



Achieving Multidimensional Educational Goals Through Standard-Oriented Teaching. An Application to STEM Education

Anja Schiepe-Tiska^{1*}, Anna Heinle¹, Paula Dümig¹, Frank Reinhold^{2,3} and Kristina Reiss^{1,2}

¹Centre for International Student Assessment (ZIB) e.V., TUM School of Education, Technical University of Munich, Munich, Germany, ²Heinz Nixdorf-Chair of Mathematics Education, TUM School of Education, Technical University of Munich, Munich, Germany, ³Institute for Mathematics Education (IMBF), University of Education, Freiburg, Germany

OPEN ACCESS

Edited by:

Subramaniam Ramanathan,
Nanyang Technological University,
Singapore

Reviewed by:

Eric Richter,
University of Potsdam, Germany
Indah Juwita Sari,
Universitas Sultan Ageng Tirtayasa,
Indonesia

*Correspondence:

Anja Schiepe-Tiska
schiepe-tiska@tum.de

Specialty section:

This article was submitted to
STEM Education,
a section of the journal
Frontiers in Education

Received: 06 August 2020

Accepted: 20 September 2021

Published: 18 October 2021

Citation:

Schiepe-Tiska A, Heinle A, Dümig P,
Reinhold F and Reiss K (2021)
Achieving Multidimensional
Educational Goals Through Standard-
Oriented Teaching. An Application to
STEM Education.
Front. Educ. 6:592165.
doi: 10.3389/feduc.2021.592165

Socially and in relation to the individual, schools' mission for STEM education is not limited to the teaching of knowledge and cognitive skills. Although they form an important basis for dealing with today's challenges in a self-confident and responsible manner, they alone are not enough. Positive attitudes towards learning are additional important prerequisites for lifelong learning and participation in society. However, national educational standards still focus mainly on developing cognitive competencies. They hardly take into account multidimensional educational goals that combine both cognitive and non-cognitive outcomes. At the classroom level, in everyday school life, addressing both is one of the greatest challenges. Introducing standard-oriented curricula may have the potential to shift teachers' professional perception also to non-cognitive educational goals. We argue that, in order to foster multidimensional educational goals, they need to be more clearly addressed at the policy, teacher training, and teaching level. One important research agenda within STEM education for the next years will be to examine and discuss the connection between the implementation of standard-oriented teaching, the achievement of multiple educational goals, and teachers' professional competence.

Keywords: interest, motivation, social-emotional learning, standard-oriented teaching, cognitive and non-cognitive outcomes, mathematics and science education, teachers' professional competence

INTRODUCTION

Both, socially and in relation to the individual, the mission of schools for STEM education (science, technology, engineering, and mathematics) is not limited to the teaching of (content) knowledge and cognitive skills. However, in daily school life, the focus of teaching is mostly on strengthening achievement development and performance (Schiepe-Tiska, 2019). Little room is given to explicitly strive for other learning goals such as developing interests or social-emotional learning. If anything, these goals are addressed implicitly or they are perceived as side effects to reaching cognitive learning goals. Hence, schools often do not provide resources (e.g., instruction materials, specific courses or activities) or create conditions (e.g., training teachers, devoting teaching hours, receiving school administration support), that would promote striving for other learning goals (Schiepe-Tiska et al., 2021). The global Coronavirus pandemic in 2020 has made this obvious again, as the main interest in public awareness had been on how much learning losses students would experience due to school closings. However, although cognitive learning outcomes form an important foundation for dealing

with today's challenges in a self-confident and responsible manner, they alone are not enough. They need to be complemented by so called "non-cognitive" factors as additional and important school outcomes (e.g., Schiepe-Tiska, Roczen et al., 2016; OECD, 2018a). Together, cognitive and non-cognitive outcomes can be summarized under the term of *multidimensional educational goals*.

In STEM education, reaching multidimensional educational goals is particularly important at the end of compulsory school as this is a decisive phase of identity development. At this point, students develop clear ideas about themselves, and clarify their relation with others and the world in general. Thus, in addition to questions about ones' own interests or ideas about occupational choices, the examination with social and political participation becomes more relevant (Blossfeld et al., 2015; Schiepe-Tiska, 2019).

International large-scale assessments such as the *Programme for International Student Assessment (PISA)* also have adapted the perspective of cognitive and non-cognitive outcomes for mathematics and science (OECD, 2017; OECD, 2018b). This was an important step as PISA aims to provide an internationally embedded, realistic view of countries' reached learning outcomes (i.e., benchmarking), that are oriented at defined standards (i.e., monitoring). At the country level, these frameworks provide opportunities to engage in normative discussions about cultures' central objectives that are important for our current understanding of the world—regarding education in general and STEM education in particular. These discussions, in turn, are reflected in present school practices and teaching policies.

