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Students' mathematical beliefs and motivation in the context of inquiry-based mathematics teaching

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ABSTRACT
In this paper, we investigate the learning experiences, beliefs and motivations of students in classes where the mathematics teachers have received support for using inquiry-based learning activities. Data were collected from 248 students in the age-range 11–16 using electronic questionnaires. Our results show that key features of inquiry-based mathematics were only moderately reflected in these students' beliefs about the subject, their dispositions towards mathematics were less positive across the transition from primary to secondary school, and with respect to motivation this decline was stronger for girls than for boys. Furthermore, medium to strong correlations between belief- and motivation subdomains were found, for instance, students who view mathematics as a creative subject and/or have a growth mindset of mathematics also tend to find this subject enjoyable and perceive it as useful. Finally, our results indicate that inquiry-based teaching has a potential for fostering positive dispositions towards mathematics, as students who often experience inquiry-related activities in class also tend to see mathematics as a creative and interesting subject that will be useful for them in the future.

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KEYWORDS
Inquiry-based learning; beliefs; motivation

1. Introduction

For the last couple of decades, serious concerns have been raised about students' participation in – and interest for learning – science, mathematics and technology (see e.g. OECD, 2008). As summarized in Henriksen (2015), many young people opt away from science and mathematics during their secondary education, and Engeln et al. (2013) argue that a lack of proficiency and interest among students in mathematics and science subjects may hinder young people becoming active and productive members of society – especially in a rapidly changing world. Furthermore, a population proficient in science, technology and mathematics has been seen as necessary for economic growth and prosperity (Engeln et al., 2013). More recently, Inquiry Based Learning (IBL) has been proposed and received a lot of political and economic support – especially in Europe – as an approach to teaching

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and learning that could improve students' interest in, motivation for, and learning of both mathematics and science (Artigue & Blomhøj, 2013; Rocard et al., 2007).

IBL can be loosely defined as a way of teaching where students work in ways similar to how mathematicians and scientists work (Artigue & Blomhøj, 2013). More specifically, this means that students are provided opportunities to pose questions, explore situations, and develop their own approaches towards solutions. The term inquiry itself refers back to the work of John Dewey (1933), who developed an entire pedagogical theory on the assumption that motivated investigations of our surroundings and related reflections, condensed as reflective inquiry, is the driving force for the development of all types of human knowledge. Although IBL, and other student-centered approaches to teaching such as problem-based learning and discovery learning, have been criticized for ignoring human cognitive structures (Kirschner et al., 2006), recent meta-studies have shown that IBL has the potential to improve students learning of and motivation for mathematics, as well as change students' beliefs about mathematics as a subject (Alfieri et al., 2011; Bruder & Prescott, 2013; Lazonder & Harmsen, 2016). There is, however, a need for further research on the success of IBL in relation to the support mathematics teachers receive for using IBL.

The context of the present study is a large four-year professional development project called SUM, which set out to explore how teachers could be supported to integrate IBL in their day-to-day mathematics teaching. For three consecutive school years, teachers and researchers formed working groups which met 3–4 times a year. These groups can be viewed as co-learning partnerships, in which participants collaborated on designing, implementing and evaluating inquiry-based activities that were integrated in the teachers' own practice (see (Haavold & Blomhøj, 2019), (Roksvold & Haavold, 2021) or (Blomhøj, Haavold, & Pedersen, 2022) for a further description of the project or examples of activities). The SUM-project thus provides an opportunity for investigating the learning experiences, beliefs, and motivations of students in classes where the mathematics teachers have received this particular form of support for using IBL.

In this paper, our aim is examining to what extent these students' beliefs about mathematics as a subject reflect key features of IBL, and how beliefs and motivation variables relate to characteristics of the teaching they have received. Furthermore, we are interested in how background variables such as gender and age affect these students' beliefs and motivation.

2. Theoretical foundations and related literature

2.1. Beliefs about mathematics

Students' beliefs about mathematics and how these may influence learning has attracted a great deal of attention in mathematics education research (Leder & Forgasz, 2002). Although the term has not been used uniformly throughout the research literature, certain features seem to be recurrent. For example, both Philipp (2007) and Skott (2015) consider beliefs as subjective knowledge that is felt to be true, and as value-laden mental constructs characterized by a certain degree of commitment. According to Skott (2015), beliefs are also commonly considered relatively stable. However, in a critical analysis of the relevant research literature, Liljedahl et al. (2012) conclude that stability is not a defining characteristic of beliefs. Instead, they summarize, change is a natural development of beliefs in the face of experiences (p. 35). Finally, beliefs are also organized in complex and quasi-logically connected clusters (Philipp, 2007), and beliefs about mathematics have commonly been grouped according to beliefs about the nature of mathematics, beliefs about mathematics learning, and beliefs about mathematics teaching (Beswick, 2012; Ernest, 1989).

