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EDITED BY
Ricarda Rübben,
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University of Wuppertal, Germany
Falk Radisch,
University of Rostock, Germany

*CORRESPONDENCE
Erik Meij
th.meij@windesheim.nl

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Exploring teachers' beliefs about learning principles

Erik Meij[1,2]*, Anneke Smits[2] and Martijn Meeter[1]

[1]Human Movement and Education Division, Vrije Universiteit Amsterdam, Amsterdam, Netherlands,
[2]LEARN! Research Institute, Windesheim University of Applied Sciences, Zwolle, Netherlands

Teachers hold conscious or subconscious beliefs about pedagogy, education and learning that are deeply ingrained and steer their daily pedagogical reasoning. Numerous studies have aimed to reveal these beliefs, but whether specifically principles of learning are part of teachers' beliefs has not yet been addressed. This study investigated whether teachers' explicit and implicit beliefs are consistent with scientific principles of learning. For that purpose, a multiple-component online test was constructed. In an implicit word association task, participants had to categorize words as being linked with learning or not, with the responses and their speed analyzed for what they might reveal about beliefs about learning. In an explicit classroom statement task, participants were presented with a statement about actions in the classroom that either were or were not in line with principles of learning and asked how firmly they believed it was true (or false) and on what basis. Finally, in an explicit principle endorsement task, participants were asked how convinced they were that 10 principles of learning taken from an American Psychological Association consensus list were correct. A total of 257 pre-service and in-service teachers, teacher educators and educational scientists completed the test. Results showed that on average, 80% of the teachers did believe that the 10 principles presented were correct, although not all were endorsed with a high degree of conviction. In the implicit word association task, response times for words associated with learning were generally shorter than for other types of school related words. One principle, that adaptation of existing concepts is a slow process, was an anomaly on both tasks. Correlations between the implicit and explicit results were low. In conclusion, implicit and explicit responses reflect teacher beliefs about learning that are generally consistent with scientific learning principles, although the backing for some principles is less strong than for others.

KEYWORDS

teacher beliefs, implicit measurement, learning theories, principles of learning, teacher education

Introduction

> *Learning in schools does happen [...] and an understanding of the ways in which we believe learning takes place is really essential for those responsible for planning and implementation of programs of learning: Teachers.* (Pritchard, 2017, p. xi)

The above quote makes two things clear: Learning happens at school and the key figure in it is the teacher. Obviously, a teacher uses knowledge about learning to make the appropriate choices for a lesson that leads to learning (e.g., American Psychological Association, 2015; Schunk, 2020; Shulman, 1986; Veal and MaKinster, 1999). This choice making is called pedagogical reasoning and action (Loughran, 2019; Shulman, 1987). Ideally, teachers make their teaching decisions based on their knowledge about teaching and learning known as evidence based teaching. That knowledge can originate from formal taught theories derived from research and from experienced practice.

However, daily classroom practice does not always adhere to this ideal; teaching decisions are more often based on beliefs that originate from personal past classroom experiences (e.g., Markauskaite and Goodyear, 2014; Mellor, 2021). Although theories about learning are a standard component of most teacher education curricula, it seems notoriously difficult to let (newly) taught theory prevail over these personal beliefs in daily classroom practice decisions (e.g., Fives et al., 2015; Gleeson and Davison, 2016; Basckin et al., 2021; Meij et al., 2022). Positive practice experiences may lead indeed to a willingness to become more innovative, develop insight in the relation between theory and experiences (Mellor, 2021) and provide an opportunity to *unlearn* possible flawed beliefs (Gleeson and Davison, 2016). However, beginning teachers start in an environment that often aligns with their pre-existing beliefs. Even when a teacher initially is unwilling to conform to a–rigid – school system, social factors such as marginalization and isolation may still lead to fitting in, hampering personal development (Mellor, 2021). The theoretical knowledge formally taught then seems to "wash out" as already described 40 years ago by Zeichner and Tabachnick (1981) leading to gradual disconnection of formal theory and daily practice and more unconscious decisions based on implicit beliefs. This 'gap between theory and practice' is widely known in many fields as a persistent problem (Arteaga et al., 2024) and for teacher education is acknowledged (e.g., Korthagen, 2007) and broadly researched (e.g., Resch and Schrittesser, 2023; Hennissen et al., 2017; Korthagen, 2007; Korthagen and Kessels, 1999).

Internationally the focus in education has shifted in the last few decades from teacher- and content-centered instruction toward more student-centered learning (Schreurs and Dumbraveanu, 2014). Formative action around the question "What did your pupils actually *learn* today?" now gets more attention in teacher education and classroom practice. Formative action on this question requires theory based pedagogical reasoning with therewith knowledge of theories and principles of *learning* (PoLs) like, e.g., the role of prior-knowledge, cognitive load theory or knowledge about recalling and forgetting. More practical and comprehensible textbooks about learning in education for teachers have become available that stay close to daily classroom practice (e.g., Didau, 2015; Kirschner and Hendrick, 2024; Willingham, 2021) and even textbooks with more condensed PoLs that student teachers can use for tomorrow's lesson plan (e.g., Bates, 2019; Surma et al., 2019). Such texts that communicate research findings in an accessible and comprehensible way and are easily applicable probably have contributed to the shift of focus on learning in the classroom (Schmidt, 2024).

