Mathematical worldviews and preferences for learning styles of student teachers

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Abstract: This paper presents the results of a study conducted with 188 student teachers who were surveyed using questionnaires to assess their mathematical worldviews and learning style preferences. Linear models are used to examine group differences and connections between worldviews and learning styles. Contrary to expectations, dynamically oriented worldviews (process-related, reality-oriented) are not consistently linked to constructivist learning preferences, and static worldviews (schematic, formalistic and Platonic views) are not always linked to transmissive learning preferences. A cluster analysis can explain these discrepancies. Three clusters of similar size are found, some of which unexpectedly combine world views and learning styles: 1) Discovery Learners in the Realm of Pure Mathematics, 2) Mixed Discovery-Transmissive Learners with Real-World Orientation, and 3) Pure Transmissive Learners. The discovery of these clusters offers a broader approach to the learning preferences and the mathematical worldviews of student teachers than the scales and their assessment alone can provide. It can offer the basis for longitudinal studies to examine transitions between these clusters, especially since the cross-sectional study at hand indicates that cluster type 3 occurs in higher semesters and cluster type 2 in lower ones, which argues against an increase in constructivist beliefs on learning preferences during the study courses.

Keywords: mathematics education, teacher students, mathematical worldviews, learning preferences, constructivism

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1 Introduction

Studies on beliefs have a long tradition in educational research (Hofer & Pintrich, 1997). Especially in mathematics education (Thompson, 1992; Philipp, 2007; Hannula et al., 2019), beliefs are seen as a hinge between perceptions and understandings of mathematics and implications on learning and teaching: “Beliefs – to be interpreted as an individual’s understandings and feelings that shape the ways that the individual conceptualizes and engages in mathematical behavior” (Schoenfeld, 1985, p. 358). On the one hand, we are focused on *epistemological beliefs,* which can be described as general assumptions about the nature of mathematics and about the way in which mathematical knowledge can be gained (Hofer & Pintrich, 1997). Our background theory on epistemological beliefs relies on *mathematical worldviews* (Grigutsch, Raatz,

& Törner, 1998). On the other hand, we are interested in what we call *preferences for learning styles,* i. e. preferences for learning methods on the base of the assumption that these methods are seen to be useful to learn, understand, and apply mathematics (Girnat & Hascher, 2021). Suppose the "hinge function" of beliefs is true. In that case, there should be a connection between epistemological beliefs and preferences for learning styles, since assumptions about the nature and accessibility of mathematical objects and insights are likely to influence which learning style one considers conducive to gaining mathematical knowledge. In the study at hand, we combine these approaches to investigate both types of beliefs simultaneously with respect to a sample of 188 student teachers.

2 Theoretical background and previous findings

The initial work of Grigutsch, Raatz, & Törner (1998) established a data-based theory of mathematical worldviews that consists of four to five aspects: the *formalism* aspect, the *schema/tool* aspect, the *process* aspect, the *application* aspect, and, in some studies, the *Platonism* aspect (Grigutsch & Törner, 1998). These aspects can be described as follows: The formalism aspect is characterised by strength and rigor; "The schema aspect focuses on schemata and algorithms in mathematics and describes mathematics as a 'complete' set of knowledge: mathematics is a 'toolbox' and a 'formula package'" (Grigutsch & Törner, 1998, p. 15); the process aspect highlights creativity and individual explorations; the application aspect points out the practical use of mathematics in real-world situations; the Platonism aspect is based on Plato's philosophy of mathematics with a rigid distinction between the "real" (physical) world and a "transcendent" world of mathematical ideas, implying a certain kind of epistemology: Mathematical ideas pre-exist in an immutable world of its own kind and mathematical insights can only be gained by a non-empirical access to this world following the ways of axioms, logic, and deduction. The formalism, the Platonism, and the schema aspect are described as *static*, the process and application aspect as *dynamic,* with respect to the way mathematicians, teachers or students deal with mathematics. Empirical studies show positive correlations within these two groups and negative between them. As far as the Platonism aspect is integrated, the correlation structure is more complex (Grigutsch & Törner, 1998, p. 26):

Table 1. Correlations between aspects of mathematical worldviews (Grigutsch & Törner, 1998, p. 26, coefficients in the upper triangle matrix; significance levels in the lower half)