In our study, we are interested in beliefs about mathematics that relates to key features of inquiry-based mathematics teaching. IBL is premised on an epistemological belief of mathematics as creative human endeavour, primarily focusing on the investigative processes of mathematics (Ernest, 1989), and this epistemological position is reflected in a pedagogy where students are provided with opportunities to both explore and explain mathematics. Furthermore, as teaching mathematics is envisioned as facilitating students' active knowledge construction through exploratory and open-ended processes (Artigue & Blomhøj, 2013), a key premise is that all students have the capacity for learning and becoming proficient in mathematics. With respect to the nature of mathematics, we therefore focus on views of mathematics as a subject that is creative, humanistic and related to the world we live in, and call this belief dimension *Mathematics is a creative subject*. Turning to beliefs about mathematics teaching, the subdomain we are interested in concerns views that mathematics instruction should provide students with opportunities to explore and try out their own ideas, and we call this *Mathematics instruction should be inquiry-based*. Finally, when it comes to beliefs about mathematics learning we are interested in beliefs reflecting a growth mindset (Dweck, 1999), that mathematical ability is not fixed but may be cultivated. We call this final belief subdomain *Mathematical ability is not innate.*

2.2. Motivation

Motivation has long been the focus of mathematics education research, and to a large extent, this research has focused on students' beliefs, values and goals as primary influencers of motivation (Eccles & Wigfield, 2002). In this respect, beliefs are not limited to the beliefs about mathematics as a subject described in the previous section, but include beliefs about one's own mathematical ability or the usefulness of mathematics.

The importance of competence beliefs have been demonstrated by numerous empirical studies showing that students with high competence beliefs and self-efficacy perform better and are more motivated for learning (see e.g. Hacket & Betz, 1989; Pajares & Miller, 1994; and also Eccles & Wigfield, 2002). But although competence beliefs are important for motivation, feeling confident that you will perform well at an activity may not be a sufficient reason for actually participating in said activity. Another broad group of motivational theories are those focusing on the reasons individuals have for engaging in tasks or activities (Eccles & Wigfield, 2002), a prominent example being the concept of intrinsic/extrinsic motivation in self-determination theory (Ryan & Deci, 2000). Self-determination theory defines *intrinsic motivation* as 'the doing of an activity for its inherent satisfactions rather than for some separable consequence' (Ryan & Deci, 2000, p. 56). Intrinsic motivation can arise when an individual finds a task or an activity inherently interesting, and may be seen as contrasting with *extrinsically motivated* activities, which are performed for instrumental reasons – for instance rewards or other desirable consequences of engaging in the activity. Intrinsic motivation has been shown to relate to better task persistence, greater engagement, and higher performance (Rigby et al., 1992; Ryan & Deci, 2000).

A somewhat different perspective is offered by the expectancy-value theory of achievement-related choices (Eccles, 2005). Here, a student's motivation for engaging in an activity is thought to depend on two sets of beliefs: (1) the student's expectations for success, which relates to their competence beliefs as well as their estimation of the difficulty of the activity, and (2) how students value the activity. The latter includes an intrinsic value related to the enjoyment a student may experience when engaging in an activity or the subjective interest the individual has in the activity, and a utility value relating to how engagement may be useful to the student, for instance with respect to their future career prospects (Eccles & Wigfield, 2002). As in the case of competence beliefs, empirical research has convincingly demonstrated that both experiencing enjoyment and perceiving mathematics as useful positively influence student's performance (see e.g. Weidinger et al., 2020).

In this study, we will conceptualize students' motivation for mathematics through the constructs of *perceived competence, intrinsic value*, and *utility for future life.*

2.3. Beliefs and motivation in relation to age, gender and teaching characteristics

Previous research has shown that students' mathematical self-confidence and enjoyment of mathematics decline across grade levels (Christensen & Knezek, 2020; Kaarstein & Nilsen, 2016), and similar trends are found for student's views about the usefulness of mathematics (Forgasz et al., 2015). Furthermore, numerous studies have demonstrated gender differences regarding beliefs and attitudes about mathematics. Generally, boys report more positive attitudes towards learning mathematics (Else-Quest et al., 2010), while girls report lower self-confidence (Perez-Felkner et al., 2012). With respect to utility value, some studies indicate that boys are more likely to agree with statements describing mathematics as important (Perez-Felkner et al., 2012). However, the picture is less clear when it comes to attribution of success. For example, Leder (1992) found that boys emphasized ability while girls tended to emphasize effort, indicating that girls to a larger extent have a growth mindset with respect to mathematics ability. On the other hand, Perez-Felkner et al. (2012) found that boys tended to score higher on a measure of the belief that most people can learn to master mathematics, i.e. that boys to a larger degree indicated that mathematical ability is not innate.

With respect to teaching, the picture is somewhat mixed. Inquiry-based approaches have indeed been shown to potentially influence students' beliefs about mathematics in a positive way (e.g. Boaler, 1998). For example, Gijsbers et al. (2020) recently found that guided inquiry-based teaching strategies and tasks in authentic realistic contexts can improve secondary students' beliefs about the relevance of mathematics to real-life situations, while Fielding-Wells et al. (2017) highlighted how inquiry-based learning may increase student motivation for mathematics. Furthermore, in a retrospective analysis Moyer et al. (2018) found that high-school seniors who had followed a reform-oriented curriculum in lower secondary school exhibited a more relational vision of mathematics than students who had followed a traditional curriculum. However, Moyer et al. also found that an instrumental view of mathematics still was the most prevalent, and that there were no differences between the groups in terms of their emotional dispositions toward mathematics or perceived competence (Moyer et al., 2018).

2.4. Research questions and hypotheses

Our focus in this paper is on investigating the beliefs and motivations of students in classes where the mathematics teachers have been supported in integrating inquiry-based activities in their mathematics teaching. The short literature review above gives us some indications of what to expect, but less is known about the belief domains we are interested in and how they relate to motivation variables and teaching approaches. Specifically, we will address the following research questions:

(1) What characterizes these students' motivation for mathematics and beliefs about mathematics as a subject, and to what extent do these dispositions differ across gender and school level?
(2) How do motivational variables and student beliefs about mathematics relate to each other, and to what extent do these relationships differ across gender and school level?
(3) How do these students' motivation for mathematics and beliefs about mathematics as a subject relate to characteristics of the teaching they have received, and does this differ across gender and school level?