However, what if these principles clash with the conscious or subconscious convictions and beliefs teachers hold about teaching and learning, which are deeply ingrained (Pajares, 1992).

According to conceptual change theory, deeply rooted concepts linked with numerous personal experiences, beliefs and mental images are difficult to change (Vosniadou et al., 2020). Introducing new ideas about learning, such as those presented during teacher training, do not plainly replace existing concepts. Conceptual change is slow and stepwise and even parallel concepts may exist next to each other for a long time (Vosniadou, 2013). Therefore, daily pedagogical decisions are often persistently based on teachers' implicit personal ideas of "good teaching" from their own past school experiences (e.g., Karavas and Drossou, 2010; Loughran, 2019; Zakaria and Ab Wahid, 2023).

While many teachers may thus teach lessons based on beliefs rather than evidence-based pedagogical reasoning, certainly not all these lessons are ineffective. The question arises: if these lessons are effective nonetheless, do those guiding beliefs perhaps reflect correct scientific principles of learning? The objective of this study is to explore such beliefs about principles of learning. The question we focus on in this paper is: *Are teachers' beliefs, either implicit or explicit consistent with scientific principles of learning?* Such insights might be directly helpful in finding more effective teaching strategies for theories and principles of learning being offered in teacher education as the prior knowledge of starters and teacher educators can hinder as well as enforce each other.

Teacher beliefs

Teacher beliefs are considered important because of their strong influence on teacher behavior and classroom outcomes (Sykes, 2011; Zakaria and Ab Wahid, 2023). Several studies have reported on the content and significance of implicit prior knowledge for deliberate pedagogical reasoning. (e.g., Glogger-Frey et al., 2018; Markauskaite and Goodyear, 2014). McAfee and Hoffman (2021, p. 1) stated that teacher beliefs are especially "egregious because teacher beliefs exert direct influence upon curriculum development, pedagogy, and the construction of effective learning environments."

Teacher beliefs have sustained a huge body of literature (2,100 articles reported in eric.ed.gov in 2023) and inspired a dedicated research handbook (Fives and Gregoire Gil, 2015). Despite this abundant research, the construct of teacher belief has always been considered ambiguous (Pajares, 1992). In their lucid summary of the literature, Fives and Buehl stated:

> *…defining the term 'teachers' beliefs' is not difficult because several authors have done so. What is difficult is getting authors to consistently define and use terms within and across fields that examine these.* (2012, p. 473)

Nonetheless, there are some unresolved issues: whether beliefs differ from knowledge, whether they are fixed or prone to change in different contexts (Fives and Buehl, 2012) and how they are part of larger belief systems. Beliefs are seldomly tightly delimited, and are assumed to be elements of a larger complex and interrelated belief system. Lawson et al. (2019) stated that such a system is constantly evolving and that change in one belief is unlikely to be decisive for changing behavior. Fives and Buehl (2012) also highlighted the importance of recognizing that a belief is likely to be interconnected with other beliefs (e.g., Vosniadou et al., 2020). Fives et al. (2015) warned that such interlocking beliefs must first be clarified, as they might blur the research on teachers' beliefs, for example, whether the focus is on beliefs about learning or about teaching.

A distinction is typically made between implicit and explicit beliefs (Sykes, 2011; Wilcox-Herzog et al., 2015). *Implicit beliefs* are considered to develop and reside in the subconscious, whereas *explicit beliefs* are deliberately formed and known to the holder. Implicit beliefs are forged gradually through experience, while explicit beliefs can be formed through personal experiences as well as information acquired by the individual. Implicit beliefs are therefore not malleable by consciously available information, whereas explicit beliefs are (Wilcox-Herzog et al., 2015). Ellis (2005) defined criteria to distinguish the two when operationalized for measurement. Responses based on implicit knowledge are more based on the feel than on rules, emerge under time pressure, focus more on meaning than on form, are more consistent and stem from early learning.

McAfee and Hoffman (2021) stated that many teachers fail to realize that their messages to their students may not be evidence-based, but reflect their personally entrenched beliefs developed over a lifetime. They showed that many teacher beliefs about teaching and learning are based on misconceptions about pertinent topics in educational psychology, illustrated by an extensive list of misconceptions and neuro-myths. They stated that although misconceptions are often studied, misconceptions among teachers regarding effective teaching are neglected. That is where our focus lies. We aim to focus on implicit as well as explicit beliefs about the basic principles of learning.

Measuring implicit beliefs

Measuring implicit knowledge, beliefs, attitudes or convictions is fraught with difficulties. One inherent difficulty is that when outsiders probe for an implicit belief, it becomes conscious and stops being implicit (Sykes, 2011). Therefore, indirect methods of eliciting implicit beliefs have been developed. *Indirect measurement* means "an inference of a construct without instruction to report it, assuming no introspective awareness of the construct" (Greenwald and Lai, 2020, p. 420).

In measures of implicit memory, response speed is assumed to reflect the strength of implicit beliefs, associations, or memories. The reasoning behind this is that reaction time correlates with accessibility, reflecting the strength of implicit associations. Accessibility has been defined as:

> The likelihood that an attitude will be automatically activated from memory on encountering the attitude object. Accessibility is assumed to depend on the strength of the associative link in memory between the representation of the object and the evaluation of the object: the stronger the memory link between the object and its evaluation, the more quickly the attitude will come to mind. Attitudes that come quickly to mind are believed to be better guides to behavior (American Psychological Association, 2018, attitude-accessibility).