For instance, the poor performance of Germany in PISA 2000 introduced a change in its educational policy perspective (Klieme et al., 2003). While before it was mainly oriented towards a defined curriculum (input orientation), the question of which learning goals should be achieved (output orientation) came more into focus. One of the goals had been to give teachers more space and freedom about how to reach different learning goals. Consequently, standard-oriented curricula were introduced, which may have the potential to shift teachers' professional perception to non-cognitive educational goals in addition to cognitive outcomes. For the next years, an important research agenda within STEM education will be to examine and discuss the connection between fostering multidimensional educational goals, the implementation of standard-oriented teaching, and teachers' professional competence.

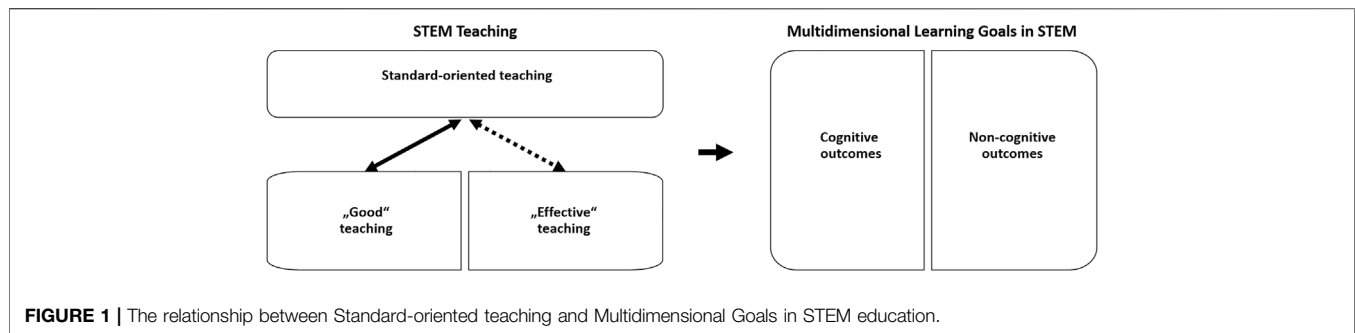
We draw on these developments and argue that more balance between cognitive and non-cognitive learning goals is needed—at both the system and the school level. We introduce the concept of multidimensional educational goals and apply it to STEM. Using the example of Germany, we will outline how a change in educational policy perspective—from input to output—may facilitate this balance. We will discuss the potential and challenges of standard-oriented teaching for pursuing different learning goals. Moreover, we will briefly present a current research project studying these relationships, which will be linked to PISA 2022 in Germany.

MULTIDIMENSIONAL EDUCATIONAL GOALS IN STEM

Multidimensional educational goals provide a framework in which both, cognitive and non-cognitive outcomes, are presented. In contrast to cognitive outcomes, non-cognitive outcomes are characterized as constructs that are not identified with traditional indicators of cognitive capability or intellectual functioning (Rieger et al., 2017). According to multiple reviews and studies, these factors are essential for success in education as well as in occupation (Almlund et al., 2011; Kautz, et al., 2014) and they are important prerequisites for lifelong learning and an active participation in society (e.g., Prenzel, 2012; Schiepe-Tiska, Roczen et al., 2016). They shape the identity and personality of students and thus—together with cognitive outcomes—influence decisions about educational pathways (e.g., Parker et al., 2014). This is particularly relevant as the United States as well as Europe report an increasing need for STEM professionals at different levels of expertise (Cappelli, 2015; Cedefop, 2017). This trend is still growing with the worlds' change due to technological progress and digitalization.

Hence, in STEM education, non-cognitive outcomes are not only determinants of cognitive learning outcomes, but important educational goals themselves (see also Blossfeld et al., 2015; Schiepe-Tiska, Roczen et al., 2016). They influence whether students engage actively and of own accord in situations where science and mathematics competencies are necessary. Science provides the most profound explanations we have about our material world and the ability to reason mathematically and understand computational thinking concepts is important for keeping up with the worlds' change driven by new technologies. Hence, students need to recognize how important and significant STEM education is for their daily life *and* the society. Only when they feel meaningfully connected to STEM they are willing to engage with STEM and address ethical and political dilemmas such as climate change, develop critical orientations and thinking skills, and value scientific approaches to inquiry (cf. OECD, 2018b; OECD, 2020).