3. Method

As already noted, the developmental activities in the SUM-project lasted for three consecutive school years. Some of the participating teachers did not join until the beginning of the second year, therefore, data for our study were collected in the final semester (spring 2020) of this project, thus ensuring that all the participating students had experienced some inquiry-based teaching in their mathematics classes. Electronic questionnaire responses were collected from 248 primary school (grades 5–7) and secondary school (grades 8–10) students, attending 3 different schools participating in the SUM-project. The students were in the age-range from 11 to 16, 49% were male, and 32% of them came from the primary school level. The collection and handling of data in this project was assessed by the Norwegian Centre for Research Data (NSD), project number 54660, and written informed consent was secured from all participants (for children under 15, informed consent is given by the parents).

The questionnaires contained items measuring students' motivation and beliefs in mathematics along the aforementioned belief domains (Mathematics as a creative subject, Mathematics instruction should be inquiry based, Mathematics is not an innate ability) and motivation constructs (Intrinsic value, Perceived competence, Utility for future life). In addition, the questionnaires included background questions (age, gender, school, etc.) and questions about the teaching they have received.

3.1. Belief and motivation scales

All belief and motivation items were answered along a 5-point Likert scale (1: completely disagree, 5: completely agree). In a previous validation study using a pilot dataset collected

Table 1. Constructs with sample items. Shorthand names are given in parentheses.

Scale	No of items	Sample item	α
Mathematics as a creative subject (Creative)	3	Mathematics is first and foremost about understanding the world around us	0.59
Mathematics is not an innate ability (Adventitious)	3	Everyone can become proficient in mathematics	0.77
Mathematics instruction should be inquiry-based (Inquiry)	3	In mathematics class we should first and foremost experiment and try out our own ideas	0.58
Intrinsic value	5	I enjoy doing mathematics	0.91
Perceived competence	4	I have good mathematical skills	0.94
Utility for future life (Future utility)	4	Mastering mathematics will help me get a job later in life	0.77

with a partially overlapping sample of students in the fall of 2019, we established that these items form robust measures of the belief- and motivation domains under consideration, with acceptable internal reliability and discriminant validity (Pedersen & Haavold, 2022). Table 1 shows an overview of these constructs with sample items, as well as values of Cronbach's alpha calculated for the data in the present study. The alpha-values for the scales Creative and Inquiry are here lower than optimal,[1] but of the same the magnitude as scales used to measure beliefs about the nature of mathematics in other studies (see e.g. Wilkins & Ma, 2003). We deem both of these scales satisfactory for our use, but recognize that care should be taken when interpreting the results.

For each scale, student scores were calculated by computing the arithmetic mean of the associated items that had valid, non-missing values. This ensures that the scale values lie in the same range as the original Likert scale. Negatively worded items have been reversed, so that a high score indicates agreement with the described belief domains or positive motivational dispositions.

3.2. *Teaching characteristic scale*

Twelve questionnaire items asked students about their perception of the teaching they had received. Sample items include 'In mathematics class, we work individually on tasks similar to textbook examples', 'In mathematics class, we discuss different ways of solving problems' and 'In mathematics class, we work on inquiry tasks'. These items were answered along a 5-point Likert scale (1: almost never, 5: almost always). An exploratory factor analysis using Principal Axis Factoring and oblique rotation was performed on these items, in order to identify a possible factor structure. Three items were excluded to improve the interpretability due to low communalities and/or high cross-loading. The factorability of the 9 remaining items was deemed satisfactory (with a Kaiser-Meyer-Olkin measure of 0.81, as well as significant Bartlett's Test of Sphericity), and two factors were extracted in the analysis.

Seven items loaded onto factor 1 (eigenvalue $= 3.2$, 35.8% of variance), with factor loadings in the range 0.49–0.68. All these items describe mathematics classes where students work on challenging problems and inquiry tasks, devising their own solution strategies and discussing different ways of solving problems (possibly in groups or with the aid of concrete materials). We therefore call this factor Inquiry-based mathematics activities (IMBA), as these are all activities present in inquiry-oriented classrooms. The internal reliability of the IBMA scale was deemed good, with a Cronbach alpha of 0.80.

Only two items loaded onto factor 2 (eigenvalue = 1.4, 15.9% of variance), with factor loadings of 0.61 and 0.65. As both of these items describe teaching or activities that heavily rely on the textbook, we call this factor Textbook-based activities (TBA). It should be noted that the use of two-item scales is debated, as the reliability inevitably will be lower than for longer scales. On the other hand, there is some empirical evidence that two-item subscales of longer measures can adequately represent their parent scales (Jensen et al., 2003), and a two-item scale will usually have a better content validity than a single item. For the TBA-scale, we assessed internal reliability using the Spearman-Brown coefficient, as this is recommended for two-item measures (Eisinga et al., 2013). The calculated value of 0.58 is somewhat lower than optimal, but of the same magnitude as similar scales developed in other studies (see e.g. DeMonbrun et al., 2017). We therefore deem both scales satisfactory for our use, as long as care is taken when interpreting the results.

For both teaching characteristic scales, student scores were calculated by computing the arithmetic mean of the associated items that had valid, non-missing values. Again, this ensures that the scale values lie in the same range as the original Likert scale. High scores on the teaching characteristic scales thus indicate that this type of teaching is perceived to be frequently used in class.

