes the false belief that the two hemispheres work independently from each other (see, e.g., Howard-Jones, 2014; Tardif et al., 2015). However, the two hemispheres always work together in healthy individuals. Moreover, text processing often activates spontaneous mental imagery (Begg & Paivio, 1969), resulting in similar neurological procedures for processing texts and pictures (e.g., Begg & Paivio, 1969; Ganis et al., 2004; see, e.g., also Howard-Jones, 2014).

Third, the *naïve-summation misconception* is that the more media are applied and the more modalities are therefore involved, the better learners' knowledge acquisition. People with this misconception expect differences in retention depending on the quantity of the used modalities. For example, it is assumed that learning by doing results in the greatest retention (90%), followed by learning through saying or writing (70%), next comes leaning by watching and listening (50%), then leaning by watching only (30%) and by listening only (20%), with learning by reading resulting in the worst outcome (10%; see, e.g., Lalley & Miller, 2007; Subramony et al., 2014; Weidenmann, 2002). However, the extent of active processing and successful integration with prior knowledge rather than the mere number of media used to present information predicts retention (e.g., Craik & Tulving, 1975; see, e.g., also Mayer, 2021).

Fourth, the *motivation-primacy misconception* is that multimedia material is effective mainly because it increases learners' motivation. More precisely, learners are assumed to be more strongly motivated to engage with multimedia material than with text-only material, which fosters their learning (e.g., Eitel et al., 2019; Weidenmann, 2002). People with this misconception would add appealing pictures even when they are not directly relevant to the text content but actually distract from processing it and therefore can be detrimental to learning (seductive-details effect; see, e.g., Sundararajan & Adesope, 2020).

Previous research revealed that the described misconceptions about multimedia learning are highly prevalent among student and in-service teachers. This is especially true for the learning-styles misconception (76–98%; Dekker et al., 2012; Deligiannidi & Howard-Jones, 2015; Dündar & Gündüz, 2016; Eitel et al., 2021; Ferrero et al., 2016; Howard-Jones et al., 2009; Karakus et al., 2015; Krammer et al., 2019; Macdonald et al., 2017; Menz et al., 2020; Papadatou-Pastou et al., 2017; Pei et al., 2015; Simmonds, 2014; Tardif et al., 2015). The hemispheric-isolation misconception is also widely endorsed among these populations (49–89%; Dekker et al., 2012; Deligiannidi & Howard-Jones, 2015; Dündar & Gündüz, 2016; Düvel et al., 2017; Eitel et al., 2019, 2021; Ferrero et al., 2016; Howard-Jones et al., 2009; Karakus et al., 2015; Krammer et al., 2019; Macdonald et al., 2017; Papadatou-Pastou et al., 2017; Pei et al., 2015; Simmonds, 2014; Tardif et al., 2015). Concerning the naïve-summation misconception, there is less empirical evidence. Yet, a recent study by Eitel et al. (2021) indicated that 81% of the investigated student and in-service teachers had this misconception. Accordingly, in another study, student teachers clearly agreed above chance to the items “One always learns better from text and pictures than from text alone” (78%) and “One learns better by using multiple sensory channels than by using one sensory channel” (94%; Eitel et al., 2019). Furthermore, the motivation-primacy misconception was held by 42% of the student and in-service teachers in the recent study by Eitel et al. (2021). In line with this finding, (student) teachers considered students' motivation and interest as main reasons for using multimedia material (e.g., Dreher & Kuntze, 2015; Dreher et al., 2016). In another study, many student teachers agreed to the item that “Illustrations in math textbooks should mainly motivate” (45%; Eitel et al., 2019). Taken together, albeit the motivation-primacy misconception might be endorsed somewhat less

commonly, the described misconceptions about multimedia learning are clearly present among student and in-service teachers. Such misconceptions can be detrimental for several reasons. First, based on their misconceptions, the student teachers might apply multimedia material that is actually ineffective or even detrimental for their students' learning. Second, the student teachers might waste time and money. For example, the learning-styles misconception might cause them to spend useless time on diagnosing students' learning styles and on designing the supposedly adaptive instruction. Third, the misconceptions can impair the student teachers' own learning and professional development. Fourth, the student teachers might distribute their misconceptions among their students and colleagues. Therefore, to prevent the detrimental impact of misconceptions, they need to be addressed in teacher education.

Refutation texts as a method to address misconceptions

Research has shown that refutation texts are useful to address misconceptions and improve learners' comprehension (see, e.g., Guzzetti et al., 1993; Tippett, 2010). A refutation-text passage typically consists of three elements: (a) the description of a misconception, (b) the alert that the misconception is false, and (c) the scientifically correct information (see, e.g., Tippett, 2010). By coactivating the misconception and the related correct information in a learner's memory, the texts trigger conceptual-change processes needed to correct a misconception. Such processes include, for example, the experience of a cognitive conflict, dissatisfaction with one's knowledge, and the establishment of coherence in one's knowledge (e.g., Ariasi & Mason, 2011, 2014; Kendeou & Van den Broek, 2007; McCrudden & Kendeou, 2014; Prinz et al., 2019; Van den Broek & Kendeou, 2008; see also the Knowledge Revision Components framework by Kendeou & O'Brien, 2014).