	Formalism	**Schema**	**Process**	**Application**	**Platonism**
Formalism	1	0.235*	-0.072	0.223*	-0.221*
Schema	0.018	1	-0.052	-0.169	0.198*
Process	0.477	0.605	1	0.234	0.003
Application	0.020	0.094	0.019	1	0.147
Platonism	0.027	0.049	0.978	0.144	1

The second part of our theoretical background is based on an investigation of preferences for mathematical learning styles. It was part of the first Swiss national assessment of mathematical competencies in grade 9 (Angelone & Keller, 2019). The idea of examining learning styles is founded in the distinction between transmissive and constructivist learning: “Constructivists claim that knowledge is actively constructed by the child, not passively received from the environment.” (Lesh & Doerr, 2003, p. 532). The transmissive view can be defined as the opposite: Mathematical knowledge is perceived passively by learners, presented by teachers via theory, rules, and examples, and it is internalised by learners via memorising, repeating, and following the rules. The core concept of constructivism, the discovery learning method, is typically enriched by several additions, e. g. integrating real-world problems, negotiation techniques of social and communicative learning, problem solving, open tasks, self-differentiation, cognitive activation, and self-directed learning (Duit, 1995; Leuders, 2015). The Swiss assessment had to limit the number of scales to four. The choice fell on constructivist discovery learning methods in general (disc.learn), communicative learning (com.learn) and references to real-world problems (real.ref). These constructivist concepts and the preferences for transmissive learning (trans.learn) were operationalised by scales of three to eight items. The correlations, including the mathematical test, are as follows:

Table 1. Correlations between preferences for learnings style and the test (Girnat & Hascher, 2021, p. 535, coefficients in the upper triangle matrix; significance levels in the lower half)

	Test	**Trans.learn**	**Disc.learn**	**Real.ref**	**Com.learn**
Test	1	0.181***	0.242***	0.025**	−0.136***
Trans.learn	<0.001	1	0.420***	0.511***	0.174***
Disc.learn	<0.001	<0.001	1	0.442***	0.204***
Real.ref	<0.01	<0.001	<0.001	1	0.412***
Com.learn	<0.001	<0.001	<0.001	<0.001	1

Regarding the findings on mathematical worldviews (table 1), the results presented in table 2 might be surprising: It would be plausible that there had to be two groups of factors like the dynamic and static aspects of the worldviews: the transmissive preferences as a "static" and all the other preferences as a "dynamic" group of constructivist aspects, since the dynamic aspects seem to be related to constructivist learning styles as their "background philosophy", whereas the static aspects are supposed to go hand in hand with preferences for transmissive learning styles. However, discovery learning methods are positively correlated (0.420***) to transmissive preferences, whereas some of the constructivist aspects are low correlated.

In addition to the correlations, the Swiss assessment detected some remarkable gender differences. To make the differences comparable to other studies, they were expressed by regarding the male pupils as the references group and measuring the difference to the female group by Cohen's *d* (Cohen, 1988):

Table 2. Gender differences in Girnat & Hascher (2021), p. 536, expressed in Cohen's *d*

	Cohen's *d* (female group – male group)	**Significance level**
Test	-0.151***	<0.001
Trans.learn	0.247***	<0.001
Disc.learn	-0.560***	<0.001
Real.ref	-0.217***	<0.001
Com.learn	-0.034*	<0.05

If we now try to find a connection between mathematical worldviews and learning styles, Mui's (2004) review on personal epistemology and mathematics shows that learners' epistemological beliefs, such as the constructivist versus positivist view, decisively shape their learning behaviour. Constructivist views encourage an active, exploratory approach to maths, while positivist perspectives support more passive forms of learning. In addition, different mathematical worldviews should influence the choice of forms of knowledge and learning methods. Learners who view maths as variable and dynamic value different ways of knowing and tend to have specific learning styles that reflect these views (Russell, 2016). Sloan (2002) showed that a global learning style of prospective teachers correlates with higher maths anxiety. This anxiety can in turn influence the way maths is perceived and preferred to be learnt. Which suggests that certain learning styles may harmonise better with certain worldviews. As further research, it is explicitly mentioned that 'the relationship between domain-specific beliefs and students' use of various types of learning strategies' (Muis, 2004, p. 366) should be investigated. This is where this study comes in and attempts to empirically investigate the connection between mathematical worldviews and learning styles in mathematics.