3.3. Data analysis

Measures of central tendency and variance were calculated for each of the belief- and motivation constructs (see Table 2, further discussed in the results section). For some of the variables (e.g. Future utility and Adventitious), we noticed a clear deviation from the normal distribution. In the following, we therefore employ the non-parametric Mann-Withney U-test to assess whether motivation for mathematics and beliefs about mathematics as a subject differ across gender and school level. Possible relationships between the motivational variables, student beliefs about mathematics and teaching characteristics are investigated by calculating Spearman correlation coefficients. Finally, we test whether differences in correlation coefficients across gender and school level are statistically significant by transforming the correlation coefficients to z-scores using the Fischer Z-transformation

$$z_S = \frac{1}{2}\log_e\left(\frac{1+r}{1-r}\right),$$

Table 2. Descriptive statistics.

	N	Median	Mean	St. dev.	Skewness	Kurtosis
Belief domains						
Creative	247	3.33	3.26	0.789	−0.023	−0.307
Adventitious	247	4.67	4.23	0.830	−1.311	1.786
Inquiry	248	3.33	3.38	0.732	−0.002	−0.181
Motivation constructs						
Intrinsic value	248	3.40	3.32	0.897	−0.396	−0.180
Perceived competence	248	3.75	3.53	1.00	−0.575	−0.214
Future utility	248	4.25	4.22	0.797	−1.191	1.590

Table 3. Test statistics (Mann-Whitney U-test).

	N primary	N secondary	U	|Z|	*p*
Creative	79	168	4402.5	4.303	< .001
Adventitious	79	168	5626.5	1.968	.049
Inquiry	80	168	4420	4.399	< .001
Intrinsic value	80	168	5520	2.278	.023
Perceived competence	80	168	5047	3.181	.001
Future utility	80	168	4589	4.102	< .001

and approximating the variance by $Var(z_S) = 1.06/(n-3)$ as suggested by Fieller et al. (1957).

4. Presentation and discussion of results

In the following, results are presented and discussed for each of the three research questions separately. Common themes will then be addressed in the concluding section.

4.1. RQ1: Student scores on belief and motivation measures

Addressing our first research question entails describing the students' motivation for mathematics and beliefs about mathematics as a subject, and investigating the extent to which these dispositions differ across gender and school level.

Table 2 shows descriptive statistics for each of the belief- and motivation measures. Looking at the student group as a whole, we note that they to a large extent agree that mathematical ability is not innate (Adventitious), and that mathematics will be useful for them in the future. However, their median scores are only slightly above the neutral midpoint of the scale (3) when it comes to the belief domains Creative and Inquiry. This implies that the students to a lesser extent agree that mathematics is a creative subject where the purpose is to solve interesting problems and understand the world around them, or that mathematics instruction should be inquiry based. Thus, we find that some key features of inquiry-based mathematics are only moderately reflected in these students' beliefs about the subject.

Many studies have documented a decline in students' attitude towards mathematics over the transition from primary to secondary school (Christensen & Knezek, 2020; Evans et al., 2018; Tuohilampi et al., 2014). Figure 1 compares the central tendency (median) for the belief- and motivation constructs by school level, and shows a decline for all 6 measures. Mann–Whitney U tests (summarized in Table 3) show that on the 5% level, this decline is statistically significant for all the belief- and motivation constructs, albeit only just so for the Adventitious construct. In a previous study, Wilkins and Ma (2003) found that although students developed less positive attitudes toward mathematics and its social importance with increasing age, their notion of the nature of mathematics did not tend to change. Our results modify this picture, as we find that the secondary school students to a significantly lesser extent agree that mathematics is a subject which is creative, humanistic and related to the world we live in.

Turning to gender, previous research has demonstrated differences regarding beliefs and attitudes about mathematics, but few previous studies have considered the belief constructs we are interested in. Looking at our student group as a whole, we found the perceived

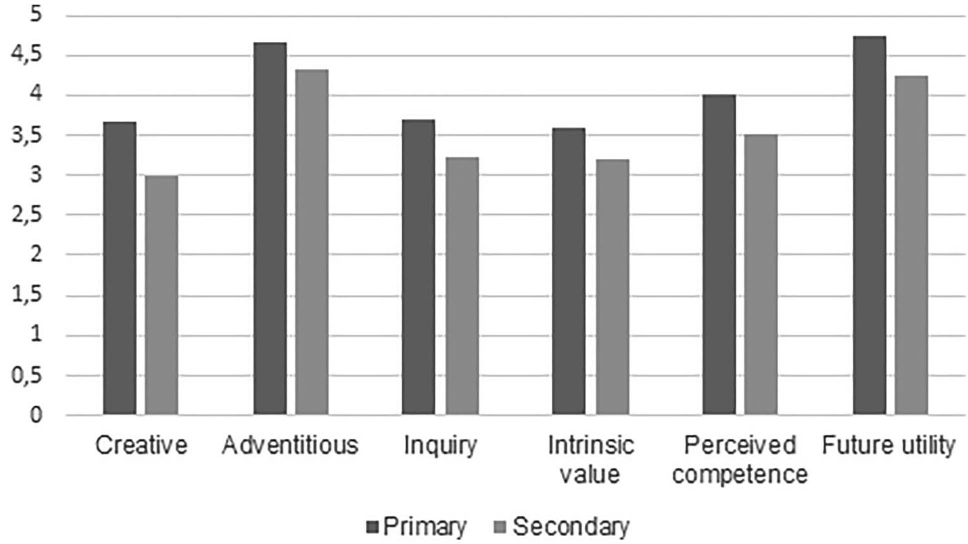

Figure 1. Median values of belief- and motivation constructs across school level.

