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ORIGINAL PAPER

Environment–attitude relationships: girls in inquiry-based mathematics classrooms in the United Arab Emirates

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Abstract

Girls' attitudes towards mathematics can impact their achievement and career choices in STEM fields. Can the introduction of inquiry-based learning (IBL) in mathematics classes generate positive associations between girls' perceptions of the learning environment and their attitudes towards mathematics? Based in the United Arab Emirates, this study provided important information about the relationships between learning environment factors central to an inquiry method and student engagement. Data collection involved administering two surveys to female mathematics students (N=291) in four schools: one to assess students' perceptions of the learning environment and another to assess students' attitudes towards mathematics. Positive and statistically-significant (p<.01) associations emerged between learning environment factors important to an inquiry approach and students' attitudes. These findings provide important information about how IBL might improve girls' attitudes towards mathematics classes and whether IBL environments are related to their attitudes.

Keywords Attitudes · Inquiry-based learning · Learning environments · Mathematics education · Self-efficacy · Task value · United Arab Emirates

Introduction

Traditionally, boys have achieved higher grades in mathematics than girls (OECD, 2016). Research findings suggest that this gender disparity can have long-term consequences that impact students' career aspirations to pursue mathematical fields (OECD, 2020). Of particular concern is the under-representation of girls in the high-performing levels in mathematics, creating a consistent gender gap in STEM-related professions, which are often amongst the highest-paying occupations (Anaya et al., 2021). Further, this gender imbalance reduces opportunities for women and for students who can participate and contribute to these fields

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(Cimpian et al., 2016). The stereotypical view can exacerbate the notion that mathematics is a male pursuit (Leder & Forgasz, 2010) and lead to relatively low numbers of female role models in the field (Lee & Anderson, 2014).

The research reported in this article forms part of a wider study of the introduction of an inquiry-based approach in an all-girl setting (Robinson, 2020) amidst a large-scale educational reform effort in public schools in Abu Dhabi, UAE. A significant focus of the reform effort included a shift from traditional teaching methods to IBL techniques, requiring teachers to use exploration projects based on real-world contexts. This approach is widely viewed as an authentic approach to teaching and learning mathematics (Amaral et al., 2002). For this study, IBL was defined as a "student-centered pedagogy that uses purposeful, extended investigations, set in the context of real-life problems, as both a means for increasing student capacities and as a feedback loop for increasing teachers' insights into student thought processes" (Supovitz et al., 2000, p. 332).

As a teaching approach, IBL can encourage students to think critically (Marshall et al., 2010), reason (Staples, 2007), develop a deep understanding (Makar, 2007), and develop positive identities regarding mathematics (Staples, 2007) while experiencing opportunities to delve into topics that link to their real lives (Gholam, 2019). This approach is a far cry from the traditional methods used in the UAE that rely on memorising facts (Marshall & Horton, 2011). Notably, the inquiry approach encourages students to reflect critically (Leikin & Rota, 2006) and be intellectually engaged in the task (Oliver, 2007).

While there have been many studies of relationship between learning environments and student attitudes, to date, few have examined relationships between IBL and students' attitudes (see, for example, Jiang & McComas 2015). Although research suggests that IBL increases student enthusiasm and enjoyment for learning (Sheppard, 2008), these studies are limited. To our knowledge, no studies have focused on whether the unique environment created in inquiry-based classrooms is related to girls' attitudes, and none have been carried out in a Middle Eastern context. Therefore, the research reported in this article fills this research gap by investigating whether associations exist between students' perceptions of their learning environment and attitudes towards mathematics. The research objective was to *investigate whether associations exist between girls' perceptions of their learning environment and attitudes towards mathematics.*

Background

Field of learning environments

When considering the efficacy of educational processes, much attention is paid to students' achievement scores. While this is an indisputably important indicator, it does not provide an understanding of students' experiences (OECD, 2017). Given the large amount of time that students spend in classrooms during their school years, the context of learning is a pivotal factor in their success. The notion of the context of learning is underpinned by the work of Lewin (1936) who contended that an individual's interactions with the environment is a strong determinant of his or her behaviour.

The psychosocial environment, as opposed to the physical environment, encompasses culture, ambiance, or atmosphere of a classroom, which is strongly influenced by the students and teachers and their interactions (Fraser, 2015). Over the past 50 years, the use of learning environment measures as process criteria has proved helpful in determining the efficacy of innovations by allowing the researcher to examine changes in the learning context through the perceptions of those closest to the change – the students (e.g. Khalil & Aldridge 2019; Koul et al., 2018). Since Walberg (1968) and Moos (1974) carried out the first studies in the field, numerous instruments have been developed. Despite the vast range of surveys designed to assess the learning environments in different contexts and countries (Fraser, 2012), none have been developed to examine the unique learning environments of classrooms using IBL. The specific context of the education reform required developing a learning environment instrument to assess this unique context.

Attitudes towards mathematics

The importance of encouraging and supporting students' positive attitudes is widely recognised (Ing & Nylund-Gibson, 2017). In mathematics classes, attitudes include whether students engage in or avoid mathematical activities, as well as their beliefs about their ability in mathematics and whether mathematics is useful (Neale, 1969). For girls, the need to encourage positive attitudes is particularly prevalent given that they are often underrepresented in STEM courses and programmes (Hyde, 2014).