3 Research questions

Our study is motivated by two interests: 1) We want to examine relations between mathematical worldviews and preferences for learning styles. Thus, we integrated items of both topics in the same questionnaire. Regarding previous findings, the (assumed) relationship between dynamic and static aspects of worldviews and transmissive and constructivist learning preferences is unclear. Our study is designed to clarify this issue. 2) The Swiss assessment reveals substantial gender differences. We aim to examine these differences in the context of student teachers, and, additionally, to explore other relevant subgroups. Thus, we can give first indications of how such views evolve and which subset decides to become a math teacher. However, our work provides no definitive answers in this regard, but it could motivate further research. The research questions are as follows:

- RQ1: How are the scales of mathematical worldviews and learning preferences of student teachers, and how are they correlated?
- RQ2: Can the scales of mathematical worldviews explain learning preferences as predictors in linear models with learning preferences as dependent variables?
- RQ3: Are there differences with respect to mathematical worldviews and learning preferences, and differences depending on gender, study program or semester?
- RQ4: Can cluster analysis be used to exploratively find groups that are homogeneous in themselves but differ from each other?

4 Materials, sample, and methods

The items are based on two sources: To examine mathematical worldviews, we adapted the items of Baumert et al. (2009) to student teachers. The items from Girnat & Hascher (2021) were adapted analogously. We added the *social learning* aspect (soc.learn), which was previously unavailable due to space constraints. This aspect is also seen as part of the constructivist learning preferences. Table 4 shows examples of the items, translated into English, and Cronbach's α as a measure of the internal consistency of the scales (Cronbach, 1951). All items have a four-point Likert scale from "strongly disagree" (1) to "strongly agree" (4). Thus, the theoretical mean of each item is 2.5.

Table 3. Examples for Items used in the study and α-values of the scales.

Scale	Item (example)	α
Formalism	Mathematics is characterised by rigor, namely a definitional rigor and a formal rigor of mathematical argumentation.	0.69
Schema	Mathematics consists of learning, remembering, and applying.	0.63
Process	In mathematics, you can find and try out many things yourself.	0.63
Application	Many mathematical topics have a practical use.	0.74
Platonism	Mathematical laws have always existed independently of humans.	0.79
Trans.learn	I learn math well when the lecturers show us a new procedure and we repeat this procedure using lots of examples.	0.74
Disc.learn	I like math problems where you can discover math for yourself.	0.81
Real.ref	Math problems should always have a topic from everyday life and not be purely mathematical.	0.76
Com.learn	Mathematics often only becomes clear to me when I talk to fellow students about the subject.	0.82
Soc.learn	I like working on mathematical problems in groups when studying mathematics.	0.78

The study was carried out at the University of Hildesheim in January 2024. Teacher training courses in mathematics are offered for primary schools (grades 1 to 4) and lower secondary schools (grades 5 to 10). Both types comprise a total of 10 semesters, 6 of which are in the bachelor's degree programme (B.Sc.) and 4 in the master's degree programme (M.Ed.): In the B.Sc. programme, the courses in mathematics predominate, and there are hardly any differences between the primary and secondary courses. In the M.Ed. programme, courses in mathematics education and internships at schools predominate, and the differences between the primary and secondary courses are large (University of Hildesheim, 2022). Only about 50% of first-year students complete their studies. Almost all dropouts occur before completing the B.Sc. degree. If changes are considered depending on the semester of study, then it should be borne in mind that the changes may not be due to actual changes, but also to the fact that students with certain beliefs might have already dropped out of their studies. 188 student teachers took part in the survey, 127 females, 51 males, and 0 diverse ones; 147 with a focus on primary schools and 41 with a focus on secondary schools; 140 in the bachelor's degree and 48 in the master's degree. The number of semesters ranged from 1 to 10, with an average of 3.13.

Two methods were used for the evaluation: structural equation models for group differences, correlations, and linear models (Loehlin & Beaujean, 2017; R Core Team, 2024) with the R package *lavaan* (Rosseel, 2012) and explorative cluster analyses with the R package *mclust* (Scrucca et al., 2023). Since structural equation models are used, all reported correlations are latent ones and all linear models are based on latent variables. Missing values (less than 5% per item) are treated by full information maximum likelihood methods. The structural equation models are estimated using a robust maximum likelihood method that compensates for deviations from a normal distribution.

5 Results

In table 5, the means of the scales are reported. The scales range from 1 to 4; their theoretical mean is 2.5. The means and standard deviations are given for the sample; the means and the differences to the reference group (male, primary school, and bachelor's degree) are given for the subgroups (gender, focus, and degree) using Cohen's *d* with significance indications by asterisks (* for $p<0.05$, ** for $p<0.01$, and *** for $p<0.001$).