In the research tradition of science education, non-cognitive outcomes are mostly summarized under the umbrella term *attitudes*. Attitudes are an individual's affective, cognitive, and behavioral reactions towards an object or phenomenon (Rosenberg and Hovland, 1960). In science, they can be differentiated into *attitudes towards science* and *scientific attitudes* (Gardner 1975; Klopfer 1971; Osborne et al., 2003). Attitudes towards science refer to the affects, beliefs, and values students hold about an object such as school science or scientists themselves (Tytler and Osborne, 2012). They include constructs such as interest in and enjoyment of science, perceived value of science, or attitudes of peers and friends towards science (see also Schiepe-Tiska et al., 2016). Scientific attitudes refer to how students think about science. They display dispositions to look for material explanations and to being skeptical about many of these explanations (Osborne et al., 2003). For both facets, however, there is still no consensus about how many sub-constructs exist, how these can be classified, or how they can



be labeled and interpreted (see Kerr and Murphy, 2012 for a similar argument).

In contrast to science, in mathematics, the importance of attitudes is more hesitantly accepted (Hannula et al., 2016; Schukajlow et al., 2017). The most examined non-cognitive characteristic is mathematics anxiety (e.g., Strohmaier et al., 2020). It is a common phenomenon across countries, cultures, and ages and it massively influences students' mathematics achievement and their willingness to engage with mathematics beyond the school context (e.g., OECD, 2013; Schiepe-Tiska and Schmidtner, 2013). Other non-cognitive outcomes such as interest in mathematics or mathematics self-concept/self-efficacy are additionally important but less often examined. However, for example, for high-achieving students in mathematics, these motivational-affective characteristics explain why and how these students translate their potential into performance (Ziernwald et al., 2021).

From a practical perspective, one major challenge for STEM teachers when pursuing multidimensional learning goals is that they can influence or compete with each other. For example, in depth analyses of Germany's PISA 2015 data showed that science teaching, providing students with cognitive activating learning opportunities, such as explaining ideas or drawing conclusions, as well as doing experiments was related to higher levels of science competencies as compared to teaching that is little cognitive activating and does not allow conducting own experiments. However, for enjoyment and interest, the picture was more differentiated. Only teaching that offered cognitive activating learning activities and the possibility of doing experiments more often was related to higher science enjoyment and interest. Cognitive activating science teaching with rare opportunities for doing experiments was less related to science enjoyment (Schiepe-Tiska et al., 2016). Hence, a balanced consideration of cognitive and non-cognitive learning goals is needed.

STANDARD-ORIENTED TEACHING

National educational standards formulate subject-specific and interdisciplinary cognitive basic qualifications that students in a country should have acquired by a certain point in their school careers (e.g., KMK, 2003; KMK, 2005). These standards mainly

formulate cognitive learning goals but, in part, they also refer to non-cognitive outcomes.

One of the main learning environments to address multidimensional educational goals in STEM systematically is the classroom (see Figure 1). Normative, pedagogical principles and current standards play an important role in schools and describe features of "good" teaching (Berliner, 2005). For example, good science teaching is oriented at the idea of inquiry-based science teaching, in which students experiment and solve authentic science problems while learning the underlying scientific principles and developing corresponding concepts (Bruner, 1961).

In Germany, national educational standards were introduced as part of the educational reform in response to Germany's poor results in STEM in the first participation in TIMSS and PISA (Baumert et al., 2001; Beaton et al., 1996). These standards are formulated for different levels of educational qualification. For example, in mathematics, the standards for the intermediate school leaving certificate state that "the mission of school education goes beyond the acquisition of cognitive skills. Together with other subjects, mathematics teaching also aims at personality development and value orientation" (KMK, 2003, p. 6). This multidimensional formulation of learning goals in relation to standard-oriented teaching is in line with initiatives in other countries such as United Kingdom, Canada, the United States, or Switzerland (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010; EDK, 2011; Department for Education, 2014; Ontario M. o. E., 2006).

Germany's national standards represent not only a joint, mandatory framework for quality assurance of STEM teaching but also for the development of STEM teaching (KMK, 2010). Consequently, introducing the standards aimed at shifting the focus in teaching from being exclusively on the input, (i.e., learning and subject content) to more predefined, explicitly stated learning goals (i.e., output). Hence, the standards define requirements and liabilities that should be achieved at a particular point in time (Klieme et al., 2003), but in contrast to conventional curricula they are less detailed and do not prescribe in detail which topics have to be covered and how these topics have to be sequenced in particular (KMK, 2010). In theory, these standards can give teachers more freedom to choose how to reach learning goals as they "do not define the intervention methods or materials necessary to support

students” (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010, p.4). Hence, they offer possibilities to focus on achieving cognitive and non-cognitive educational goals (KMK, 2010).