Research on refutation texts has mostly been conducted in natural science domains, such as physics and biology, but comparatively scarcely in the area of psychology and education and with (student) teachers in particular (for exceptions, see, e.g., Ferrero, Konstantinidis, et al., 2020; Ferrero, Hardwicke, et al., 2020; Gill et al., 2004; Menz et al., 2020; Prinz et al., 2019; Salisbury-Glennon & Stevens, 1999). Prinz et al. (2019) examined student teachers and compared refutation and standard texts with regard to their effectiveness in counteracting statistical misconceptions (e.g., the misconceptions that covariance proves causality). Their results showed that reading a refutation text was more effective not only to improve the student teachers' comprehension but also to support them in applying their acquired statistical knowledge to understand an educational research report. This finding suggests that refutation texts have the potential to promote student teachers in transferring their enhanced knowledge (for transfer effects of refutation texts, see also Beker et al., 2019; Kendeou et al., 2016; Trevors et al., 2017; Weingartner & Masnick, 2019).

Moreover, Ferrero, Konstantinidis, et al. (2020) and Ferrero, Hardwicke, et al. (2020) explored to what extent pre- and in-service teachers' misconceptions about educational topics (e.g., the learning-styles misconception, the misconception that stimulus-rich environments improve pre-school children's brains) are reduced after reading typical refutation texts, refutation texts with information about the origin of the misconceptions, or no texts. Although the two refutation-text types did not differ from each other, they were more effective than no texts. However, this effect was short-lived and did not translate to sustainably impairing the pre- and in-service teachers' intentions to apply educational methods in line with the misconceptions, indicating that transfer effects were harder to achieve.

Furthermore, Menz et al. (2020) investigated the refutability of preservice teachers' misconceptions about different topics from educational psychology (e.g., the learning-styles misconception, the misconception that class size influences students' learning). They varied whether the correct information in the refutation texts was backed up with empirical studies (i.e., empirical refutation texts) or personal experiences by other teachers (i.e., anecdotal refutation texts). The results revealed that the misconceptions were diminished through reading the refutation texts. Yet, the percentage of preservice teachers who reduced their misconceptions was only low to moderate and, contrary to expectation, this reduction was more pronounced after reading the empirical than the anecdotal refutation texts. Transfer was not investigated in this study.

Overall, the reported findings suggest that, although refutation texts are useful for addressing student teachers' misconceptions, their effectiveness is limited. Hence, additional persuasive text features might be needed to change student teachers' misconceptions in the area of educational psychology and to support them in transferring their enhanced knowledge to the classroom, for example, with regard to conducive instructional decisions about multimedia material.

Concessive refutation texts as a method to address misconceptions

A reason why the refutation texts were of limited use for revising the preservice teachers' misconceptions in the study by Menz et al. (2020) and for diminishing student teachers' intentions to apply misconception-based methods in the studies by Ferrero and colleagues (Ferrero, Konstantinidis, et al., 2020; Ferrero, Hardwicke, et al., 2020) might be that, during their educational history, student teachers have gained many experiences with and beliefs about teachers, classrooms, and instruction. Personal-history-based beliefs about good teaching practices might actually be quite powerful, making the revision of misconceptions in that area particularly difficult (e.g., Holt-Reynolds, 1992). The adherence to their teaching beliefs might be an expression of student teachers' professional agency. More precisely, they might strive after preserving their professional self-concepts and after maintaining high perceived autonomy and competence (e.g., Achinstein & Ogawa, 2006; Musanti & Pence, 2010). Thus, when reading typical refutation texts stating that their pedagogical-psychological knowledge is incorrect, they might experience a threat to their professional self-concepts and perceived autonomy and competence. In this case, refutation texts might stimulate anger, which in turn leads to the rejection of the new correct information, hindering conceptual change (e.g., Trevors et al., 2016; see, e.g., also Sinatra & Seyranian, 2016). In fact, Trevors et al. (2016) found that a higher self-concept was associated with more negative emotions when reading a refutation text, which in turn impaired the acquisition of the correct knowledge. Consequently, it might be beneficial to adapt the argumentation in a refutation text in a way that fosters (student) teachers' acceptance of the correct information, for example, by means of concessions.

Research in the area of communication and persuasion has shown that the likelihood that people change their point of view is typically increased after two-sided argumentation that provides arguments for and against an advocated position compared with one-sided argumentation that only supports one position (e.g., O'Keefe, 1999; see, e.g., also Hovland et al., 1953). The former typically comprises concessions. Hence, adding concessive statements to refutation texts that acknowledge true aspects of a misconception might raise the chances of conceptual change. Such concessive refutation

texts provide more balanced feedback concerning one's knowledge and not exclusively negative feedback as typical refutation texts do. This balanced feedback might lead to lower levels of anger, fostering conceptual change (see, e.g., Molloy et al., 2012; Sinatra & Seyranian, 2016). For example, concerning the learning-styles misconception, it could be admitted that learners were found to classify themselves as visualizers or verbalizers according to their preferences before stating that it is, however, empirically unsupported that visualizers actually learn better with pictures and verbalizers with texts. Support for the notion that the argumentation structure can play a role for the effectiveness of refutation texts was provided by Kendeou et al. (2016; see also Trevors et al., 2017; Van Boekel et al., 2017). They found greater learning effects when the correct information in refutation texts was explained and justified by multiple authoritative sources (e.g., a science teacher and a scientific article) instead of by one authority or by personal opinion.