Table 4. Group differences (means and Cohen's *d* for the differences)

Scale	**Sample**	**Gender**			**Study Focus**			**Degree**		
	mean (SD)	**male**	**fem.**	***d***	**prim.**	**sec.**	***d***	**B.Sc.**	**M.Ed.**	***d***
Formalism	2.93 (0.45)	2.97	2.93	-0.09	2.93	2.99	0.15	2.93	3.00	0.17
Schema	2.73 (0.50)	2.88	2.70	-0.32**	2.72	2.87	0.31	2.78	2.60	-0.37*
Process	3.06 (0.47)	2.97	3.08	0.24	3.06	3.07	0.03	3.09	2.96	-0.27
Application	3.13 (0.52)	3.09	3.13	0.08	3.10	3.21	0.22	3.12	3.11	-0.01
Platonism	2.95 (0.59)	3.09	2.92	-0.29	2.96	3.03	0.11	2.99	2.92	-0.12
Trans.learn	3.13 (0.44)	2.98	3.17	0.47**	3.14	3.12	0.02	3.13	3.04	-0.21
Disc.learn	2.49 (0.68)	2.70	2.39	-0.31**	2.45	2.72	0.41*	2.50	2.48	-0.04
Real.ref	2.93 (0.59)	2.88	2.97	0.17	2.94	2.90	-0.08	2.89	3.09	0.35*
Com.learn	2.86 (0.64)	2.86	2.85	-0,02	2.83	2.89	0.09	2.82	2.92	0.16
Soc.learn	3.03 (0.69)	3.12	2.98	-0,20	3.01	2.97	-0.06	3.03	2.95	-0.12

Regarding the entire sample, it is noticeable that (almost) all scales have a mean above the theoretical average as this has been the case for the beliefs in the data of Baumert et al. (2009) as well. Among the learning style preferences, discovery learning has the lowest value at 2.49, and transmissive learning has the highest at 3.13. Among the mathematical worldviews, the process and application aspects are the most pronounced at 3.06 and 3.13. This result may be surprising, since the dynamic aspect stands out among the worldviews, but discovery learning, which is closest to it "philosophically", does not.

When it comes to gender differences, the situation is similar as for ninth grade pupils (table 3): Female student teachers prefer transmissive methods (d = 0.47**) and value discovery learning styles less (d = -0.31**), although they place less importance on the schema aspect (d = -0.32**). The differences between the foci of the studies are rather inconspicuous. When comparing bachelor's and master's students, it is noticeable that there are generally few differences. Only the schema aspect is valued less in the master's programme (d = -0.37*) and realistic applications are valued more highly (d = 0.35*).

Table 5. Latent correlations between all scales of the questionnaire (coefficients in the upper triangle matrix; significance levels in the lower half)

	Form.	**Sch.**	**Pro.**	**Appl.**	**Plat.**	**Trans.**	**Disc.**	**Real.**	**Com.**	**Soc.**
Form.	1	0.417**	-0.150	0.022	0.196	0.294*	0.083	0.212	-0.004	-0.050
Sch.	0.003	1	-0.305*	-0.068	0.131	0.694***	-0.269*	0.381*	0.199	0.304**
Pro.	0.219	0.026	1	0.751***	0.301*	-0.083	0.706***	-0.241*	0.123	0.383**
Appl.	0.829	0.525	<0.001	1	0.163	-0.093	0.421***	-0.013	0.115	0.171
Plat.	0.077	0.231	0.012	0.119	1	-0,032	0,230*	-0.053	0.098	0.128
Trans.	0.412	<0.001	0.502	0.367	0.748	1	-0.397**	0.281*	0.064	0.130
Disc.	<0.001	0.018	<0.001	<0.001	0.026	0.001	1	-0.207*	0.049	0.264*
Real.	0.058	0.006	0.051	0.894	0.570	0.025		1	0.282*	0.177
Com.	0.968	0.066	0.247	0.236	0.314	0.515	0.605	0.014	1	0.730***
Soc.	0,614	0.008	0.001	0.075	0.177	0.179	0.004	0.065	<0.001	1

Table 6 lists the latent correlations. If we look at mathematical worldviews, the situation is similar, but more pronounced than in the study of Grigutsch and Törner (table 1): The correlation between the application and the process aspect is higher, and the correlation between the schema and the process aspect is negative. The Platonism aspect surprises with its consistently positive correlations. If we look at the learning styles on their own, the situation differs from that among ninth grade pupils (table 2): Transmissive and discovery learning styles are negatively correlated. This result is more likely to be expected theoretically. What is surprising, however, is that the connection to reality correlates positively with transmissive learning styles and negatively with discovery learning preferences. If we combine learning styles and worldviews, we get results that one might have assumed theoretically: Discovery learning correlates clearly positively with the process and application aspect and transmissive learning with the formalism and schema aspect. It is rather surprising that the connection to real-world applications correlates positively with the schema aspect and negatively with the process aspect.