competence scores of boys ($Md = 3.75$) to be higher than those of girls ($Md = 3.50$). A Mann–Whitney U Test indicated that this difference was statistically significant, $U(N_b = 121, N_g = 127) = 8878.00, z = 2.124, p = .034$. No significant gender differences were found for the other belief- and motivation constructs in Table 2. However, if we take school level into account, the picture regarding the motivation constructs changes somewhat:

- For the primary school students, girls scored higher on Intrinsic value ($Md_{IE} = 3.80$) and Future utility ($Md_{FU} = 5.00$) than boys ($Md_{IE} = 3.2$ and $Md_{FU} = 4.75$, respectively), and these differences were statistically significant with $U(N_b = 41, N_g = 39) = 561.50, z = 2.297, p = .022$ for differences in Intrinsic value and $U(N_b = 41, N_g = 39) = 569.50, z = 2.361, p = .018$ for Future utility. Furthermore, Perceived competence did not differ between girls and boys at the primary school level.
- For the secondary school students, there was a statistically significant difference between the Perceived competence scores of boys and girls ($Md_b = 3.75, Md_g = 3.25, U(N_b = 80, N_g = 88) = 4168.0, z = 2.066, p = 0.039$), but there were no differences with respect to Intrinsic value and Future utility.

Taken together, this shows that the decline in motivation across the transition to secondary school was stronger for girls than for boys, and that the difference in perceived competence did not appear until secondary school. No such gender differences were found with respect to the decline in beliefs.

4.2. RQ2: Intercorrelation between belief and motivation constructs

Addressing our second research question entails investigating the relationship between the belief domains and motivational variables, and to what extent these relationships differ across gender and school level.

Table 4. Belief and motivation intercorrelations.

Scale	1	2	3	4	5
1. Creative					
2. Inquiry	0.30**				
3. Adventitious	0.29**	0.12			
4. Intrinsic value	0.41**	0.10	0.43**		
5. Future utility	0.48**	0.06	0.40**	0.47**	
6. Perceived competence	0.20**	0.15*	0.29**	0.59**	0.31**

**Correlation is significant at the 0.01 level. *Correlation is significant at the 0.05 level.

Table 4 shows the bivariate Spearman (non-parametric) correlation coefficient between the each of three scales measuring students' beliefs and the three scales measuring students' motivations.[2] The strongest correlation is found between Intrinsic value and Perceived competence, which is to be expected as strong cyclical relationships between mathematics enjoyment and confidence have also been found in other studies (see e.g. Christensen & Knezek, 2020). A separate analysis further revealed that this correlation between intrinsic value and perceived competence is stronger for girls than for boys ($\rho_g(125) = .68^{**}$, $\rho_b(119) = .51^{**}$), and using the Fischer Z-transformation we found that this difference was statistically significant with $p = .047$ (two-sided). An optimistic interpretation of this is that for both genders, activities that promote mathematical enjoyment will contribute to increased confidence, which in turn will increase the enjoyment, and as this relationship is stronger for girls, such activities have the potential to counter the development of gender differences in motivation.

Furthermore, there are some moderately strong relations between belief- and motivation constructs: the scales Creative and Adventitious are both positively related to Intrinsic value and Future utility, indicating that students who view mathematics as a creative subject and/or have a growth mindset of mathematics also tend to find this subject enjoyable and perceive it as useful. The correlation coefficients do not say anything about the directions of these relationships, however, other researchers have found evidence supporting a hypothesis that ascribing to a growth mindset promotes valuing (both intrinsic and utility) of mathematics (Degol et al., 2018). We therefore find these correlational relationships promising, as they give further support to the notion that efforts targeting mathematic-related beliefs also may have a positive influence on student motivation.

Further investigations also revealed that some of the subscale intercorrelations significantly differs between primary-level and secondary-level students. For example, while the median scores of both the Adventitious and Intrinsic value constructs were lower for secondary school students (see Figure 1), the aforementioned relationship between these constructs was significantly stronger for the secondary school students ($\rho_{prim}(78) = .24^{**}$, $\rho_{sec}(166) = .50^{**}$, $p_{diff} = .030$). On the other hand, we find a stronger relationship between Creative and Future utility for the primary school students than for the secondary school students ($\rho_{prim}(78) = .60^{**}$, $\rho_{sec}(166) = .36^{**}$, difference statistically significant with $p = .029$). These differences show that it is not just the degree of motivation or agreement with belief domains that may change with increasing age, but also the relationship between the belief- and motivation domains.

Table 5. Descriptive statistics for the teaching-characteristic scales.

Scale	Median	25-percentile	75-percentile
IBMA	3.14	2.74	3.42
TBA	4.00	3.50	4.50

Table 6. Subscale correlations with teaching characteristics.

	Creative	Adventitious	Inquiry	Intrinsic value	Perceived competence	Future utility
IBMA	0.45**	0.27**	0.023	0.29**	0.10	0.35**
TBA	−0.001	0.012	−0.025	−0.017	0.14*	0.13*

**Correlation is significant at the 0.01 level. *Correlation is significant at the 0.05 level.

4.3. RQ3: Influence of teaching characteristics

Addressing our third research question entails investigating how these students' motivation for mathematics and beliefs about mathematics as a subject relate to characteristics of the teaching they have received, and to what extent these relationships differ across gender and school level.