The present study

In this study, we investigated the prevalence and refutability of misconceptions about multimedia learning among student teachers. We examined student teachers rather than in-service teachers because it seems desirable to correct the misconceptions early in teachers' careers to prevent their detrimental impact.

Previous research has shown that misconceptions about multimedia learning are highly prevalent among student teachers (e.g., Eitel et al., 2021; Menz et al., 2020). We expected to replicate this finding by revealing that many of the participating student teachers endorse multimedia-learning misconceptions (Hypothesis 1).

Research generally indicates the effectiveness of refutation texts for inducing conceptual change (see, e.g., Tippett, 2010). Thus, we assumed that refutation texts would be more effective in revising misconceptions about multimedia learning than standard texts (Hypothesis 2a). In addition, given the superiority of two-sided over one-sided argumentation for persuasion (see, e.g., Hovland et al., 1953), we expected that refutation texts with concessive statements would be more effective than refutation texts without concessive statements (Hypothesis 2b).

Although transfer effects might be harder to achieve (Ferrero, Konstantinidis, et al., 2020), it has been revealed that refutation texts can support student teachers' knowledge transfer (Prinz et al., 2019). Hence, we hypothesized that transfer in terms of the conducive selection of multimedia material would be enhanced after reading refutation texts compared with after reading standard texts (Hypothesis 3a). Analogous to the effects on conceptual change, we expected that refutation texts with concessive statements would be more effective concerning transfer than refutation texts without concessive statements (Hypothesis 3b).

Attenuating feelings of anger can foster conceptual change (e.g., Trevors et al., 2016). Thus, we assumed that the beneficial effect of adding concessive statements to refutation texts on conceptual change and transfer would be driven by a reduction in anger (Hypothesis 4).

Method

Participants and design

A total of $N=96$ ($M=23.22$ years, $SD=3.04$; 24% male, 76% female, 0% diverse) students from Germany who aimed at working in the teaching profession participated in this experiment. They were recruited by offering a compensation of 10 € for taking part in this study. On average, the participants studied for 5.42 ($SD=3.91$) semesters (i.e., they were in their third year of studying). They indicated that they are going to teach at an elementary school ($n=21$), secondary school ($n=54$), or at another school type (e.g., special-education or vocational-education school, $n=21$). In Germany, student teachers typically study at least two school subjects. The most common school subjects the participants studied were German ($n=31$), mathematics ($n=27$), and English ($n=18$).

The required number of participants was determined a priori by conducting a power analysis with G*Power (Faul et al., 2007). Based on previous research (e.g., Menz et al., 2020; Prinz et al., 2019), we expected medium to large effects of the text type on conceptual change and transfer ($\alpha=0.05$, $\beta=0.20$, $\eta^2=0.10$, numerator $df=2$). The analysis resulted in a recommended sample size of 90 participants.

The participants were randomly assigned to one of three groups on an individual basis (i.e., no group assignment). There were $n=32$ participants in the standard-texts (control) group, $n=32$ participants in the refutation-texts group, and $n=32$ participants in the concessive-refutation-texts group. Depending on the experimental condition, the participants received one of three text versions that addressed the four common misconceptions about multimedia learning (i.e., learning-styles, hemispheric-isolation, naïve-summation, and motivation-primacy misconceptions).

Material

Standard texts

Each standard text contained scientifically correct information concerning one of the four misconceptions. For instance, the text on the motivation-primacy misconception stated that “Images are beneficial for learning because they can contribute to a better understanding of the learning material. For example, textual information about spatial relationships such as ‘The aorta is next to the superior vena cava’ is to some extent ambiguous. In contrast, an image specifies whether the aorta is to the left or right of the superior vena cava. If an image is presented along with a text, the image can reduce ambiguity in the text and thus prevent false interpretations of the textual information. Images can also render difficult or abstract verbal descriptions easier to understand. ...” The complete text is provided in Appendix A.

Refutation texts

Each refutation text contained the same information as the respective standard text but provided two additional sentences at the beginning. The first sentence stated the misconception (e.g., “Many people believe that images support learning because they increase learners’ motivation and interest”). The second sentence explicitly stated the incorrectness of the misconception (e.g., “However, this assumption is incorrect”; i.e., refutational cue). Thus, each refutation text comprised the three typical elements of refutation texts: (1) Description of the misconception, (2) mentioning of its incorrectness, (3) provision of the scientifically correct information (see Tippett, 2010; see also Appendix A).