To further examine the relationships between mathematical worldviews and learning style preferences, these dependencies were evaluated using linear models. Since the worldviews could be viewed as a philosophical background theory of learning preferences, they were used as predictors of learning preferences. The process was two-step: In a first, “full” model, all five worldviews were used as predictors of one learning style; in a second, “reduced” model, all predictors that were not significant in the full model were removed. Table 7 shows the results. The regression coefficients (b) are standardised.

Table 6. Linear models to explain learning style preferences by mathematical worldviews

Dep. Var.	**Model**	**Predictors b**					**Model parameters/indices**		
		Form.	**Schem.**	**Proc.**	**Appl.**	**Plat.**	**R^2**	**RMSEA**	**SRMR**
Trans.learn	1	0.064	0.800***	0.399	-0.294	-0.206	0.577	0.050	0.076
	2	—	0.694***	—	—	—	0.481	0.047	0.073
Disc.learn	1	0.258*	-0.096	0.816***	-0.143	-0.030	0.557	0.049	0.077
	2	0.202*	—	0.736***	—	—	0.535	0.048	0.075
Real.ref	1	0.052	0.338*	-0.192	0.155	-0.076	0.187	0.052	0.079
	2	—	0.381*	—	—	—	0.145	0.046	0.067
Com.learn	1	-0.137	0.332*	0.173	0.015	0.035	0.101	0.047	0.072
	2	—	0.199*	—	—	—	0.040	0.045	0.069
Soc.learn	1	-0.061	0.580**	0.722**	-0.275	-0.061	0.409	0.048	0.074
	2	—	0.431**	0.500***	—	—	0.316	0.045	0.072

The explained variance (R^2) is mostly considerable, the size and significance of the predictors are partly in line with expectations, partly surprising: The fact that the schema aspect is the only significant predictor for transmissive learning fits with theoretical expectations. In discovery learning, the most important predictor is the process aspect, but also the formalism aspect plays a significant role. The fact that the schema aspect is the only significant predictor of real-world and communicative learning is surprising. The application aspect and the Platonism aspect do not play a significant role in any model.

The final section of our evaluation refers to an exploratory cluster analysis. The *mclust* package provides automatic model selection and proposes a three-cluster solution. Table 8 lists the properties of these clusters: their size, their distribution in the total sample, and the means across all scales. Linear models were used to check whether the clustering has a significant effect (p-value) on the means and how large it is (R^2).

Table 7. Cluster properties and their mean differences with respect to the scales

Group/Scale	Sample	Cluster 1	Cluster 2	Cluster 3	R^2	p-value
Size	188 (100%)	72 (38.3%)	63 (33.5%)	53 (28.2%)	—	—
Female	71%	65%	75%	76%	—	0.172
Secondary	18%	16%	18%	18%	—	0.832
Master	23%	26%	13%	29%	—	0.142
Semester	3.13	3.16	2.49	3.81	0.016	0.086
Formalism	2.93 (0.45)	2.79	3.05	2.99	0.054**	0.002
Schema	2.73 (0.50)	2.37	3.01	2.88	0.325***	<0.001
Process	3.06 (0.47)	3.17	3.30	2.63	0.336***	<0.001
Application	3.13 (0.52)	3.27	3.27	2.88	0.173***	<0.001
Platonism	2.95 (0.59)	2.98	3.04	2.82	0.01	0.130
Trans.learn	3.12 (0.44)	2.74	3.40	3.30	0.460***	<0.001
Disc.learn	2.49 (0.68)	2.88	2.60	1.86	0.374***	<0.001
Real.ref	2.93 (0.59)	2.70	3.22	2.88	0.136***	<0.001
Com.learn	2.86 (0.64)	2.82	3.14	2.57	0.247***	<0.001
Soc.learn	3.03 (0.69)	2.88	3.50	2.67	0.117***	<0.001