As already noted, all the participating students attended classes where the teachers had received support for integrating inquiry-based activities in their mathematics lessons through the SUM-project. This does, however, not mean that the majority of the teaching was inquiry based. The students' responses to the teaching-characteristic items are summarized in Table 5, and briefly put this shows that the amount of class-time used for Inquiry-based mathematics activities (henceforth referred to as IBMA) was moderate overall, with some students experiencing these kinds of activities relatively often, and others reporting that they were relatively seldom used. Furthermore, although the use of textbook-based activities varied, students perceived them as more prevalent than inquiry-based activities.[3]

Given the aforementioned variations in the use of inquiry-based and textbook-based activities, we have calculated bivariate Spearman correlation coefficients between belief/motivation constructs and the teaching characteristic scales. The results are shown in Table 6, and for these correlations, no significant differences were found across gender or school level.

Here, we note that there is a moderate positive correlation between the belief scale Creative and the IBMA scale, while the scales Adventitious, Intrinsic value and Future utility are all weakly but positively correlated with the IBMA scale. Although the correlations are not strong, this gives some indication that students who often experience inquiry-based mathematics activities to a larger extent see mathematics as a creative subject that will be useful for them in the future, find mathematics interesting and enjoyable, and believe that mathematical ability is the result of effort rather than something innate.

5. Concluding remarks

We have investigated the beliefs and motivations of students in classes where the mathematics teachers have received supported for integrating inquiry-based activities in their mathematics teaching. Our results show that these students to a large extent believe that mathematics ability is the result of effort, but that their beliefs about mathematics as a subject only moderately reflect other key features of IBL. Furthermore, we find that the well-documented decline in motivation across the primary/secondary transition (see e.g. Christensen & Knezek, 2020) also appear in our sample, along with a similar decline in the belief domains. With respect to the motivation variables, we find that this decline is strongest for the girls.

What, then, was the effect of the inquiry-based teaching? As we have conducted a cross-sectional study, we are not in a position to estimate effects by analysing developments in students' dispositions towards mathematics. Rather, we have taken advantage of the fact that there was a variation in the use of inquiry-based activities in class (as perceived by the students), and conducted correlational analyses. These results indicate that students who often experience inquiry-related activities in class also tend to see mathematics as a creative and interesting subject that will be useful for them in the future.

Social-cognitive motivation theories posit that students' beliefs about themselves and their school subjects influence both the nature and the extent of their engagement in classroom activities (Patrick et al., 2017). One may then ask whether the correlations in Table 6 rather indicate that teachers more frequently use inquiry-based activities in classes where students tend to see mathematics as creative, useful and interesting. Our correlational analyses cannot determine the directionality of the relationship between teachers' use of inquiry-based activities and students' dispositions towards mathematics. This may indeed be a reciprocal relationship, where teachers of classes in which students tend to see mathematics as creative, useful and interesting find it easier to integrate inquiry-based activities, which in turn positively influence students' dispositions towards mathematics. We therefore conclude that while our results support other researcher's findings that inquiry-based teaching has a potential for fostering positive dispositions towards mathematics (see e.g. Boaler, 1998; Fielding-Wells et al., 2017; Riegle-Crumb et al., 2019), more research is needed to shed light on the possible reciprocal relationship between teaching characteristics and student' attitudes.

Notes

1. In the questionnaire used for this study, we tentatively added 2 items to each of the scales Creative and Inquiry in an attempt to obtain a higher reliability. As it turned out, the slightly longer scales had lower Cronbach alphas, consequently, we have chosen to keep to the short scales that were more thoroughly validated in (Pedersen & Haavold, 2022).
2. Pearson correlation coefficients of comparable magnitudes were reported in the questionnaire validation study using a pilot dataset (Pedersen & Haavold, 2022), indicating that these correlations are reasonably stable.
3. As the data were collected after the school reopening in the spring of 2020, one may wonder to what extent students' perception of the teaching had been affected by the Covid-restrictions. The aforementioned pilot study conducted with a partially overlapping sample of students in the fall of 2019 however showed similar values for the two teaching characteristic scales.

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References

Alfieri, L., Brooks, P. J., Aldrich, N. J., & Tenenbaum, H. R. (2011). Does discovery-based instruction enhance learning? *Journal of Educational Psychology*, *103*(1), 1–18. doi:10.1037/a0021017

Artigue, M., & Blomhøj, M. (2013). Conceptualizing inquiry-based education in mathematics. *ZDM*, *45*(6), 797–810. doi:10.1007/s11858-013-0506-6

Blomhøj, M., Haavold, P. Ø., & Pedersen, I. F. (2022). Inquiry-based mathematics teaching in practice: a case of a three-phased didactical model. In J. Hodgen, E. Geraniou, G. Bolondi, & F. Ferretti (Eds.), *Proceedings of the Twelfth Congress of European Research in Mathematics Education* (CERME12, February 2–7, 2022). ERME/Free University of Bozen-Bolzano.