Concessive refutation texts

Each concessive refutation text contained the same information as the respective refutation text but extended it by a concessive statement. This statement acknowledged that parts of the misconception might be considered correct based on empirical evidence (e.g., “It is true that learners are initially somewhat more attentive and in a better mood when interesting images are added to texts”). Then, the statement explained why the misconception is nonetheless scientifically inaccurate (e.g., “Yet, this interest is only short-lived and not necessarily beneficial to learning”; see also Appendix A).

Due to the experimental manipulation, the three text versions differed in length. On average, the standard texts comprised 143 words, the refutation texts 179 words, and the concessive refutation texts 222 words. Yet, the difficulty in terms of the readability of the text versions as indicated by the Flesch-Reading-Ease score (Flesch, 1948) was similar. The average for the standard texts was 35.00, for the refutation texts 36.50, and for the concessive refutation texts 35.25, indicating a rather high difficulty level of the texts. The scientifically correct information that was presented concerning each misconception (i.e., the third element in the refutation texts) was exactly the same in all three text versions. The texts did not include visualizations.

Measures

Pre- and posttest

The pre- and posttest were identical and consisted of the misconceptions-about-multimedia-learning questionnaire (MMLQ; Eitel et al., 2021). This questionnaire contains 32 items that participants need to agree or disagree with. In addition, participants have to indicate their certainty in each answer on a 5-point Likert-scale ranging from 0 (*very uncertain*) to 4 (*very certain*). Four target items (incorrect statements) assess each misconception, for example: “A text without illustrations does not support learning because students do not become motivated” (see Appendix B for all target items). Moreover, each misconception scale comprises four filler items (correct statements) that mention true facts related to the misconception, such as: “A picture should be added to learning material if it supports understanding”. The filler items ensure that there is an equal number of correct and incorrect statements, which reduces the impact of response tendencies.

To calculate a misconception score for the pretest and the posttest, only the 16 target items were used. Specifically, the misconception score was calculated by multiplying the values for correct and incorrect responses (i.e., not agreed to: +1, agreed to: -1) by the respective confidence ratings (i.e., 0 to 4). Very low response confidence led to a value of 0 regardless of response correctness (i.e., $\pm 1 \times 0 = 0$). Greater confidence in an incorrect response reflected stronger endorsement of a misconception and resulted in a more negative value (e.g., $-1 \times 4 = -4$). In contrast, greater confidence in a correct response indicated stronger certainty about correct knowledge and yielded a higher positive value (e.g., $+1 \times 4 = +4$). The values were averaged across all 16 items. Thus, the misconception score could range from -4 to +4.

A conceptual-change score was then calculated by subtracting the misconception score obtained in the pretest from the misconception score obtained in the posttest. The possible range for the conceptual-change score was -8 to +8, with larger scores above zero indicating greater conceptual change (e.g., if a participant scored -4 in the pretest and +4 in the posttest, the conceptual-change score would be $+4 - (-4) = +8$). We obtained acceptable and high internal consistency for the pretest ($\alpha = 0.74$) and the posttest ($\alpha = 0.84$), respectively.

Transfer test

To assess transfer, we applied a material-selection test. Overall, there were four selection tasks. In each task, the participants were provided with two alternative multimedia materials and had to indicate which of them they would choose for implementation in class. After their selection, participants had to explain their choice in a response field. For example, participants had to decide whether they would provide students with a plain text only or with a text that also includes a decorative picture (see Appendix C for an example). Participants received 1 point if they both chose the correct answer and provided a correct explanation for it (e.g., "Decorative pictures typically do not support learning but can even have detrimental effects. This is because they do not cover learning-relevant content."). Thus, participants could reach a maximum of 4 points in this test. Internal consistency of this scale was rather low ($\alpha = 0.41$). However, the rather low alpha coefficient reflects the fact that the four tasks referred to different aspects of multimedia learning. More specifically, there was only one task rather than multiple items per misconception such as in the pre- and posttests. Thus, the obtained alpha coefficient can be considered acceptable in the context of this study (cf., e.g., Schmitt, 1996; Van Loon et al., 2015). Two raters independently scored the participants' answers to the material-selection transfer test with high interrater agreement, Cohen's $\kappa = 0.91$, 95% CI [0.87, 0.96].

Anger

Participants' anger was assessed with the German version of the positive-and-negative-affect schedule (Krohne et al., 2016). Participants rated different adjectives on a 5-point Likert scale ranging from 1 (*not at all*) to 5 (*extremely*). We instructed the participants to indicate how they are feeling at the moment, thus measuring their situational affectivity. Three items assessing anger (angered, hostile, irritable) were aggregated into a scale, which showed acceptable internal consistency ($\alpha = 0.73$).

Control variables

We assessed participants' need for cognition, which reflects affinity for mental work. We used the German short version of the need-for-cognition scale consisting of 16 items, for example: "I really enjoy a task that involves coming up with new solutions to problems" (Bless et al., 1994). Participants rated each item on a 7-point Likert-scale ranging from 1 (*completely disagree*) to 7 (*completely agree*). The scale showed good internal consistency ($\alpha=0.82$). Moreover, we asked for participants' gender, age, and semester of study.