Holland et al. (2003) investigated this correlation between response time (RT) and attitude strength. They concluded that the strength of a conviction may indeed be inferred from its accessibility and, thus, from RT data.

Whether an indirect measure truly reflects only implicit beliefs is very hard to establish, and often highly questionable (Corneille and Hütter, 2020). Moreover, how direct and indirect measures relate is still an open question. Low correlations between direct and indirect measurements around a construct were reported by Nosek and Smyth (2007) and by van den Bergh et al. (2010). For implicit memory, Martens and Wolters (2002) found that circumstances reducing explicit memory also reduced some forms of implicit memory (known as repetition priming), but not another (semantic priming). This suggests that whether direct and indirect measures of a given construct are correlated is an open question.

Nevertheless, Jost (2019) advocated that, despite the concerns, attempting to measure implicit beliefs remains necessary because of the importance that educational scientists attribute to such implicit teacher beliefs. Denessen et al. (2022) reviewed 49 studies and concluded that indirect measurements remain potentially interesting for understanding teachers' attitudes.

This study

In sum, teachers' pedagogical reasoning is affected by their beliefs, some of which may be implicit. Eliciting implicit beliefs requires indirect measurement, even though the reverse inference – that implicit measures reflect only implicit beliefs – is invalid. We therefore set out to explore indirect measurement of beliefs about principles of learning and their relations with direct measurement. The first research question is:

> RQ1: *What do indirect measurement based on reaction times reveal about beliefs about principles of learning?*

To answer this question, we constructed a word association task, where we studied if participants associated words with learning by measuring RTs. These words were taken from principles of learning that summarize scientific knowledge on learning (American Psychological Association, 2015). We then tested to what extend the participants could apply these principles in classroom situations and whether they endorsed them and how strongly, to answer the following question:

> RQ2: *To what extent are teachers convinced of validated principles about learning?*

Then we tested whether the outcomes of the indirect and direct measurements were correlated:

> RQ3: *Is there a correlation between the results of the indirect and direct measurements?*

Positive correlations would be an indication that the beliefs are recognized both consciously and unconsciously and that someone's knowledge and conviction are probably based on equal principles. Negative or absence of a correlation would imply that–later–acquired knowledge is not in accordance with–prior–beliefs and that parallel concepts might be present.

Materials and methods

Participants

Responses were collected from an exploratory online test instrument in Dutch that was open for everyone in the Netherlands, between March and July 2022. There was no active recruitment other than sending invitations to all teacher education institutes in the country with the question if they would bring it to the attention. Anyone aware of the survey was allowed to respond to it; a specific question asked for participants' role of which one option was 'not in education'. Due to legislation on personal data, only characteristics that could be relevant to the research were asked and therefore not, for example, home or workplace and gender. It was strictly stated that participation was anonymously. Participants all provided informed consent before starting. The study was performed in accordance with protocol #2019–151, approved by ethical review board of Vrije Universiteit Amsterdam, Faculty of Behaviour and Movement Sciences.

Five hundred and sixteen people started the survey, 307 of whom fully completed all four components (see Instrument). Ten participants answered with below-chance accuracy in the implicit word association task (all questions had equal answers and/or all reaction times < 10 ms) or had an average reaction time ±3 *SD* outside the overall average RT and these participants were dropped from the sample. Since the study was about teacher beliefs, 22 participants who indicated that they do not work in education were excluded for this study. This was also done for the 16 participants who indicated "I'm reading really slowly," since in this study response speed was the central dependent measure. (These participants were indeed 10.5% slower than the others, on average.)

This left 257 participants: 60 pre-service teachers, 104 teachers from secondary education, seven teachers from vocational education, 28 teachers from higher education, 47 teacher educators and 11 educational researchers. Participants taught a variety of different subjects. Ages ranged from 17 to 68 years ($M = 38.5$, $SD = 14.5$). Student teachers had completed 1 to 4 years of internships (average 2.1). Teachers had an average of 15.5 years of classroom experience ($SD = 11.1$).

Development and validation of the instrument

To be able to compare different measures of teacher beliefs about learning in educational contexts, a standard for comparison is needed on which there is broad consensus, despite the bewildering variety of learning theories (Bates, 2019; Schunk, 2020). Because in the Dutch teacher education no standard on theories or principles of learning exists (Meij et al., 2022), we therefore based our instrument on the American Psychological Association report, *Top 20 Principles from Psychology for PreK-12 Teaching and Learning* (American Psychological Association, 2015), developed as a consensus summary of what is known about learning. This had as an additional advantage that the principles reflect established relationships between a specific teaching strategy and student achievement (Woolfolk, 2020). Therefore, they translated more easily into words and statements close to daily teaching practice.