Beswick, K. (2012). Teachers' beliefs about school mathematics and mathematicians' mathematics and their relationship to practice. *Educational Studies in Mathematics*, *79*(1), 127–147. doi:10.1007/s10649-011-9333-2

Boaler, J. (1998). Open and closed mathematics: Student experiences and understandings. *Journal for Research in Mathematics Education*, *29*(1), 41–62. doi:10.2307/749717

Bruder, R., & Prescott, A. (2013). Research evidence on the benefits of IBL. *ZDM*, *45*(6), 811–822. doi:10.1007/s11858-013-0542-2

Christensen, R., & Knezek, G. (2020). Indicators of middle school students' mathematics enjoyment and confidence. *School Science and Mathematics*, *120*(8), 491–503. doi:10.1111/ssm.12439

Degol, J. L., Wang, M. T., Zhang, Y., & Allerton, J. (2018). Do growth mindsets in math benefit females? Identifying pathways between gender, mindset, and motivation. *Journal of Youth and Adolescence*, *47*(5), 976–990. doi:10.1007/s10964-017-0739-8

DeMonbrun, M., Finelli, C. J., Prince, M., Borrego, M., Shekhar, P., Henderson, C., & Waters, C. (2017). Creating an instrument to measure student response to instructional practices. *Journal of Engineering Education*, *106*(2), 273–298. doi:10.1002/jee.20162

Dewey, J. (1933). *How we think: A restatement of the relation of reflective thinking to the educative process*. DC Heath.

Dweck, C. S. (1999). *Self-theories: Their role in motivation, personality, and development*. Psychology Press.

Eccles, J. S. (2005). Subjective task value and the Eccles et al. model of achievement-related choices. In A. J. Elliot, C. S. Dweck (Eds.), *Handbook of competence and motivation* (pp. 105–121). Guilford, New York.

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology*, *53*(1), 109–132. doi:10.1146/annurev.psych.53.100901.135153

Eisinga, R., Grotenhuis, M. T., & Pelzer, B. (2013). The reliability of a two-item scale: Pearson, Cronbach, or Spearman-Brown? *International Journal of Public Health*, *58*(4), 637–642. doi:10.1007/s00038-012-0416-3

Else-Quest, N. M., Hyde, J. S., & Linn, M. C. (2010). Cross-national patterns of gender differences in mathematics: A meta-analysis. *Psychological Bulletin*, *136*(1), 103–127. doi:10.1037/a0018053

Engeln, K., Euler, M., & Maass, K. (2013). Inquiry-based learning in mathematics and science: A comparative baseline study of teachers' beliefs and practices across 12 European countries. *ZDM*, *45*(6), 823–836. doi:10.1007/s11858-013-0507-5

Ernest, P. (1989). The impact of beliefs on the teaching of mathematics. In P. Ernest (Ed.), *Mathematics teaching: The state of the art* (pp. 249–253). Falmer.

Evans, D., Borriello, G. A., & Field, A. P. (2018). A review of the academic and psychological impact of the transition to secondary education. *Frontiers in Psychology*, *9*, 1482. doi:10.3389/fpsyg.2018.01482

Fielding-Wells, J., O'Brien, M., & Makar, K. (2017). Using expectancy-value theory to explore aspects of motivation and engagement in inquiry-based learning in primary mathematics. *Mathematics Education Research Journal*, *29*(2), 237–254. doi:10.1007/s13394-017-0201-y

Fieller, E. C., Hartley, H. O., & Pearson, E. S. (1957). Tests for rank correlation coefficients. I. *Biometrika*, *44*(3/4), 470–481. doi:10.2307/2332878
Forgasz, H., Leder, G., Mittelberg, D., Tan, H., & Murimo, A. (2015). Affect and gender. In Pepin, B., Roesken-Winter, B. (Eds.), *From beliefs to dynamic affect systems in mathematics education*. Advances in Mathematics Education. Springer, Cham. doi:10.1007/978-3-319-06808-4_12
Gijsbers, D., de Putter-Smits, L., & Pepin, B. (2020). Changing students' beliefs about the relevance of mathematics in an advanced secondary mathematics class. *International Journal of Mathematical Education in Science and Technology*, *51*(1), 87–102. doi:10.1080/0020739X.2019.1682698
Haavold, P. Ø., & Blomhøj, M. (2019). Coherence through inquiry based mathematics education. In Jankvist, U. T., Van den Heuvel-Panhuizen, M., & Veldhuis, M. (Eds.), *Proceedings of the Eleventh Congress of the European Society for Research in Mathematics Education* (CERME11, February 6–10, 2019). Utrecht, the Netherlands: Freudenthal Group & Freudenthal Institute, Utrecht University and ERME.
Hackett, G., & Betz, N. E. (1989). An exploration of the mathematics self-efficacy/mathematics performance correspondence. *Journal for research in Mathematics Education*, *20*(3), 261–273.
Henriksen, E. K. (2015). Introduction: Participation in science, technology, engineering and mathematics (STEM) education: Presenting the challenge and introducing Project IRIS. In Henriksen, E., Dillon, J., Ryder, J. (Eds.), *Understanding Student Participation and Choice in Science and Technology Education* (pp. 1–14). Springer, Dordrecht. doi:10.1007/978-94-007-7793-4_1
Jensen, M. P., Keefe, F. J., Lefebvre, J. C., Romano, J. M., & Turner, J. A. (2003). One- and two-item measures of pain beliefs and coping strategies. *Pain*, *104*(3), 453–469. doi:10.1016/S0304-3959(03)00076-9
Kaarstein, H., & Nilsen, T. (2016). 4 motivasjon. In Bergem, O. K., Kaarstein, H., & Nilsen, T. (Eds.), *Vi kan lykkes i realfag. Resultater og analyser fra TIMSS 2015* (pp. 63–77). Universitetsforlaget. doi:10.18261/97882150279999-2016-05
Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, *41*(2), 75–86. doi:10.1207/s15326985ep4102_1
Lazonder, A. W., & Harmsen, R. (2016). Meta-analysis of inquiry-based learning: Effects of guidance. *Review of Educational Research*, *86*(3), 681–718. doi:10.3102/0034654315627366
Leder, G. C. (1992). Mathematics and gender: Changing perspectives. In D. A. Grouws (Ed.), *Handbook of research in mathematics teaching and learning* (pp. 597–622). Macmillan.
Leder, G. C., & Forgasz, H. J. (2002). Measuring methematical beliefs and their impact on the learning of mathematics: A new approach. In G. C. Leder, E. Pehkonen, & G. Törner (Eds.), *Beliefs: A hidden variable in mathematics education?* (pp. 95–113). Springer.
Liljedahl, P., Oesterle, S., & Bernèche, C. (2012). Stability of beliefs in mathematics education: A critical analysis. *Nordic Studies in Mathematics Education*, *17*(3–4), 101–118. https://ncm.gu.se/wp-content/uploads/2020/06/17_34_023040_liljedahl.pdf
Moyer, J. C., Robison, V., & Cai, J. (2018). Attitudes of high-school students taught using traditional and reform mathematics curricula in middle school: A retrospective analysis. *Educational Studies in Mathematics*, *98*(2), 115–134. doi:10.1007/s10649-018-9809-4
OECD. (2008). *Encouraging student interest in science and technology studies*. OECD Publishing. https://doi.org/10.1787/9789264040892-en
Pajares, F., & Miller, M. D. (1994). Role of self-efficacy and self-concept beliefs in mathematical problem solving: A path analysis. *Journal of Educational Psychology*, *86*(2), 193–203. doi:10.1037/0022-0663.86.2.193
Patrick, H., Ryan, A. M., & Kaplan, A. (2007). Early adolescents' perceptions of the classroom social environment, motivational beliefs, and engagement. *Journal of Educational Psychology*, *99*(1), 83–98. doi:10.1037/0022-0663.99.1.83
Pedersen, I. F., & Haavold, P. Ø. (2022). Developing and validating survey instruments for assessing beliefs and motivation in mathematics. In J. Hodgen, E. Geraniou, G. Bolondi, & F. Ferretti (Eds.), *Proceedings of the Twelfth Congress of European Research in Mathematics Education (CERME12, February 2–7, 2022)*. ERME / Free University of Bozen-Bolzano.