Procedure

The data collection took place in sessions with up to four participants. The same experimenter was present in all sessions. The materials were presented on a computer and the participants could progress in a self-paced manner. The experimental procedure contained seven steps. First, the participants provided informed consent and answered some demographic questions. Second, the participants completed the pretest consisting of the misconceptions-about-multimedia-learning questionnaire. Third, they filled out the need-for-cognition questionnaire. Fourth, the participants were instructed to carefully read four texts about multimedia learning (constantly in the same sequence: learning styles, motivation primacy, naïve summation, and hemispheric isolation). Depending on their condition, they read standard texts, refutation texts, or concessive refutation texts. Fifth, the participants answered questions assessing their anger. Sixth, they completed the posttest by again answering the misconceptions-about-multimedia-learning questionnaire. Seventh, the participants took the material-selection transfer test. Finally, the participants were debriefed and compensated for their participation. The experiment took about 40 min.

Results

An alpha level of 0.05 was used for all analyses. As effect size measure, we report eta-squared (η^2). Values of 0.01, 0.06, and 0.14 represent thresholds for small, medium, and large effects, respectively (Cohen, 1988). The descriptive statistics for all variables are reported in Table 1.

Preliminary analyses

Participants' gender, $\chi^2(2)=0.46$, $p=0.796$, Cramér's $V=0.07$, and need for cognition, $F(2, 93)=0.88$, $p=0.418$, $\eta^2=0.02$, did not significantly differ between the conditions. Yet, there were marginally significant differences between the conditions regarding participants' age, $F(2, 93)=2.73$, $p=0.071$, $\eta^2=0.06$, and significant differences regarding their number of semesters at university, $F(2, 89)=4.22$, $p=0.018$, $\eta^2=0.09$. However, neither of the two variables was significantly related to conceptual change (age: $r=0.02$, $p=0.866$; semester: $r=0.20$, $p=0.054$) or transfer (age: $r=-0.08$, $p=0.415$; semester: $r=0.06$, $p=0.571$). We therefore analyzed the hypotheses without adding covariates (note that similar results were obtained when running the analyses with these variables as covariates).

Table 1 Descriptive statistics for the study variables as a function of experimental condition

Variable	Standard texts <i>M (SD)</i>	Refutation texts <i>M (SD)</i>	Concessive-refutation texts <i>M (SD)</i>	All student teachers <i>M (SD)</i>
Gender	78% female, 22% male	72% female, 28% male	78% female, 22% male	76% female, 24% male
Age	22.50 (2.58)	24.19 (3.59)	22.97 (2.68)	23.22 (3.04)
No. of semester	4.38 (2.98)	7.07 (4.30)	4.97 (3.98)	5.42 (3.91)
Need for cognition	4.64 (0.65)	4.84 (0.67)	4.64 (0.78)	4.70 (0.70)
Pretest misconception score	-0.48 (0.82)	-0.58 (1.16)	-0.53 (1.02)	-0.53 (1.00)
Posttest misconception score	1.82 (1.49)	2.32 (1.18)	2.17 (0.90)	2.10 (1.22)
Conceptual-change score	2.29 (1.08)	2.90 (0.88)	2.70 (1.02)	2.63 (1.02)
Transfer score	2.94 (1.11)	2.75 (0.95)	3.09 (0.96)	2.93 (1.01)
Anger	1.25 (0.70)	1.23 (0.50)	1.16 (0.31)	1.21 (0.53)

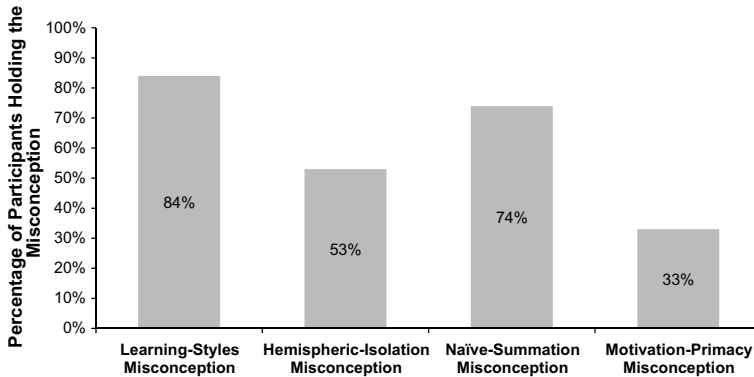


Fig. 1 Percentage of participants endorsing each misconception in the pretest

Prevalence of multimedia-learning misconceptions

Overall, the misconception score in the pretest was negative ($M = -0.53$, $SD = 1.00$), with no significant difference between the conditions, $F(2, 93) = 0.08$, $p = 0.922$, $\eta^2 < 0.01$. Thus, in line with Hypothesis 1, misconceptions about multimedia learning were present among the participants across conditions.

