SAME MATH, DIFFERENT STORY: CONTEXT AND STUDENTS' BELIEFS ABOUT THE RELEVANCE OF MATHEMATICS

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This paper examines how students attribute relevance to mathematically equivalent tasks in different contexts. Drawing on expectancy-value theory, relevance is considered across four perspectives (subjective/objective × present/future). A teaching unit on circle calculations and radian measure in the context of wind energy was implemented in grade 10 (N = 26). An analysis of group interviews shows that the authentic context mainly elicited objective relevance, while subjective relevance attributions remained rare. Quantitative data indicate higher relevance beliefs about mathematics in general than for the specific content. Consequently, contextualization can highlight societal and curricular relevance, but additional metacognitive reflection appears necessary to foster students' subjective relevance attributions.

INTRODUCTION

Mathematics is of fundamental importance for (modern) societies: It underpins technological innovation, informs political and economic decision-making, and structures everyday activities ranging from personal finance to navigating digital environments. Yet, a discrepancy persists between this objective societal importance of mathematics and subjective perceptions of its value (*relevance paradox*; Niss, 1994). This paradox is particularly concerning in light of large-scale assessment results. International comparative studies such as PISA have repeatedly shown not only stable performance gaps between different countries but, in the case of Germany, also indications of a steady decline in mathematics performance over recent cycles (OECD, 2023). These trends raise questions about students' opportunities to learn, their engagement with mathematical content, and the conditions under which students are willing to invest effort in learning mathematics. If learners do not perceive mathematics as relevant, they may be less motivated to engage deeply with the subject, which in turn can affect achievement and exacerbate existing performance trends. At the same time, mathematics is increasingly recognized as a key qualification in a wide range of professions, also in non-STEM fields (e.g., Rohenroth, 2023). Thus, a certain level of mathematical competence is not only a prerequisite for specialized technical or mathematical roles, but also a central component of general employability and informed citizenship.

Against this background, mathematics teaching faces a dual challenge: While ensuring that students acquire the curricular content and competences defined in national standards, it needs to address students' perceptions of (ir)relevance of mathematics by

making visible how mathematical ideas are meaningfully embedded in practices beyond the mathematics classroom. One approach to bridging this gap is the design and implementation of contextualized teaching units. In such units, curricular content is not treated in isolation but situated within authentic contexts. To highlight the importance of mathematics in the workplace and to give students early insights into different careers, authentic aspects of the world of work where the curricular content is functionally employed can be used (e.g., Wulff, 2023). The underlying assumption is that contextualizing curricular content in authentic professional contexts may support students in recognising the objective practical and (future) subjective personal significance of what they are learning in the mathematics classroom. By highlighting concrete and authentic situations in which mathematical concepts are used – both in STEM and non-STEM careers – such teaching units may contribute to a stronger sense of relevance and, consequently, to higher engagement in the mathematics classroom and more sustained mathematics learning.

In this contribution, we investigate how specially designed contextualized teaching units, based on authentic professional contexts and aligned with the regular curriculum, can foster students' relevance attribution to mathematics.

THEORETICAL BACKGROUND

The term *relevance* is widely used in mathematics education research, yet often remains conceptually vague or inconsistently defined (Eilks et al., 2013). In the present study, relevance is defined by drawing on expectancy-value-theory (EVT; Eccles & Wigfield, 2002). Within this framework task value beliefs are central determinants of students' motivation, persistence and achievement-related choices. Task value is decomposed into the components intrinsic value, attainment value, utility value, and cost. For our purpose, we conceptualize relevance as a compound of (a) attainment value and (b) utility value. Attainment value captures the personal importance of something, whereas utility value refers to the perceived usefulness of something for achieving present or future goals. Consequently, someone perceives something as relevant when it is experienced as personally important and/or useful. Relevance is thereby not treated as an inherent property of a mathematical content, but as a value attributed by an individual in a particular socio-cultural context. Thus, the same mathematical content can be experienced as highly relevant by one student and as irrelevant by another.