For this study, an online instrument was developed that consisted of four parts. The instrument was in Dutch, for translation see the Appendix. All four parts were based on the same set of principles of learning (American Psychological Association, 2015). To keep the length of the questionnaire manageable, we focused on five cognitive and five affective learning principles. Since the APA Top-20 list does not include principles that deal with the influence of memory in a school situation, we decided to use three APA Top-20 cognitive principles and added two other principles that have been extensively studied in education. The first is that "Verbal and visual information combined in learning can mutually activate each other," based on dual coding theory (Paivio, 1991) and empirically tested in education (e.g., Wu and Puntambekar, 2012). The second is "Adapting existing (mis) conceptions is a slow and laborious process," which stems from conceptual change theory (Duit and Treagust, 2012; Vosniadou, 2013). Next to these, we chose the cognitive PoLs: "Long-term learning and skill is largely dependent on practice" (APA Principle 5: practice); "Prior knowledge affects learning" (APA Principle 2: prior knowledge); and "Learning is based on context and transfer of contexts needs to be facilitated" (APA Principle 4: context). The affective PoLs we chose were: "Students beliefs about their intelligence affect their cognitive learning" (APA Principle 1: belief); "Students tend to enjoy and learn better when they are intrinsically motivated" (APA Principle 9: motivation); "Emotional well-being influences educational performance" (APA Principle 15: emotion); 'Setting goals that are short-term (proximal), specific, and moderately challenging enhances motivation more than establishing goals that are long-term (distal), general, and overly challenging' (APA, # 12); and Learning is situated within multiple social contexts. (APA, #13).

The choice for these PoLs was twofold: they are each easily identifiable on their own, but they have a strong interrelationship between them. Uncovering such interconnection in responses may point to deeper understanding of learning mechanisms. For instance, if someone understands the role of both prior knowledge and transfer, an even deeper insight could be expected where learning is seen *as* the transfer of previous experiences (Bransford et al., 2000) and that is the base of conceptual change (Vosniadou, 2013).

The first test was a word association task. Respondents were shown 60 words, one at a time, and asked "Do you *associate … with learning?*." Participants were asked to answer YES or NO by clicking as fast as possible, and response time (RT) was measured in milliseconds. Of the total of 60 words, 20 "learning words" were about learning and were directly derived from the selected principles. Twenty "school words" were about school, but not specifically about learning (e.g., white board or classroom), and 20 "nonsense words" were related to neither education nor learning (e.g., chicken or car door). For all words, see the Appendix.

Selection and validation of the 20 learning words was done by asking eight experts on learning (four researchers and four teacher educators, all in the educational sciences) which of the 40 candidate words best captured the essence of each of the 10 learning principles. The 20 words that scored highest and were also rated as unambiguous were presented to a second group of 14 experts, who were asked which words matched which of the 10 principles. More than 90% of the words were placed correctly for eight principles; for the other two principles, words were chosen after a discussion with 4 of the respondents. The 40 words not related to learning (school words and nonsense words) were picked by the first author and checked for familiarity and being in the right category by the other two authors. Words were presented in a fixed random order for all participants.

The second part of the instrument, which will not be discussed further, was a classroom-situation query that consisted of two open-ended questions in which a daily situation in the classroom was briefly described, followed by the question, "What do you think is going on here?." Qualitative results are to be reported in a separate paper.

The third component was a classroom statement task, which was a three-tier test in which respondents were presented with 10 statements, one at a time, describing either recommended or non-recommended teaching practices. Each statement was based on one of the 10 chosen principles of learning. Six items were formulated to be consistent with the principle, and the other four were inconsistent. In the first tier, respondents were asked to use a 5-point Likert scale to rate how confident they were that the statement was true or false. In the second tier, respondents were asked why the statement was true or false, and were given four options to choose from, with the correct answer corresponding to the learning principle. (The third tier asked participants to rate their confidence in their choice, but this will not be discussed further). For the statements, see the Appendix.

Validation of this component took place in two steps. The authors formulated three statements for each learning principle, and these were presented to the same eight experts who validated the previous task. They were asked which statement they thought was the best educational translation of the principle. We picked the one chosen by most experts. Then, four of the statements were reversed to represent a non-recommended practice. The statements were then presented to 10 pre-service teachers, who were asked why they thought the statements were correct or not. In this way, an inventory was made of possible correct and incorrect answers (misconceptions). The literature was checked for all statements to determine whether more known misconceptions existed. In that case, they were also included as alternative answers in the Tier 2 question. If the student interviews and the literature did not provide four possible answers, the first author formulated the remaining response options.

The fourth component was an explicit principle endorsement questionnaire. The 10 learning principles were translated literally into Dutch and presented as such. Respondents then had to rate the extent to which they were convinced the principles were correct, on a scale from 0 to 100%.

The order of presentation of the four components of the test, from more implicit to more explicit, was chosen to minimize the likelihood of answers on one component influencing those on the later ones (e.g., first presenting the principle endorsement questionnaire might have made learning principles salient, altering the answers for the other components).

Procedure

The four assessment components described were offered in one online test using Qualtrics© software, under the title, "What Do I know about Learning?" (in Dutch: 'Wat weet ik van leren?'). It was described to participants as a 15- to 20-min anonymous test for scientific purposes. We promised participants that they would receive their personal score in terms of percentage of correct answers for Components 1 and 3 upon completion.

A pilot run was done in November 2021 with 34 respondents. Some minor language changes were done, and the test was launched in March 2022 and given wide publicity via email and social media.