Orienting teaching at defined standards (in Germany called *competence-oriented teaching*), describes a new dimension of “good” teaching (Helmke, 2017; Müller et al., 2013; see **Figure 1**). However, it has rarely been tested empirically whether it is also a criterion for “effective” teaching (Berliner, 2005), that enables the achievement of multidimensional goals. Moreover, how standard-oriented teaching is related to other criteria of high effective teaching has also rarely been examined. One challenge is that, up to now, no consistent definition of standard-oriented teaching besides its focus on learning outcomes and the organization of learning as a cumulative process exists (Lenski et al., 2017). One suggestion for approaching a definition is made by Drieschner (2009), who describes four characteristics of standard-oriented teaching: 1) it establishes links between learning contents and real-life problems, 2) it encourages an active examination of a specific subject area, for example by enabling students to find several solutions or to formulate their own questions, 3) it reinforces social learning activities, and 4) it provides learning materials that are appropriate for students at different competence levels. However, again, the focus is more on reaching cognitive learning goals rather than taking a multidimensional perspective.

DISCUSSION AND FUTURE DIRECTIONS

The world of the 21st century is characterized by rapid developments - above all in technology. In order to deal with the resulting environmental, economic, and social challenges, it is education's responsibility to equip future generations for the growing complexity as well as for dealing with increasing uncertainties (OECD, 2018a). Hence, education should not only focus on the development of subject-specific knowledge, but simultaneously on a broader set of skills, attitudes, and values. In STEM, a balanced pursuit of both cognitive and non-cognitive educational goals should be a central aim. In order to foster such multidimensional educational goals, they need to be addressed at different levels.

At the educational system level, although multidimensional goals are to some extent included in countries' national standards, standards' focus is still on developing knowledge that can be applied to different contexts and rather disregard non-cognitive learning goals (KMK, 2003; KMK, 2005). School laws and policies may name different non-cognitive goals more specifically, but they are still rather abstract declarations of intent and often a hodgepodge of characteristics (see also Blossfeld et al., 2015). Germany's current PISA results reflect this flaw: Although, students' mathematics and science competencies were stable above the OECD-average (Reinhold et al., 2019; Schiepe-Tiska et al., 2019), enjoyment and instrumental motivation in both—mathematics and science—were below the OECD-average and declined between two PISA cycles (Schiepe-Tiska and Schmidtner, 2013; Schiepe-Tiska et al., 2016). This was also true

for science self-efficacy. In order to enable a systematic development of multidimensional goals, first, they would need to be defined, classified, and specifically named for different developmental stages in countries' national educational standards.

At the school and classroom level, concepts of how to foster these goals explicitly together with and in addition to cognitive outcomes are needed. The teachers' mission is to transfer these goals into practice. For that, standard-oriented teaching can offer a fruitful and promising framework as it gives teachers more open spaces for designing their teaching and focusing on different learning goals. However, in order to enable them for pursuing multidimensional goals, awareness needs to be created by including them as mandatory part in teacher training curricula. Teachers need to be trained in identifying and evaluating multidimensional learning goals and to develop their diagnostic competences beyond students' achievement. Researchers could support teachers in that by developing suitable instruments focusing on identifying and evaluating multidimensional goals. Needless to say, teachers' own development of professional competence should be organized under the perspective of a multidimensional development so they can function as role models for their students.

In addition, specific recommendations and examples on how to implement striving for multiple goals in daily (subject-specific) classrooms are missing. One opportunity for the design of standard-oriented teaching, that may support teachers in addressing multidimensional goals, are tasks (Besser et al., 2013). Tasks play a prominent role particularly in STEM education (Knoll, 2003). In mathematics instruction, they represent central learning opportunities (Reiss and Hammer, 2013) that determine the course of instruction almost completely (Kuger et al., 2017). In science, (textbook) tasks play a somewhat less central, but still important role and are often used as lessons' supplements (Wendt et al., 2017). Tasks offer numerous possibilities to focus on real-life problems, initiate active and in-depth examinations, as well as social learning processes. Hence, they have the potential to offer learning opportunities addressing different cognitive and non-cognitive outcomes (e.g., Rellensmann and Schukajlow, 2017). However, an analysis of current German mathematics and physics textbook tasks showed that the theoretical opportunities for the motivational potential of tasks remain unexploited (Heinle et al., 2021).

From a research perspective, thus far, there is no evidence to what extent multidimensional goals are considered in current teaching practice. Our research project “*Classroom Experience, Characteristics & Outcome: Multidimensional educational goals and the views of students and teachers*” (Ceco) draws on this gap and examines the relation between multidimensional educational goals, standard-oriented teaching, and teachers' professional competence in mathematics and science by using a multi-method design (Ceco Team, 2020). We will investigate to what extent teachers consider different learning goals defined in PISA and national educational standards while preparing and teaching their lessons and how this relates to the selection and design of tasks they use for learning vs. examinations. Linked to PISA 2022, Ceco supplements the international design of the PISA study in Germany with specific components at the input, process, and outcome levels. Two ninth grades as well as their mathematics and science teachers will be sampled additionally.