Building on the task-value-based definition, relevance can be further differentiated along two conceptual dimensions: (a) subjective vs. objective and (b) present vs. future. Hereby the subjective-objective distinction separates the *subjective relevance* (what is subjectively perceived as relevant) and *objective relevance* (what is normatively or socially defined as relevant, independently of whether each individual endorses it). The present-future distinction separates *present relevance* (perceived relevance for current situation, needs or identities) and *future relevance* (perceived relevance for anticipated roles, careers or life situations).

Crossing these dimensions yields a 2 x 2 matrix of relevance perspectives:

- Subjective-present relevance: What is individually perceived as relevant now (e. g., for one's daily life or a student's school life).
- Subjective-future relevance: What is individually perceived as relevant for one's future (e. g., for one's future (job) life).
- Objective-present relevance: What is normatively or socially perceived as relevant in the current situation (e. g., social life, current needs of society).
- Objective-future relevance: What is normatively or socially perceived as relevant in the future (e. g., social life, future societal challenges).

Interpreting the relevance paradox (Niss, 1994) within this framework emphasizes that mathematics is often assigned high objective relevance (e. g., for technology, economy, higher education), while students often experience low subjective relevance. From the perspective of EVT, this mismatch suggests that especially the utility value ascribed to mathematics by experts does not necessarily translate into students' own value beliefs. A central question in recent research is therefore how instructional design can support the development of higher subjective relevance attributions. One approach is the use of relevance interventions (e.g., Gaspard et al., 2022) that explicitly aim to strengthen students' utility value beliefs regarding a curricular content. One example is to use contextualized teaching units that embed curricular content in meaningful, authentic contexts that stem from everyday life, societal issues or the world of work (Walton & Yeager, 2020). The underlying assumption is that contextualisation can make visible why and how mathematical content matters, thereby increasing the perceived relevance of the curricular content. In the case of professionally oriented contexts, e. g., wind energy, the aim is to highlight the objective-future vocational relevance of mathematics.

However, existing research also indicates that authentic contextualisation is not sufficient to reliably enhance perceived relevance, but that a metacognitive reflection is needed (Geisler & Rach, 2023). Students need (guided) opportunities to actively reflect why and for whom a mathematical content might be relevant, to connect it to their own current and future goals and identities, and to reflect the role of mathematics in different life domains. Consequently, it is not merely the presence of a context, but students' perception of this context as subjectively relevant in connection with students' meaning-making regarding the importance of the mathematical content within the context that is crucial.

In line with the meaning-making perspective, the present study examines the following research question: How do students attribute relevance to a contextualized mathematical content depending on the authenticity of the context?

METHOD

Data were collected with a total of 26 grade 10 students (average age: 15,67; 12 female, 14 male) from two high school classes in Northern Germany by guideline-based group

interviews and pre-post-questionnaires. The interviews took place after the students had completed a contextualized teaching unit on the curricular content circle calculations and radian measure. The teaching unit was implemented by the regular mathematics teacher as part of the standard curriculum and designed to integrate an authentic context from the field of wind energy (e. g., distance travelled by blade tip) and was taught showcasing and reflecting these applications to wind turbines. All students had previously received the same teaching unit in order to have equivalent experience with an authentic context. The following group interviews were then based on three contexts that differed significantly from one another in terms of their degree of authenticity.

Design of the interviews

In order to investigate how students attribute relevance to the specific content of circle calculations and radian measure, eight group interviews were conducted in groups of 2 - 4 students after the teaching unit. Interviews took place in a separate room during regular lesson time, were audio-recorded and transcribed verbatim. Each interview lasted between 11 and 21 minutes (Ø = 14:53). In order to investigate how students attribute relevance to mathematics, three mathematically equivalent tasks on arc length were designed, differing only with respect to their context.