Data analysis

First, the data from the word association task were cleaned. Scores for the first four words on the test were discarded because the RTs were notably longer than all others, due to participants getting started up. The last word from the test also had to be deleted because the tool did not correctly register the RT on this item. Therefore, only 19 learning words, 18 school words and 18 nonsense words remained. Then logarithms of RTs were taken, and values more than 3*SD* below or above participants' personal average RT were winsorized at 3*SD*. In order to reliably compare representative results, RTs of incorrect responses for the 19 learning words (= NO) were removed. To remove the effect of personal response speed, RTs for learning words were divided by the average personal RT for the 18 nonsense words. These values are further referred to as 'corrected RTs'.

To address RQ1, (*What do indirect measurement based on reaction times reveal about beliefs about principles of learning?*), RTs and number of correct YES-answers were calculated for the word association task, and the results for the three different word categories were compared.

For RQ2 concerning the degree to which teachers explicitly endorse validated learning principles, we analyzed scores on the classroom statement test and the principle endorsements separately for each principle. We then calculated the average scores for all 10 principles, as well as for the cognitive and affective principles separately.

For RQ3, correlations were calculated between RTs and percentage of correct YES-answers of the word association task and the levels of agreement from the principle endorsement questionnaire.

Results

What do indirect measurement based on reaction times reveal about beliefs about principles of learning?

For this research question, we focused on RTs and percentage of correct YES-answers from the implicit word task. "Correct YES-answers" refers to all YES keystrokes indicating that participants associated a learning word with learning. If strength of beliefs can indeed be inferred from shorter RTs (Holland et al., 2003), shorter RTs for responding YES for the learning words would indicate stronger belief that a learning word was indeed a learning-related word. Participants with beliefs in alignment with the learning principles should react faster to the learning words than the school words that might not be strongly linked with convictions about learning. Shorter RTs and fewer YES-answers would be expected for the nonsense words that are clearly not connected with school or learning. Mean RTs and % Yes-answers for the different word categories are in Table 1.

As expected, RTs for the learning words were on average shorter than for the school words, $t(256) = -7.57$, $p < 0.001$, suggesting that the former were more strongly associated with learning. Nonsense

TABLE 1 Average reaction time and percentage of words for which participant answered that it is connected with learning (YES-answers) for the three categories of words in the word association task ($N = 257$).

Word categories	Mean RT (SD) [log sec] (SD)	Mean YES-answers [%] (SD)
Learning words ($n = 19$)	0.262 (0.091)	92 (11)
School words ($n = 18$)	0.289 (0.099)	67 (22)
Nonsense words ($n = 18$)	0.266 (0.110)	7 (11)

words (e.g., chicken, car door) also had shorter RTs than the school words, $t(256) = -4.58$, $p < 0.001$. The learning words and nonsense words had comparable RTs, $t(256) = 1.06$, $p = 0.288$. In addition, for the learning words, the percentage of correct YES-answers was correlated, with RT (Pearson $r = -0.385$, $p < 0.001$).

Having established that participants associated the learning words with learning, we analyzed the learning words by type of learning principle, as shown in Table 2.

Table 2 shows the data for individual principles. As explained, raw RTs reflect personal reaction speed and other cognitive factors and therefore are unreliable measures of cognition. (In fact, we found a relation between raw RT and age: $r = 0.295$, $p < 0.001$). Therefore, we normalized RTs by dividing those for the learning words by the average personal RT for the 18 nonsense words, which produced values around 1, with lower values indicating faster responses for the learning words and higher accessibility. We can see that words linked with some principles had shorter RTs and might thus reflect stronger beliefs, such as "Repetition is important," "Motivation affects learning" and "Students' personal beliefs about their capacities affect their learning," In contrast, learning words related to the principle concerning "Dual coding theory," "Slow conceptual change" and "Emotions affect learning" had longer RTs. These RT-values also corresponded to higher and lower percentages of YES-answers, respectively, which was in line with by the positive and statistically significant Pearson correlation between RTs for learning words and correct YES-answers ($r = -0.385$, $p = 0.000$).

A repeated-measures ANOVA was conducted for the corrected RTs to check for differences across the individual learning principles. Mauchly's test for sphericity was violated, so a Greenhouse–Geisser correction ($\varepsilon = 0.70$) was applied. Differences between the principles were found, $F(6.3, 793) = 20.7$, $p < 0.001$, $\eta_p^2 = 0.141$. Post-hoc testing (Bonferroni) showed a cluster of principles with short RTs that did not mutually differ (motivation, repetition and context) and one with long RTs (dual coding, conceptual change and emotions). The RTs for the other principles differed significantly from those two clusters.

TABLE 2 Average values for RTs, correct YES-answers for words related to the 10 learning principles ($N = 257$).

Principle	Mean corrected RT (two words per principle) [1]	SD's away from overall mean	Correct YES-answers [%]
All 10 principles	1.017 *SD* = 0.214	--	92.6
5 Cognitive principles	1.049	0.15	91.1
5 Affective principles	0.990	−0.13	94.0
Prior knowledge	1.018	<0.01	95.7
Repetition	0.911	−0.50	96.9
Learning context[1]	0.936	−0.38	98.8
Conceptual change	1.013	0.02	84.6
Dual coding	1.132	0.54	85.8
Beliefs	0.923	−0.44	95.3
Motivation	0.901	−0.54	98.8
Goals	0.990	−0.13	97.5
Emotions	1.103	0.40	89.5
Social context	0.991	−0.12	89.3

[1]For this principle, only one word was available. Numbers are not averages.