They will be visited in a mathematics and science lessons to assess teaching characteristics as well as motivational-affective learning goals in particular. In addition, tasks will be analyzed regarding their orientation on competencies defined in PISA and Germany's national standards as well as their cognitive activating and motivational potential. The results will provide the opportunity to compare rather distal teaching and learning characteristics from PISA with more proximal characteristics in daily school life. Moreover, the link with PISA will enable examining aspects of achievement, motivational, and socio-economic heterogeneity of classes related to standard-oriented teaching and multidimensional learning goals.

REFERENCES

- Almund, M., Duckworth, A. L., Heckman, J., and Kautz, T. (2011). *Personality Psychology and Economics*. Cambridge: National Bureau of Economic Research. doi:10.3386/w16822
- Beaton, A. E., Martin, M. O., Mullis, I. V. S., Gonzalez, E. J., Smith, T. A., and Kelly, D. L. (1996). *Science Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study (TIMSS)*. Boston College: Center for the Study of Testing, Evaluation, and Educational Policy.
- Berliner, D. C. (2005). The Near Impossibility of Testing for Teacher Quality. *J. Teach. Educ.* 56 (3), 205–213. doi:10.1177/0022487105275904
- Besser, M., Blum, W., and Klimczak, M. (2013). "Formative Assessment in Everyday Teaching of Mathematical Modelling: Implementation of Written and Oral Feedback to Competency-Oriented Tasks," in *International Perspectives on the Teaching and Learning of Mathematical Modelling. Teaching Mathematical Modelling. Connecting to Research and Practice*. Editors G. A. Stillman and G. Kaiser (New York: Springer), 469–478. doi:10.1007/978-94-007-6540-5_40
- Blossfeld, H.-P., Bos, W., Daniel, H.-D., Hannover, B., Köller, O., Lenzen, D., et al. (2015). *Bildung. Mehr Als Fachlichkeit [Education. More than Cognitive Outcomes]*. Wiesbaden, Germany: VS Verlag für Sozialwissenschaften.
- Bruner, J. S. (1961). The Act of Discovery. *Harv. Educ. Rev.* 31, 21–32.
- Cappelli, P. H. (2015). Skill Gaps, Skill Shortages, and Skill Mismatches. *ILR Rev.* 68 (2), 251–290. doi:10.1177/0019793914564961
- Ceco Team (2020). *Classroom Experience, Characteristics & Outcome: Multidimensional Educational Goals and the Views of Students and Teachers*. Munich, Germany: Centre for International Student Assessment (ZIB). Available at: <http://zib.education/en/research/current-zib-projects/ceco.html>.
- Cedefop (2017). *Annual Report 2016*. Brussels, Germany. Available at: https://www.cedefop.europa.eu/files/4154_en.pdf. doi:10.2801/474919
- Department for Education (2014). *National Curriculum in England: Mathematics Programmes of Study: Key Stage 4*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/331882/KS4_maths_PoS_FINAL_170714.pdf.
- Drieschner, E. (2009). *Bildungsstandards praktisch: Perspektiven kompetenzorientierten Lehrens und Lernens [Educational standards in practice: perspectives of competence-oriented teaching and learning]*. Wiesbaden: VS Verlag für Sozialwissenschaften/GWV Fachverlage GmbH. doi:10.1007/978-3-531-91343-8
- EDK (2011). *Grundkompetenzen für die Mathematik: Nationale Bildungsstandards [Basic competences for mathematics: National educational standards]*. Bern: EDK.
- Gardner, P. L. (1975). Attitudes to Science: A Review. *Stud. Sci. Educ.* 2 (1), 1–41. doi:10.1080/03057267508559818
- Hannula, M. S., Di Martino, P., Pantziara, M., Zhang, Q., Morselli, F., Heyd-Metzuyanim, E., et al. (2016). *Attitudes, Beliefs, Motivation and Identity in Mathematics Education*. Advance online publication. doi:10.1007/978-3-319-32811-9
- Heinle, A., Schiepe-Tiska, A., Reinhold, F., Heine, J.-H., and Holzberger, D. (2021). *Supporting Student Motivation in Class: The Motivational Potential of Tasks. [Manuscript submitted for publication]*. Germany: TUM School of Education, Technical University of Munich.