- **Version 1** presented the task in the context of wind energy. Building on the preceding teaching unit, students were asked to determine the tip distance travelled by the tip of a rotor blade of a wind turbine over a given angle of rotation. The version included a picture of the wind turbine and closely mirrored the authentic context used in the teaching unit. It was intended to connect directly to the instructional experience of the mathematics classroom.
- **Version 2** embedded the task in a familiar, but inauthentic context. The task was to calculate the length of the circular arc traced by a truck's windscreen wiper as it moves from one position to another. The version included a drawing of a generic truck windscreen with wiper.
- **Version 3** presented the same arc length problem in a decontextualized, purely mathematical form. The task was to calculate the length of a circular arc on the basis of a given radius and angle without any situational framing.

In each group interview, students were confronted with all three versions of the task. The order of presentation was not varied across groups. Within the interview, students were not asked to work on the problem, but to (1) choose the version that seemed most relevant to them and to explain their decision to the others and (2) to discuss what exactly has to be calculated in the different versions and whether and why this is relevant (a) to them now or in the future and (b) for society now or in the future. The semi-structured interview guideline prompted students to comment on their emotions and attitudes towards each version such as interest, usefulness, and relevance of the task for their present and future lives, as well as on similarities and differences between the three versions. The interviewer encouraged students to elaborate on and justify their

views, and to respond to one another. For the purposes of this contribution an initial qualitative content analysis (Mayring, 2022) was conducted to determine the frequency of students' explicit and implicit references to agreement and disagreement regarding subjective and objective relevance (a) of the context (wind energy, truck windscreen wiper, mathematical context), and (b) of the specific mathematical content (circle calculations and radian measure) in the contexts (authentic, inauthentic, mathematical).

Pre-post questionnaire

In addition to the group interviews, a pre-post questionnaire was administered to all participating students to obtain insights into their relevance attributions before and after the contextualized unit. The pre-data was collected shortly before the beginning of the teaching unit, the post-data immediately after its completion.

Table 1: Information on questionnaire scales; reliability (McDonald's *Omega*) for pre (relevance mathematics)/post (relevance mathematics)/post (relevance circle calculations & radian measure).

Scale (# items)	Sample item	Reliability
Relevance for school life (4)	The content from my math classes often helps me understand the content in other subjects.	.74/.80/.81
Relevance for daily life (5)	I know of various situations in my everyday life where the content from my math lessons is relevant.	.80/.73/.84
Relevance for future life (5)	I think that the content of my math lessons is relevant for my future life.	.79/.78/.83
Relevance for job life (6)	The content from my math lessons will often help me in my future studies/career.	.58/.78/.84
Relevance for social life (2)	I believe that the content of my math lessons is relevant for tackling social challenges.	.82/.92/.93

Table 1 shows the included scales addressing students' perceived relevance of mathematics to their school life, their daily and future life as well as to job and social life in general (pre- and post-measurement) and the same scales regarding the perceived relevance of the curricular content of circle calculations and radian measure (only post-measurement). Responses were collected using 6-point-Likert-scales (1 = totally disagree to 6 = totally agree). By combining the quantitative questionnaire data with the qualitative data from the group interviews, we aimed to capture both changes in students' reported relevance attributions over time and the qualitative nuances of how they make sense of contextualized mathematical content.

RESULTS

To address the research question, students' statements were coded with respect to perceived relevance of (a) the context and (b) the mathematical content in the context,

and then assigned the four perspectives of the 2 x 2 relevance matrix (subjective/objective x present/future). A subset of 78 % of all coded segments was double-coded; intercoder reliability was satisfactory (Cohen's κ = .881/.853 for a/b).

Table 2: Number of positive (negative) statements assigned to the respective relevance perspectives for the three contexts.

(a) Perceived relevance of context (Total: 54)						
	Authentic		Inauthentic		Mathematical	
	Present	Future	Present	Future	Present	Future
Subjective	5 (1)	2 (-)	- (6)	2 (-)	5 (6)	-
Objective	15 (-)	9 (-)	2 (-)	- (1)	-	-
(b) Perceived relevance of mathematical content in context (Total: 47)						
	Authentic		Inauthentic		Mathematical	
	Present	Future	Present	Future	Present	Future
Subjective	5 (-)	- (2)	- (4)	- (1)	2 (1)	1 (-)
Objective	21 (-)	-	5 (5)	-	-	-