Perez-Felkner, L., McDonald, S.-K., Schneider, B., & Grogan, E. (2012). Female and male adolescents' subjective orientations to mathematics and the influence of those orientations on postsecondary majors. *Developmental Psychology*, *48*(6), 1658–1673. doi:10.1037/a0027020

Philipp, R. A. (2007). Mathematics teachers' beliefs and affect. In F. K. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (Vol. 1, pp. 257–315). Information Age Publishing.

Riegle-Crumb, C., Morton, K., Nguyen, U., & Dasgupta, N. (2019). Inquiry-based instruction in science and mathematics in middle school classrooms: Examining its association with students' attitudes by gender and race/ethnicity. *AERA Open*, *5*(3), 233285841986765. https://doi.org/10.1177/2332858419867653

Rigby, C. S., Deci, E. L., Patrick, B. C., & Ryan, R. M. (1992). Beyond the intrinsic-extrinsic dichotomy: Self-determination in motivation and learning. *Motivation and Emotion*, *16*(3), 165–185. doi:10.1007/BF00991650

Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H., & Hemmo, V. (2007). *Science education now: A renewed pedagogy for the future of Europe*. Office for Official Publications of the European Communities.

Roksvold, J., & Haavold, PØ. (2021). Using pathologies as starting points for inquiry-based mathematics education: The case of the palindrome. In Nortvedt, G. A., Buchholtz, N., Fauskanger, J., Hreinsdáttir, F., Hähkiöniemi, M., Jessen, B. E., Kurvits, J., Liljekvist, Y., Misfeldt, M., Naalsund, M., Nilsen, H. K., Pálsdóttir, G., Portaankorva-Koivisto, P., Radišić, J., & Wernberg, A. (Eds.), *Bringing Nordic mathematics education into the future. Preceedings of Norma 20: The ninth Nordic Conference on Mathematics Education* (pp. 233–240), Oslo, June 1–4 2021. Svensk förening för matematikdidaktisk forskning. Skrifter från Svensk förening för matematikdidaktisk forskning, 14.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68–78. doi:10.1037/0003-066X.55.1.68

Skott, J. (2015). Towards a participatory approach to 'beliefs' in mathematics education. In B. Pepin & B. Roesken-Winter (Eds.), *From beliefs to dynamic affect systems in mathematics education. Advances in Mathematics education* (pp. 3–23). Springer International. https://doi.org/10.1007/978-3-319-06808-4_1

Tuohilampi, L., Hannula, M. S., Laine, A., & Metsämuuronen, J. (2014). Examining mathematics-related affect and its development during comprehensive school years in Finland. In Nicol, C., Oesterle, S., Liljedahl, P., & Allan, D. (Eds.) *Proceedings of the Joint Meeting of PME 38 and PME-NA 36 (July 15–20, 2014)*, Vol. 5, pp. 281-288. Vancouver, Canada: PME.

Weidinger, A. F., Spinath, B., & Steinmayr, R. (2020). The value of valuing math: Longitudinal links between students' intrinsic, attainment, and utility values and grades in math. *Motivation Science*, *6*(4), 413–422. doi:10.1037/mot0000179

Wilkins, J. L., & Ma, X. (2003). Modeling change in student attitude toward and beliefs about mathematics. *The Journal of Educational Research*, *97*(1), 52–63. doi:10.1080/00220670309596628