For each misconception, we also determined the percentage of participants revealing a negative score in the pretest, indicating the endorsement of the misconception. The results are displayed in Fig. 1. It becomes clear that all four misconceptions were prevalent with the learning-styles misconception being endorsed most commonly.

Effects on conceptual change

To test our hypotheses concerning conceptual change, we conducted planned orthogonal contrasts, which are independent linear comparisons between the conditions of a factor. First, we contrasted both refutation-texts conditions (with and without concessions) to the standard-texts condition by using the following contrast weights: standard-texts condition: -2 , refutation-texts condition: 1 , concessive-refutation-texts condition: 1 . Second, we tested whether concessions yielded an added value to refutations and applied the following contrast weights: standard-texts condition: 0 , refutation-texts condition: -1 , concessive-refutation-texts condition: 1 . Supporting Hypothesis 2a, the first contrast showed that participants in the refutation-texts conditions showed greater conceptual change than the participants in the standard-texts condition, $t(93) = 2.36$, $p = 0.020$, $\eta^2 = 0.06$. Contrary to Hypothesis 2b, however, there was no significant difference between the refutation-texts condition and the concessive-refutation-texts condition, $t(93) = -0.81$, $p = 0.422$, $\eta^2 = 0.01$ (see Fig. 2).

In an exploratory manner, we also examined our hypotheses concerning conceptual change for each of the four misconceptions separately. The results are provided in Appendix D.

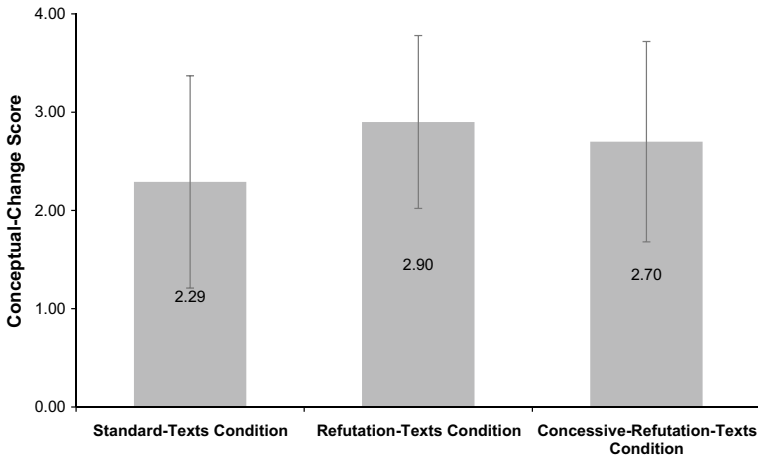


Fig. 2 Conceptual-change scores in the three experimental conditions. Error bars represent standard deviations

Effects on transfer

To test our hypotheses concerning transfer, we conducted the same planned orthogonal contrasts as with regard to conceptual change. The first contrast revealed no significant difference between the refutation-texts conditions and the standard-texts condition, $t(93) = -0.07$, $p = 0.943$, $\eta^2 < 0.01$, which does not support Hypothesis 3a. In addition, contrary to Hypothesis 3b, the concessive-refutation-texts condition did not significantly differ from the refutation-texts condition, $t(93) = 1.36$, $p = 0.176$, $\eta^2 = 0.02$.

Again, in an exploratory manner, we also examined our hypotheses concerning transfer for each of the four misconceptions separately. The results are reported in Appendix E.

Effects via anger

To test whether anger mediated effects of concessive statements in refutation texts on conceptual change and transfer, we conducted mediation analyses following the procedure by Hayes (2018) using 10,000 bootstrap samples. Experimental condition (traditional vs. concessive refutation texts) served as the independent variable, anger as the mediator variable, and the conceptual-change or the transfer score as the dependent variable. It was assumed that concessions would reduce feelings of anger occurring when reading typical refutation texts. Thus, the analyses did not include the standard-texts condition but were run on the refutation-texts and concessive-refutation-texts conditions only. Neither concerning conceptual change, $b = -0.04$, $SE = 0.06$, 95% BCa CI [-0.15, 0.08], nor concerning transfer, $b = -0.01$, $SE = 0.05$, 95% BCa CI [-0.14, 0.04], did the results reveal a significant mediation effect as the confidence intervals included zero. This outcome is not in line with Hypothesis 4. It is important to note, however, that the anger scores were very low in general in the sample, indicating floor effects (see Table 1).

Discussion

As instruction commonly covers multimedia material, it is important that teachers acquire correct knowledge about multimedia learning. Hence, the aim of this study was to provide insights into the prevalence and refutability of misconceptions about multimedia learning among student teachers.

Prevalence of multimedia-learning misconceptions

As expected, the prevalence of most misconceptions was high. Especially the learning-styles misconception was held by a large percentage of the student teachers, namely by 84%. This result is in accordance with previous research showing the wide distribution of this misconception across different groups of learners and countries (e.g., Dekker et al., 2012; Dündar & Gündüz, 2016; Eitel et al., 2021; Ferrero et al., 2016; Papadatou-Pastou et al., 2017; Pei et al., 2015; Tardif et al., 2015). Also the three other misconceptions about multimedia learning were held by a rather large percentage of the student teachers (33–74%), which is in line with prior studies (e.g., Dekker et al., 2012; Düvel et al., 2017; Eitel et al., 2019, 2021; Ferrero et al., 2016; Howard-Jones et al., 2009; Macdonald et al., 2017; Simmonds, 2014).