Table 2 summarizes the number of statements assigned to each relevance perspective for the three task contexts. For the perceived relevance of the context, most statements referred to the objective relevance of the authentic context (wind energy). Subjective relevance attributions to this context were comparatively rare. By contrast, the other two contexts elicited only a few (negative) explicit relevance statements. A similar picture emerged for the perceived relevance of the mathematical content within the context, indicating that students frequently referred to circle calculations and radian measure as objectively important within the context of wind energy. Overall, the qualitative findings indicate that the professionally contextualized authentic version was most likely to trigger references to objective relevance, while explicit subjective relevant attributions – both present and future – remained comparatively scarce across all three versions.

Table 3 presents findings from the pre- and post-measurement regarding students' perceived relevance of mathematics in general (pre and post) and the specific content of circle calculations and radian measure (only post). Across all domains, students reported moderate perceived relevance of mathematics. Only the perceived relevance of mathematics for social life increased significantly (* $p < .05$). Compared to the perceived relevance of mathematics in general, the perceived relevance of the specific content was significantly lower in each domain (** $p < .001$).

Table 3: Mean values (standard derivation) for pre-and post-test and *t*-test-results (* $p < .05$).

	Pre Mathematics	Post Mathematics	Post CC & RM
Relevance for school life	3.39 (0.82)	3.58 (0.91)	2.76 (0.97)**
Relevance for daily life	3.31 (1.04)	3.40 (1.01)	2.61 (1.12)**
Relevance for future life	3.77 (0.86)	3.64 (1.03)	2.68 (1.04)**
Relevance for job life	4.39 (0.66)	4.10 (1.02)	3.24 (1.16)**
Relevance for social life	3.26 (1.22)	3.96 (1.53)*	2.50 (1.40)**

In conclusion, the quantitative data suggests that the contextualized unit did not substantially shift students' global relevance attributions, but that students differentiate clearly between the relevance of mathematics in general and that of a specific curricular content, even when taught in an authentic context with basic meta-cognitive reflection.

DISCUSSION

Drawing on a relevance framework grounded in EVT, this study explored how students attribute relevance to mathematically equivalent tasks presented in different contexts, and how an authentic contextualized unit on circle calculations and radian measure relates to their relevance beliefs. Our findings suggest that the authentic wind energy context (version 1) was effectively primarily in activating objective relevance beliefs, especially pertaining the present x objective perspective. The comparison between the three task contexts (authentic vs. inauthentic vs. mathematical) underscores this pattern. This resonates with existing research that simply embedding mathematics in authentic contexts may highlight objective relevance, but does not automatically translate into higher subjective relevance attributions (e. g. Walton & Yeager, 2020; Gaspard et al., 2022). The qualitative data are consistent with this interpretation: Students endorsed the objective relevance of mathematics in general, however, this endorsement did not transfer to the particular content taught, even when embedded in an authentic context chosen to highlight its utility. Consequently, the data suggests that the contextualized unit may have aligned with existing objective relevance attitudes, without sufficiently fostering students' individual meaning-making about *why* this mathematical content should matter to *them*.

The present study is subject to several limitations. This preliminary exploratory investigation involved a small sample size from only two classes, which limits the generalizability of the findings. The qualitative results are based on a first, predominantly descriptive analysis; further qualitative work is still pending. Furthermore, no systematic field experiments with controlled variation of contextual features (e. g., authenticity, professional domains, structured metacognitive reflection) have yet been conducted. Consequently, future research should employ larger, more diverse samples and systematically varied field experiments on contextual features and

metacognitive reflection to examine their differential effects on students' subjective and objective relevance attributions.

Despite the limitations, the results of this study suggest several implications for the design of contextualized mathematics teaching: Authentic contexts appear to strengthen students' discourse about the societal importance of mathematics, thereby making objective relevance more salient. However, they are not sufficient on their own to enhance subjective relevance attributions. In accordance with recent research on relevance interventions, our results indicate the necessity for explicit integrated opportunities for metacognitive reflection that extend beyond reflection in conversation with the students.

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