To what extent are teachers explicitly convinced of principles about learning?

This question was answered based on responses to the principle endorsement questionnaire, where participants were asked how convinced they were about the selected learning principles. A second indicator was the response to the classroom statement test, with educational situation statements based on the selected learning principles. Table 3 shows the total results from these two components for all 10 principles, and then the results are split up for cognitive and affective principles. The three variables reported were all significantly positively correlated; Pearson r values were between 0.200 and 0.596; all $p < 0.05$.

These results showed that, on average, participants were 85% convinced of the validity of the learning principles and were 83% confident about the truth of the principles expressed in the classroom statement test. A difference between cognitive and affective principles was observed, where participants seemed more convinced of the latter. When asked if the classroom statements were true or not and why, around 78% connected the classroom situation with the correct principle of learning. However, when results were analyzed per principle, further differences emerged (see Table 4).

Differences between confidence levels and endorsements were tested by repeated measures ANOVA. For both tests, Mauchly's test for sphericity was violated. A Greenhouse–Geisser correction ($\varepsilon = 0.73$) was applied to the mean classroom statement scores. Confidence in the correctness of the classroom statements was not equal for all principles, $F(6.58, 1{,}670) = 360$, $p < 0.001$, $\eta_p^2 = 0.586$. *Post-hoc* testing (Bonferroni) showed that means differed significantly for most pairs of principles, except between motivation, goals, emotions and social context and between motivation, emotion and prior knowledge.

A Greenhouse–Geisser correction ($\varepsilon = 0.5$) was applied for the mean scores for conviction regarding principle endorsement. The scores were not equal across the principles, $F(5.48, 762) = 58.1$, $p < 0.001$, $\eta_p^2 = 0.296$. Post-hoc testing (Bonferroni) again showed significant mutual differences between the means for most principles, except between dual coding, goals, contexts and repetition and between prior knowledge, beliefs, motivation and social.

The learning principle from conceptual change theory (that adapting existing misconceptions is a difficult and time-consuming process) was an anomaly, because it received the lowest scores for both mean conviction regarding principle endorsement and percentage correct for classroom statement.

The correlations between confidence in the truth of the classroom statements and conviction about principle endorsement showed weak to medium values, as reported in Table 5. The classroom statements were, of course, just one possible example of using the principle in a classroom situation. It may be that a larger sample of classroom situations would have led to higher correlations. Alternatively, it is also possible that endorsing abstractly phrased principles is not the same as being confident about their truth with regard to their application in

TABLE 3 Mean strength of beliefs and % correct answers from all participants (N = 257).

	Level of confidence (%) in truth of classroom statements Mean (SD)	% Correct on classroom statements	Level of conviction about principle endorsement (%) Mean (SD)
All 10 principles	83.0 (8.2)	77.6	84.5 (8.8)
5 cognitive principles	82.5 (11)	79.8	79.7 (11)
5 affective principles	83.4 (8.5)	75.4	89.6 (9.3)
Comparison of cognitive and affective	$t(256) = -1.32$, $p = 0.019$	$t(256) = 2.59$, $p = 0.010$	$t(256) = -10.8$, $p < 0.001$

the classroom. The correlation between confidence in the truth of the classroom statements and correctly answering their tier 2 why-question was much higher ($r = 0.620$, $p = 0.01$), showing that participants were relatively well-calibrated in their confidence.

Is there a correlation between the results of indirect and direct measurements?

We then calculated correlations between the mean RTs from the word association task, on the one hand, and the level of conviction about principle endorsement and confidence in the truth of classroom statements. Table 6 shows correlations between the RTs and proportion of correct YES-answers in the word association task on the one hand and level of conviction about the principles and confidence about the truth of the classroom statements on the other, all split for the five cognitive and the five affective principles and per principle.

For the average of all principles (affective and cognitive), small- to medium-sized correlations were found between the average corrected RT, the percentage of correct YES-answers and the level of conviction regarding endorsement of the principles. For the two categories and for the individual principles, no correlation reached significance between corrected RT and the other variables. However, for most principles, the number of correct YES-answers was significantly positively correlated with the level of conviction regarding endorsement of the principle (although not with the classroom statement outcomes).

Discussion and conclusion

This study examined whether indirect measures might reveal teachers' beliefs regarding learning principles. Based on the difference in reaction times (RTs) between learning- and school-words in the word association task, and given the correlations found—though modest—the instrument appears to offer at least a partial indication of beliefs related to the tested principles.

Taken together, participants' high confidence in the truth of classroom-related statements, their explicit endorsement of scientific principles, the frequency of correct affirmative responses, and the RTs suggest that most teachers' belief systems broadly align with selected principles of learning. However, this conclusion must remain limited in scope, as it is unclear whether implicit beliefs influence explicit responses (cf. repetition priming; Martens and Wolters, 2002). Whether such beliefs predict classroom behavior remains an open question and requires further investigation (Denessen et al., 2022).