Refuting multimedia-learning misconceptions to promote conceptual change

As misconceptions about multimedia learning may negatively affect student teachers' as well as their pupils' learning and development, we compared three methods, namely standard texts, refutation texts, and concessive refutation texts, with regard to their effectiveness in diminishing these misconceptions. As in previous research (see, e.g., Guzzetti et al., 1993; Tippett, 2010), refutation-text types were more effective than standard texts for changing the student teachers' misconceptions about multimedia learning. This finding reinforces that refutation texts represent a useful method to be applied in teacher education when it comes to the debunking of psychological misconceptions such as about multimedia learning (e.g., Menz et al., 2020). With these texts, the prospective teachers' professional knowledge can be enhanced and potential problems in classroom instruction might be prevented.

Contrary to our assumption, there was no additional benefit for conceptual change when the refutation texts included concessive statements that acknowledged true parts of a misconception (e.g., "It is true that learners are initially somewhat more attentive and in a better mood when interesting images are added to texts") before describing why the misconception is incorrect though. Based on argumentation research (see, e.g., Hovland et al., 1953), two-sided argumentation as implemented in concessive refutation texts should be more effective for changing a belief than one-sided argumentation as used in typical refutation texts. In particular, because student teachers might often hold tenacious beliefs about good teaching practices (e.g., Holt-Reynolds, 1992), concessive refutation texts were supposed to increase the student teachers' receptiveness to the correct information. Several potential reasons can explain why we did not find the expected superior effects of concessive refutation texts.

First, that the student teachers revised their misconceptions independently of whether concessions in the refutation texts were made or not might indicate that no additional argumentation and persuasion was needed. The student teachers might not have been committed to their professional knowledge to the extent expected. As the student teachers did not yet enter the professional world, their professional self-concepts might not have been fully developed and their perceived autonomy and competence with regard to their profession might have been on a comparatively low level. Thus, they might not have felt insulted by the information contradicting their incorrect knowledge. As a consequence, the concessions were superfluous. This suggestion is also supported by our results on anger. The level of experienced anger after reading the texts was very low in all conditions, and anger did not play a mediating role for the effect of the text type on conceptual change or transfer. Overall, it seems that the student teachers did not feel devalued or offended when their knowledge was corrected. Instead, they made efficient use of the new information, emphasizing the importance of addressing the misconceptions at this level of their education. Different results might be obtained with in-service teachers who typically have high professional self-concepts and high perceived levels of autonomy and competence (e.g., Achinstein & Ogawa, 2006; Musanti & Pence, 2010).

Second, there might not only be positive but also negative effects of concessions that cancel each other out. As a consequence, no difference between refutation texts with and without concessions might have emerged in this study. Concerning the positive effects, two-sided messages can enhance trust in the source, pleasant feelings of novelty, attention and motivation, as well as positive cognitions regarding the to-be-acquired information, increasing the probability of an attitude or belief revision (e.g., Crowley & Hoyer, 1994; Eisend, 2007; Hale et al., 1991). Therefore, refutation texts that include concessions might induce these favorable conditions for conceptual change. Concerning the negative effects, research has shown that attempts to revise incorrect knowledge sometimes fail (i.e., continued-influence effect, e.g., Johnson & Seifert, 1994) or even strengthen the incorrect knowledge (i.e., backfire effect, e.g., Nyhan & Reifler, 2010, or boomerang effect, e.g., Byrne & Hart, 2009). An explanation for these effects is that the repetition of the incorrect information in order to correct it strengthens that information in memory, thereby enhancing its familiarity and thus the belief in it (e.g., Lewandowsky et al., 2012; Swire et al., 2017; see also the mere-exposure effect, e.g., Bornstein & Craver-Lemley, 2017, and the illusory-truth effect, e.g., Fazio et al., 2015).¹ Therefore, although research shows that refutation texts induce conceptual change via the simultaneous activation of a misconception and the correct information in memory (e.g., Van den Broek & Kendeou, 2008), the addition of concessions might be detrimental. More specifically, refutation texts containing concessions might sometimes backfire by once more referring to the misconceptions, which might increase the familiarity with and the belief in the misconceptions. Another possibility is that a confirmation bias occurs when reading concessions. A confirmation bias is the tendency to more or less unintentionally search for, interpret, and remember information in such a way that supports one's belief and impedes the rejection of it. Such a confirmation bias can lead to the maintenance or consolidation of a belief in the face of contrary evidence (see, e.g., Ross & Anderson, 1982). Hence, when reading concessions in a refutation text, individuals might quickly perceive this information as confirming their currently held