- Helmke, A. (2017). *Unterrichtsqualität und Lehrprofessionalität: Diagnose, Evaluation und Verbesserung des Unterrichts (7. Auflage) [Teaching quality and teacher professionalism: diagnosis, evaluation and improvement of teaching]*. 7th edition. Seelze-Velber: Klett/Kallmeyer.
- J. Baumert, E. Klieme, M. Neubrand, M. Prenzel, U. Schiefele, W. Schneider, et al. (Editors) (2001). *PISA 2000: Basiskompetenzen von Schülerinnen und Schülern im internationalen Vergleich [PISA 2000: Basic competencies of students in international comparison]* (Wiesbaden, Germany: Leske + Budrich).
- Kautz, T., Heckman, J. J., Diris, R., ter Weel, B., and Borghans, L. (2014). *Fostering and Measuring Skills: Improving Cognitive and Non-cognitive Skills to Promote Lifetime success*. Paris, France: OECD Publishing.
- Kerr, K., and Murphy, C. (2012). "Children's Attitudes to Primary Science,". *Second International Handbook of Science Education*. Editors B. J. Fraser, K. Tobin, and C. J. McRobbie (Dordrecht, Netherlands: Springer Netherlands), Vol. 2, 627–649. doi:10.1007/978-1-4020-9041-7_42
- Klieme, E., Avenarius, H., Blum, W., Döbrich, P., Gruber, H., Prenzel, M., et al. (2003). *Zur Entwicklung nationaler Bildungsstandards. Eine Expertise [On the Development of National Educational Standards. An Expertise]*. Berlin: BMBF.
- Klopfer, L. E. (1971). "Evaluation of Learning in Science," in *Handbook on Formative and Summative Evaluation of Student Learning*. Editors B. S. Bloom, J. T. Hastings, and G. F. Madaus (New York: McGraw-Hill), 559–641.
- KMK = Sekretariat der Ständigen Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland (2005). *Beschlüsse der Kultusministerkonferenz - Bildungsstandards im Fach Biologie für den mittleren Bildungsabschluss (Beschluss vom 16. Dezember 2004) [Resolutions of the Standing Conference of the Ministers of Education and Cultural Affairs of the federal republic of Germany - Educational Standards in the Subject Biology for the Intermediate Educational Qualification (Resolution of 16 December 2004)]*. Wolters Kluwer.
- KMK (2003). *Beschlüsse der Kultusministerkonferenz - Bildungsstandards im Fach Mathematik für den Mittleren Schulabschluss (Beschluss vom 04. Dezember 2003) [Resolutions of the standing conference of the ministers of education and cultural affairs of the federal republic of Germany - educational standards in mathematics for the middle school certificate resolution of 04 December 2003]*.
- Knoll, S. (2003). *Verwendung von Aufgaben in Einführungsphasen des Mathematikunterrichts [Use of tasks in introductory phases of mathematics teaching]*. Tectum.
- Konzeption der Kultusministerkonferenz zur Nutzung der Bildungsstandards für die Unterrichtsentwicklung (2010). Beschluss der Kultusministerkonferenz vom 10.12.2009. [Resolution of the standing conference of the ministers of education and cultural affairs of the countries in the federal republic of Germany of 10.12.2009]. Available at: http://www.kmk.org/fileadmin/veroeffentlichungen_beschluesse/2010/2010_00_00-Konzeption-Bildungsstandards.pdf.
- Kuger, S., Klieme, E., Lüdtke, O., Schiepe-Tiska, A., and Reiss, K. (2017). Mathematikunterricht und Schülerleistung in der Sekundarstufe: Zur Validität von Schülerbefragungen in Schulleistungsstudien [Mathematics education and student performance in secondary school: On the validity of student surveys in school performance studies]. *Zeitschrift Für Erziehungswissenschaft*. 20 (S2), 61–98. doi:10.1007/s11618-017-0750-6
- Lenski, A. E., Richter, D., and Lüdtke, O. (2017). Using the Theory of Planned Behavior to Predict Teachers' Likelihood of Taking a Competency-Based Approach to Instruction. *Eur. J. Psychol. Educ.* 34 (1), 169–186. doi:10.1007/s10212-017-0356-7