Two narrower observations in the data might support one more narrow conclusion. First, RTs for previously learned words are similar to those for nonsense words, while the number of correct YES-responses remains high (Table 1), suggesting that participants needed little time to produce positive responses. According to Holland et al. (2003), such a pattern may reflect strong implicit associations. Secondly, although endorsement of principles does not correlate with RTs, it does correlate with the number of YES-responses (Table 6). This implies that participants *can recognize* the principles, but the method used does not allow a quantifiable assessment *of the extend* of that recognition. These results are consistent with previous findings that demonstrate difficulty in establishing strong correlations between explicit and implicit measures (Nosek and Smyth, 2007; van den Bergh et al., 2010).

Interestingly, the affective principles elicited shorter reaction times and a higher percentage of YES-answers than the cognitive principles. Although the origins of beliefs lie beyond the scope of this study, it is worth considering possible implications for teacher education. Are affective learning principles explicitly taught? The textbooks mentioned in the introduction seldomly address them explicitly; the APA's *Top 20 Principles of Learning* is one of the few exceptions. Moreover, affective principles are probably least used in explicit pedagogical reasoning. Nevertheless, our data suggest they are more readily associated with learning, perhaps indicating that they form part of a broader, more deeply embedded belief system (Pajares, 1992). This would align with Ellis's (2005) criteria, suggesting such beliefs have developed from early experiences both within and beyond formal education.

When considering specific principles, it is striking that all measures about conceptual change theory scored consistently lower. Conceptual change theory describes that changing existing (mis) conceptions is challenging and requires time and repetition. This notion does not appear to be a prevalent belief among the participants. Curiously, the two foundational principles underpinning the theory—"Prior knowledge determines learning" and "Long-term knowledge depends on repetition and practicing"—were strongly endorsed, indicating they are firmly held. Two explanations are possible: either teachers were never explicitly introduced to the theory and thus lack any associative memory for it, or they are familiar with it but reject it. Both scenarios would likely result in longer RTs and a higher proportion of NO-responses, which was indeed observed. A lack of knowledge then would show a variety of correct and wrong answers across both the classroom and endorsement tasks, whereas disagreement would lead to low endorsement but more correct responses in the classroom task. The results appear more consistent with the latter explanation, though no definitive conclusion can be drawn. This interpretation is supported by previous findings showing that science teacher educators in the Netherlands were largely unfamiliar with conceptual change theory and, in some cases, even skeptical of its value (Meij, 2018).

TABLE 4 Mean confidence/conviction levels and % correct answers per principle (*N* = 257).

Principle code	Principle as described in the literature	Level of confidence in truth of classroom statements (%) Mean (SD)	% Correct classroom statements	Level of conviction about principle endorsement (%) Mean (SD)
Prior knowledge	What students already know affects their learning. (APA, #2)	94.1 (12)	91.4	89.2 (13)
Repetition	Acquiring long-term knowledge and skill is largely dependent on practice. (APA, #5)	84.0 (27)	95.7	82.1 (17)
Learning context	Learning is based on context, so generalizing learning to new contexts is not spontaneous, but instead needs to be facilitated. (APA, #4)	86.2 (22)	77.4	81.8 (15)
Conceptual change	Learning requires substantial change in existing concepts, which happens slowly and in a stepwise manner (Vosniadou, 2013)	67.5 (24)	52.5	61.4 (26)
Dual coding	Cognition involves verbal and non-verbal information that reinforce each other (Paivio, 1991)	80.6 (19)	82.1	82.9 (16)
Beliefs	Students' beliefs or perceptions about intelligence and ability affect their cognitive functioning and learning. (APA, #1)	63.2 (24)	68.5	89.1 (13)
Motivation	Students tend to enjoy learning and perform better when they are more intrinsically than extrinsically motivated to achieve. (APA, #9)	90.0 (15)	91.8	90.4 (15)
Goals	Setting goals that are short-term (proximal), specific, and moderately challenging enhances motivation more than establishing goals that are long-term (distal), general, and overly challenging. (APA, # 12)	87.4 (16)	61.9	84.6 (17)
Emotions	Emotional well-being influences educational performance, learning, and development. (APA, #15)	90.6 (13)	85.2	94.9 (10)
Social context	Learning is situated within multiple social contexts. (APA, #13)	86.0 (16)	69.6	89.0 (14)

Another principle that scored somewhat lower was dual coding. It was included because it is part of everyday classroom practice and teacher education programs (e.g., Bates, 2019; Wu and Puntambekar, 2012), although it is not featured among the APA's *Top 20 Principles*. Given its relevance to everyday practice, we expected it to be readily accessible; however, the results showed particularly long RTs, despite high accuracy in the classroom and endorsement tasks (above 80%). This may indicate that the words we used in the association task were not sufficiently representative of the principle itself.

Regarding the role of emotions, a notable discrepancy emerged between the different measures. While the terms "emotion" and "positive" received high rates of YES-answers, they were not rapidly associated with learning. Nonetheless, teachers demonstrated clear agreement, in both endorsement and classroom contexts, that emotional well-being influences learning outcomes. This suggests that while teachers are able to reason about the importance of emotion, the accessibility of this association remains relatively weak. It is plausible that such general principles have been learned inductively through experience, rather than through formal instruction, resulting in a degree of context dependency, as noted by Fives and Buehl (2012).