¹ A further explanation for the backfire effect is that individuals for whom the challenged information has high personal relevance expand effort to activate evidence that supports their original belief so as to counterargue the refutation (e.g., Lewandowsky et al., 2012; Swire et al., 2017).

incorrect knowledge and fail to deeply process the subsequent information actually contradicting it. Lastly, recent research suggests that the refutation-text effect is associated with inhibitory control, that is, the ability to block dominant but inappropriate responses. More precisely, Mason et al. (2019) found that learners with greater inhibition ability were more likely to achieve maintained conceptual change after reading a refutation text. In contrast to typical refutation texts, refutation texts with concessions might require even greater inhibition to disregard the activated but incorrect information, limiting their effectiveness. Consequently, the consideration of factors such as learners' self-concepts, perceived familiarity with the information, tendency for confirmation bias, and inhibitory control might provide crucial insights into the underlying mechanisms of concessive refutation texts.

Refuting multimedia-learning misconceptions to promote transfer

Previous research has indicated that refutation texts not only foster conceptual change but also knowledge transfer (e.g., Beker et al., 2019; Kendeou et al., 2016; Prinz et al., 2019; Trevors et al., 2017; Weingartner & Masnick, 2019). For example, Prinz et al. (2019) found that reading a refutation text enhanced student teachers' statistical knowledge as well as their application of this knowledge when it came to understanding an educational research report. However, in line with the findings by Ferrero, Konstantinidis, et al. (2020) and Ferrero, Hardwicke, et al. (2020), the present study indicates that the positive effects of refutation texts might reach their limits at the point of supporting the selection of appropriate instructional material. More precisely, although refutation texts were more effective than standard texts in helping student teachers to revise their misconceptions about multimedia learning, the texts did not lead to more beneficial multimedia-material selection. It is important that teachers put their correct knowledge into practice as their instructional behaviors directly influence students' learning (e.g., Voss et al., 2014). Hence, additional methods seem to be required to support student teachers' selection of effective instructional material after misconceptions have been resolved. For example, different materials and their pros and cons could be discussed.

Limitations and future research

First, we assessed four specific multimedia-learning misconceptions. These misconceptions were chosen because of their high prevalence (e.g., Eitel et al., 2021; Menz et al., 2020) and the importance of the respective correct knowledge for student teachers' professional development. Although it can be expected that our results hold true for other misconceptions in the area of educational psychology as well (e.g., the misconceptions that there are critical periods in childhood after which certain things can no longer be learned), this should be investigated in future research.

Second, we focused on student teachers because it seems desirable to correct psychological misconceptions early in their careers so as to prevent that the misconceptions further consolidate, impair their learning, and harm their teaching practices. Nonetheless, as indicated previously, it would deepen our knowledge on the topic to repeat the study with in-service teachers. In-service teachers are likely more committed to their professional knowledge so that an added benefit of concessions in refutation texts might arise. Moreover, the

participants' professional self-concepts and perceived autonomy and competence should be assessed in future research to investigate their impact.

Third, this study did not include a delayed posttest. Therefore, it is unclear how robust the observed conceptual change is and whether a further intervention (e.g., follow-up reflection, peer discussion) would be needed to achieve long-lasting change. Consequently, future research should apply a second posttest several weeks or months after the initial refutation of the misconceptions.

Fourth, we measured the objective readability of the texts with the Flesch-Reading-Ease score (Flesch, 1948) to ensure a similar level of text difficulty across the three text versions. However, the subjective rather than the objective level of difficulty might play a role for learners' text processing. Hence, future studies might assess learners' perceived text difficulty to examine its role for the effectiveness of the different text versions (see, e.g., Ferrero, Hardwicke, et al., 2020).

Fifth, we kept the text presentation order constant for all participants. Future studies might present the texts randomized to examine whether the order has any impact on the effects. Yet, because the text topics are independent from each other and the texts are rather short, we do not expect sequence or fatigue effects to play a role.

Finally, in the tasks assessing transfer, the student teachers had to choose between two fixed sets of multimedia material. More unstructured tasks such as having participants to prepare and give lessons with multimedia by themselves without further scaffolding would provide interesting behavioral data.

Conclusion

Our study reveals that misconceptions about multimedia learning are highly prevalent among student teachers and that refutation texts support the revision of these misconceptions. These findings have important practical implications. Teacher educators should be aware of the fact that their student teachers likely endorse psychological misconceptions that need to be addressed. Otherwise, the misconceptions are going to persist during the student teachers' period of study and beyond during their professional lives. Particularly when considering that teachers typically educate thousands of pupils along their careers, it becomes clear that teachers' misconceptions in the area of educational psychology can have detrimental implications. This emphasizes the importance of preventing that teachers enter their professional lives with misconceptions in that area. To do so, refutation texts are a promising instructional method.

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Data availability The data and material are available from the corresponding author on request.

Code availability Not applicable.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The study was implemented in alignment with the principles of ethical and professional conduct of the German Psychological Society (DGPs).

Consent to participate The data was collected and saved anonymously. Informed consent was obtained from all participants.

Consent for publication All authors agreed to publication of the article in its current form.

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