The three clusters differ primarily in the criteria of transmissive learning, discovery learning, process aspect, and schema aspect. Based on these four criteria, the character of the three clusters can be described as follows: In the *first cluster*, the preferences for transmissive learning are the lowest and those for discovery learning are the most pronounced. The process aspect is in the middle range and the schema aspect is the lowest. The interest in references to reality is below average. This group could be called “*Discovery Learners in the Realm of Pure Mathematics*”. The *second cluster* stands out due to its high value in transmissive learning and its interest in real-world problems. The preferences for discovery learning are in the middle range, high values are linked to the schema and the process aspects. One could call this group “*Mixed Discovery-Transmissive Learners with Real-World Orientation*”. They occur more frequently in lower semesters and are underrepresented in the master’s programme. The *third cluster* has the lowest value in discovery learning and a relatively high value in transmissive learning. There is little interest in social and communicative learning. The members of this cluster tend to belong to a higher semester and are somewhat more represented in the master’s programme than the other clusters. One could call them “*Pure Transmissive Learners*”.

6 Conclusions

The answers to the research questions are partly in accordance with theory and partly unexpected. RQ1: The correlations of the mathematical worldviews confirm the results of Grigutsch and Törner (1998); the correlations between learning preferences among student teachers differ fundamentally from those among pupils (Girnat and Hascher, 2021): In particular, transmissive and discovery learning styles are negatively correlated here. Although the group of dynamic worldviews correlate with constructivist learning preferences and the static views with transmissive ones, the linear models (RQ2) show that there are straightforward connections only between transmissive learning and the schema aspect as well as between discovery learning and the process aspect. These correlations can be linked to the study by Muis (2004). This shows that discovery learning and constructivist approaches emphasise an active role of the learner and an explorative approach to the learning process. While discovery learning is positively correlated with the ability to transfer learnt concepts to real-world applications, the constructivist approach promotes a learning environment in which such active and explorative learning strategies can flourish. In contrast, transmissive learning and positivist perspectives focus more on a passive learner with structured and formalised knowledge. However, the schema aspect has a high predictive influence even on constructivist learning styles: on such with a reference to reality and on social and communicative learning. Substantial gender differences (RQ3) can be found among teacher training students: women prefer a transmissive learning style and tend to reject a discovering one. The comparison of master's and bachelor's degree programmes suggests that mathematical worldviews and learning style preferences remain largely constant throughout the entire course of study. The cluster analysis (RQ4) reveals three groups of approximately equal size: *Discovery Learners in the Realm of Pure Mathematics, Mixed Discovery-Transmissive Learners with Real-World Orientation,* and *Pure Transmissive Learners*. These clusters connect mathematical worldviews and preferences, especially in the first two cases, in a way that is not consistent with expectations. This result may explain why the correlations and linear models show some surprising results. It is noteworthy that cluster type 3 occurs in higher semesters and cluster type 2 in lower ones, which argues against an increase in constructivist beliefs during the study course. The discovery of the clusters offers a broader approach to the learning preferences and mathematical worldviews of student teachers than the scales and their assessment alone can do: Follow-up research would need to examine whether these three clusters can be found in other samples;

and it would need to pay attention to whether these clusters remain stable throughout the course of study. This addresses an important limitation of our study: The sample is restricted to a single university and the results relay only on a cross-sectional study, and not a longitudinal one.

Research ethics

Author contributions

T.K.: conceptualisation, methodology, data collection, data analysis, evaluation, writing
B.G.: conceptualisation, methodology, data analysis, evaluation, writing
B.W.: literature review, evaluation, writing

All authors have read and agreed to the published version of the manuscript.

Artificial intelligence

Artificial intelligence (DeepL) was used to revise the language of the article.

Funding

No funds, grants, or other support was received.

Institutional review board statement

All participants in the study were of legal age and consented to the study on a voluntary basis.

Informed consent statement

Informed consent was obtained from all research participants

Data availability statement

In order to protect the privacy of the participants and the confidentiality of the information, we have decided not to make the data sets publicly accessible. However, we recognise the importance of transparency and traceability in scientific research and are therefore prepared to make the data available on reasoned scientific request. We ask that all requests be sent in writing to the correspondence address of the corresponding author, which is given in the article. The items used in the survey are available: Kruse-Kurbach, Theresa, 2024, "Items for Mathematical Beliefs and Learning Styles of students", https://doi.org/10.25625/UW3C3V, GRO.data, V1

Conflicts of Interest

The authors declare no conflicts of interest.

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