The role of motivation scored highest across all three test components. Although correlations between implicit and explicit measures were generally low, they were slightly higher for motivation words and statements. Intriguingly, while motivation is often prioritized in teacher discourse, the empirical literature presents a more cautious picture. Meta-analyses tend to report only modest effects of motivation on academic achievement (Vu et al., 2022), and some researchers argue that these may be attributable to methodological artefacts (Núñez-Regueiro et al., 2022). Nonetheless, our findings suggest that motivation holds a central place in teachers' belief systems.

Overall, the study supports the view that teachers implicitly hold both accurate and inaccurate beliefs regarding learning principles. Given the significant influence such beliefs exert on pedagogical reasoning, we argue that teacher education should begin by explicitly eliciting student teachers' existing conceptions before introducing theoretical models. This recommendation has been made repeatedly (e.g., Korthagen and Kessels, 1999; Wilcox-Herzog et al., 2015; Gleeson and Davison, 2016; Shahzad et al., 2017; Qiu et al., 2021) and is reinforced by our earlier research (Meij et al., 2022), in which teacher educators expressed uncertainty about the practical application of formal learning theories. Moreover, when flawed beliefs or misconceptions are elicited early, conceptual change becomes more attainable. Confronting these beliefs through authentic practice-based conflict from day one is likely more effective than offering correct theory that risks becoming parallel concepts thus widening the gap between theory and practice.

We join Jost (2019) and Denessen et al. (2022), who advocated that, despite the concerns, indirect measurement remains necessary given the impact these beliefs have on teachers' pedagogical reasoning.

Limitations of the study

Although the instruments were carefully constructed and validated in several rounds, they are still some way from being a universal validated instrument. Teachers' beliefs regarding the APA principles of learning have not been investigated before. Hence, we made a first attempt to explore these beliefs. Although the words, statements, and questions we offered participants in the test were checked by experts and in the pilot round, participants' personal interpretations may have played a role. In particular, participants may have interpreted our classroom statements and the principles in various ways based on their own practice. The relatively high number of participants would mean that idiosyncrasies in interpretations would average out, but such disparate interpretations may be a factor in the low correlations between scores on explicit and implicit test components.

The low correlations between explicit and implicit measurements replicate those in other studies and feed into an open discussion (Nosek and Smyth, 2007). Whether these are a result of low test reliability cannot be established. Another explanation for low correlations may be that teachers unconsciously hold beliefs that contradict what they say consciously. For example, social desirability may have affected their explicit endorsement of the statement that emotional well-being influences learning, when this is not truly their belief.

The decision to have the data collection be through a "test yourself" module via the internet was intended to make it more motivating than just another scientific questionnaire. Although participants were clearly informed about the use of data and asked for consent, this might have led to selection bias against people with higher test anxiety, leading to a sample with more participants who are self-assured and/or are explicitly outspoken about their knowledge and convictions.

Although there are thus some methodological limitations, these do not negate our exploratory findings that most of the participants endorsed, implicitly as well as explicitly, the selected principles that reflect the science of learning.

TABLE 5 Pearson correlations between confidence about the truth of classroom statements and conviction regarding principle endorsement (N = 257).

Principle	Correlation between level of confidence in truth of and level of conviction regarding endorsement of principle Pearson r (p)
Average for all 10 principles	0.258 (<0.001)
Average for 5 cognitive principles	0.120 (0.039)
Average for 5 affective principles	0.314 (<0.001)
Prior knowledge	0.204 (0.01)
Repetition	ns
Learning context	ns
Conceptual change	0.351 (<0.001)
Dual coding	ns
Beliefs	ns
Motivation	ns
Goals	0.307 (<0.001)
Emotions	0.177 (0.029)
Social context	0.382 (<0.001)

ns means not significant.

TABLE 6 Pearson correlations between implicit word association test outcomes (corrected mean RT and number of correct YES-answers) and outcomes of direct tests (level of conviction about endorsement of principles and confidence in the truth classroom statements) (N = 257).

Principle	Corrected mean RT/ Level of conviction regarding endorsement of principle r (p)	Mean number of correct YES-answers/ Level of conviction regarding endorsement of principle r (p)	Corrected mean RT/Level of confidence in truth of classroom statement r (p)	Mean number correct YES-answers/Level of confidence in truth of classroom statement r (p)
All 10 principles	−0.180 (0.026)	0.327 (<0.001)	ns	ns
5 cognitive	ns	0.170 (0.035)	ns	ns
5 affective	ns	0.408 (<0.001)	−0.127 (0.043)	0.161 (0.010)
Prior knowledge	ns	ns	ns	ns
Repetition	ns	ns	ns	ns
Learning context	ns	0.141 (0.05)	ns	ns
Conceptual change	ns	0.139 (0.059)	ns	ns
Dual coding	ns	0.130 (0.077)	ns	ns
Beliefs	ns	0.242 (<0.001)	ns	ns
Motivation	ns	0.456 (<0.001)	ns	ns
Goals	ns	0.131 (0.073)	ns	ns
Emotions	ns	0.142 (0.050)	ns	ns
Social context	ns	0.294 (<0.001)	ns	ns

ns means not significant.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

EM: Conceptualization, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. MM: Conceptualization, Methodology, Supervision, Writing – review & editing. AS: Conceptualization, Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2025.1576123/full#supplementary-material

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