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

FUNDING

This research was funded by the Federal Ministry of Education and Research (BMBF) and the Standing Conference of the Ministers of Education and Cultural Affairs of the Federal Republic of Germany (KMK) (ZIB, 2022).

- Müller, K., Gartmeier, M., and Prenzel, M. (2013). Kompetenzorientierter Unterricht im Kontext nationaler Bildungsstandards [Competence-oriented Teaching in the context of national educational standards]. *Bildung und Erziehung* 66 (2), 127–144. doi:10.7788/bue.2013.66.2.127
- National Governors Association Center for Best Practices & Council of Chief State School Officers (2010). Common Core State Standards for Mathematics. Available at: http://www.corestandards.org/assets/CCSSI_Math%20Standards.pdf.
- OECD (2013). *Pisa 2012 Results: Ready to Learn: Students' Engagement, Drive and Self-Beliefs (Volume III)*. Paris, France: OECD Publishing.
- OECD (2017). *Pisa 2015 Assessment and Analytical Framework: Mathematics, reading, Science, Problem Solving and Financial Literacy*. Paris, France: OECD Publishing. doi:10.1787/9789264255425-en
- OECD (2018b). *PISA 2021 Mathematics Framework (Draft)*. Paris, France: OECD Publishing. Available at: <https://pisa2021-maths.oecd.org/files/PISA%202021%20Mathematics%20Framework%20Draft.pdf>.
- OECD (2020). *PISA 2024 Strategic Vision and Direction for Science (Final Draft)*. Paris, France: OECD Publishing. Available at: <https://www.oecd.org/pisa/publications/PISA-2024-Science-Strategic-Vision-Proposal.pdf>.
- OECD (2018a). *The Future of Education and Skills: Education 2030*. OECD Publishing. Available at: [https://www.oecd.org/education/2030/E2030%20Position%20Paper%20\(05.04.2018\).pdf](https://www.oecd.org/education/2030/E2030%20Position%20Paper%20(05.04.2018).pdf).
- Ontario, M. o. E. (Editor) (2006). *The Ontario curriculum: Grade 9, Applied to Academic*. Available at: <https://www.edu.gov.on.ca/eng/curriculum/secondary/mathtr9curr.pdf>.
- Osborne, J., Simon, S., and Collins, S. (2003). Attitudes towards Science: A Review of the Literature and its Implications. *Int. J. Sci. Educ.* 25 (9), 1049–1079. doi:10.1080/0950069032000032199
- Parker, P. D., Marsh, H. W., Ciarruchi, J., Marshall, S., and Abduljabbar, A. S. (2014). Juxtaposing Math Self-Efficacy and Self-Concept as Predictors of Long-Term Achievement Outcomes. *Educ. Psychol.* 34 (1), 29–48. doi:10.1080/01443410.2013.797339
- Prenzel, M. (2012). "Empirische Bildungsforschung morgen: Reichen unsere bisherigen Forschungsansätze aus? [Empirical educational research tomorrow: Are our current research approaches sufficient?]," in *Mixed methods in der empirischen Bildungsforschung*. Editors M. Gläser-Zikuda, T. Seidel, C. Rohlf, A. Gröschner, and S. Ziegelbauer (Münster, Germany: Waxmann), 273–286.
- Reinhold, F., Reiss, K., Diedrich, J., Hofer, S., and Heinze, A. (2019). "Mathematische Kompetenz in PISA 2018 - aktueller Stand und Entwicklung [Mathematics competence in PISA 2018 - Current status and development]," in *PISA 2018: Grundbildung im internationalen Vergleich*. Editors K. Reiss, M. Weis, and E. Klieme (Münster, Germany: Waxmann), 187–2010.
- Reiss, K., and Hammer, C. (2013). *Grundlagen der Mathematikdidaktik [Fundamentals of mathematics didactics]*. Springer Basel. doi:10.1007/978-3-0346-0647-9
- Rellensmann, J., and Schukajlow, S. (2017). Does Students' Interest in a Mathematical Problem Depend on the Problem's Connection to Reality? An Analysis of Students' Interest and Pre-service Teachers' Judgments of Students' Interest in Problems with and without a Connection to Reality. *ZDM Math. Educ.* 49 (3), 367–378. doi:10.1007/s11858-016-0819-3
- Rieger, S., Göllner, R., Spengler, M., Trautwein, U., Nagengast, B., and Roberts, B. W. (2017). Social Cognitive Constructs Are Just as Stable as the Big Five between Grades 5 and 8. *AERA Open* 3 (3), 233285841771769. doi:10.1177/2332858417717691
- Rosenberg, M. J., and Hovland, C. I. (1960). "Cognitive, Affective, and Behavioral Components of Attitudes," in *Attitude Organization and Change: An Analysis of Consistency Among Attitude Components*. Editors M. J. Rosenberg, C. I. Hovland, W. J. McGuire, R. P. Abelson, and J. W. Brehm (London, England: Yale University Press), 1–14.
- Schiepe-Tiska, A., Dzhaparkulova, A., and Ziernwald, L. (2021). A Mixed-Methods Approach to Investigating Social and Emotional Learning at Schools: Teachers' Familiarity, Beliefs, Training, and Perceived School Culture. *Front. Psychol.* 12, 518634. doi:10.3389/fpsyg.2021.518634
- Schiepe-Tiska, A. (2019). *Mehrdimensionale Bildungsziele in internationalen Large-Scale Assessments: Konzeptualisierung, Entwicklung und Entstehungsbedingungen am Beispiel der MINT-Fächer [Multidimensional educational goals in international large-scale assessments: Conceptualisation, development and conditions of emergence using the example of MINT subjects] [Habilitation]*. Munich: Technical University of Munich. Available at: <https://mediatum.ub.tum.de/doc/1523295/1523295.pdf>.
- Schiepe-Tiska, A., Roczen, N., Müller, K., Prenzel, M., and Osborne, J. (2016). "Science-related Outcomes: Attitudes, Motivation, Value Beliefs, Strategies," in *Assessing Contexts of Learning: An International Perspective*. Editors S. Kuger, E. Klieme, N. Jude, and D. Kaplan (New York: Springer). doi:10.1007/978-3-319-45357-6_12
- Schiepe-Tiska, A., Rönnebeck, S., and Neumann, K. (2019). "Naturwissenschaftliche Kompetenz in PISA 2018 – Aktueller Stand, Veränderungen und Implikationen für die naturwissenschaftliche Bildung in Deutschland [Science competencies in PISA 2018 – Current results, changes, and implications for science education in Germany]," in *PISA 2018: Grundbildung im internationalen Vergleich [PISA 2018: Basic education in international comparison]*. Editors K. Reiss, M. Weis, and E. Klieme (Münster, Germany: Waxmann), 211–240.
- Schiepe-Tiska, A., and Schmidtner, S. (2013). "Mathematikbezogene emotionale und motivationale Orientierungen, Einstellungen und Verhaltensweisen von Jugendlichen in PISA 2012 [Mathematically related emotional and motivational orientations, attitudes and behaviour of young people in PISA 2012]," in *PISA 2012: Fortschritte und Herausforderungen in Deutschland [PISA 2012: Progress and challenges in Germany]*. Editors M. Prenzel, C. Sälzer, E. Klieme, and O. Köller (Münster, Germany: Waxmann), 99–122.
- Schiepe-Tiska, A., Schmidtner, S., Müller, K., Heine, J.-H., Neumann, K., and Lüdtke, O. (2016). "Naturwissenschaftlicher Unterricht in Deutschland in PISA 2015 im internationalen Vergleich [Science education in Germany in PISA 2015 in international comparison]," in *PISA 2015: Eine Studie zwischen Kontinuität und Innovation*. Editors K. Reiss, C. Sälzer, A. Schiepe-Tiska, E. Klieme, and O. Köller (Münster, Germany: Waxmann), 133–176.
- Schiepe-Tiska, A., Simm, I., and Schmidtner, S. (2016). "Motivationale Orientierungen, Selbstbilder und Berufserwartungen in den Naturwissenschaften in PISA 2015 [Motivational orientations, self-concept and career expectations in the sciences in PISA 2015]," in *PISA 2015: Eine Studie zwischen Kontinuität und Innovation*. Editors K. Reiss, C. Sälzer, A. Schiepe-Tiska, E. Klieme, and O. Köller (Münster, Germany: Waxmann), 99–132.
- Schukajlow, S., Rakoczy, K., and Pekrun, R. (2017). Emotions and Motivation in Mathematics Education: Theoretical Considerations and Empirical Contributions. *ZDM Math. Educ.* 49 (3), 307–322. doi:10.1007/s11858-017-0864-6
- Strohmaier, A. R., Schiepe-Tiska, A., and Reiss, K. M. (2020). A Comparison of Self-Reports and Electrodermal Activity as Indicators of Mathematics State Anxiety. *Frontline Learning Research* 8 (1), 16–32. doi:10.14786/flr.v8i1.427
- Tytler, R., and Osborne, J. (2012). "Student Attitudes and Aspirations towards Science," in *Second International Handbook of Science Education*. Editors B. J. Fraser, K. Tobin, and C. J. McRobbie (Dordrecht, Netherlands: Springer Netherlands), Vol. 2, 597–625. doi:10.1007/978-1-4020-9041-7_41
- Wendt, H., Bos, W., Goy, M., and Jusufi, D. (Editors) (2021). *TIMSS 2015: Skalenhandbuch zur Dokumentation der Erhebungsinstrumente und Arbeit mit den Datensätzen [TIMSS 2015: Scale manual for documenting the survey instruments and working with the data sets]*. Waxmann.
- Ziernwald, L., Schiepe-Tiska, A., and Reiss, K. (2021). *Identification and Characterization of High-Achieving Student Subgroups Using Two Methodological Approaches: The Role of Different Achievement Indicators and Motivational- Affective Characteristics*. [Manuscript submitted for publication]. Germany: TUM School of Education, Technical University of Munich.

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.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Copyright © 2021 Schiepe-Tiska, Heinle, Dümig, Reinhold and Reiss. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.