Trends indicate that, compared with boys, girls feel less confident and suffer more from mathematical anxiety (Van Mier et al., 2019). Further, girls have a lower self-concept in mathematics (Mejía-Rodríguez et al., 2021) and fewer female role models to follow (Lee & Anderson, 2014). Because attitudes can be more malleable than attributes such as broad personality and cognitive ability, considering ways to improve them could help to reduce the disparities between boys and girls in achievement and career attainment (Lipnevich et al., 2016).

Most researchers agree that attitudes have three parts: a cognitive component that describes the knowledge, beliefs, and ideas about an object; an affective component which describes the feeling about an object in terms of like or dislike; and a behavioural component which describes a tendency-towards-action (Breckler, 1984). In this study, we examined three aspects, namely, one related to the cognitive component (self-efficacy) and two related to the affective component (enjoyment and task value).

A major focus of research in the field of learning environment has been the relationship between students' perceptions of the learning environment and a range of cognitive and affective outcomes. These studies have provided consistent evidence to suggest that the context in which learning takes place is indeed related to student outcomes (e.g., Galos & Aldridge, 2021; Khine et al., 2020). Despite this large body of research, the field is relatively new in the UAE with only a handful of studies having been carried out at the tertiary level (e.g., Afari et al., 2012; Hasan & Fraser, 2015; McMinn, 2019) and at the middle-school level (e.g., Aldridge & Rowntree 2021; Khalil & Aldridge, 2019). To our knowledge, however, no studies in a Middle Eastern context have involved mathematics classrooms, and none have focused on the learning environment features important to an inquiry-based setting.

Methods

Sample

The sample was drawn from four all-girl middle schools (grades 6–9) in the environs of Abu Dhabi city in the UAE. Teachers were selected for the study using a purposive sampling strategy. Criteria for teachers being exemplary in the use of explorations were developed by the researcher and these were used to select teachers for this study. The criteria were based on the requirements of the inquiry approach and recommendations were made by expert mathematics advisors based in the field. At each of the four schools, the surveys were administered to students in four mathematics classes, with the selection being based on the teachers' willingness to be involved and their use of IBL. This provided a sample of 291 students in 12 mathematics classes (77 grade 7 students, 141 grade 8 students, and 73 grade 9 students).

Instruments

A literature review indicated that, given the unique setting (involving a large-scale reform), cultural context, and IBL, there were no suitable surveys available to assess students' perceptions of the learning environment and their attitudes towards mathematics classes. Therefore, we drew on and modified existing survey scales relevant to this context. The modifications allowed us to consider the cultural context and ensure that the statements were meaningful in terms of the context and pedagogical approaches involved.

Development of the instruments involved a multi-stage process during which evidence was provided to support content and criterion-related validity (as recommended by Trochim & Donnelly 2008). As a first step, to ensure content validity, a literature review informed the selection of scales, ensuring that the constructs were highly relevant to an inquiry-based mathematics classroom. Once the scales were selected, the items were scrutinised for suitability to the culture and context, and some items were refined to ensure suitability.

This section describes the two surveys and evidence to support the content and criterion-related validity of each.

Assessing features of an IBL environment: LEIS

The newly developed Learning Environment in Inquiry Survey (LEIS) included six scales. Four scales (personal relevance, critical voice, student negotiation, and shared control) were drawn from the Constructivist Learning Environment Survey (CLES; Taylor et al., 1997) and two scales (involvement and investigation) from the What Is Happening In this Class questionnaire (WIHIC; Aldridge et al., 1999). The selection of these instruments as a starting point for the development of the new instrument was based on the usefulness of many of the scales to assess the unique learning environment developed in IBL classroom, coupled with strong evidence to support the validity reported in past research. Evidence to support the reliability and validity of the CLES, developed to assess students perceptions of factors important to constructivist classrooms has been reported in studies carried out in the US (see, for example, Peiro & Fraser 2009; Spinner & Fraser, 2005); Palestine (Zeidan, 2015); and Iran (Ebrahimi, 2015), as well as a cross-national study involving mathematics classes in Australia, Canada and the United Kingdom (Dorman et al., 2001). Similarly, strong evidence to support the reliability and validity of the WIHIC, developed to assess perceptions of contemporary classrooms, has been reported in studies in Australia and Taiwan (Aldridge & Fraser, 2000), Australia, UK and Canada (Dorman, 2003), Australia and Indonesia (Fraser et al., 2010), Australia and Canada (Zandvliet & Fraser, 2004, 2005), Singapore (Chionh & Fraser, 2009), India (Koul & Fisher, 2005), Australia (Dorman, 2008), South Africa (Aldridge et al., 2009), Korea (Kim et al., 2000), Indonesia (Wahyudi & Treagust, 2004b), UAE (Afari et al., 2012; MacLeod & Fraser, 2010), and the US (see, for example, Helding & Fraser 2013; Robinson & Fraser, 2013).

This section provides a description and justification for the inclusion of each LEIS scale. Table 1 provides an overview of the LEIS, including the name and a description of each scale, as well as the number of items in each scale. Students responded to the items using a five-point frequency response scale consisting of almost always, often, sometimes, seldom, and almost never.

Personal relevance involves making meaningful connections between the content and the individual (Priniski et al., 2018). Past research suggests that, when lessons are more relevant to a student, not only are they better able to make meaning from the learning opportunities (Vansteenkiste et al., 2018) but they are also more engaged (Priniski et al., 2018). This scale was particularly pertinent to the reform effort in Abu Dhabi where, traditionally, mathematics is taught from a theoretical perspective with little application to real-world experiences. Implementing IBL, as mandated in the reform effort, required students to use mathematics in an applied context and for their learning to be linked to a 'big question' to which they could relate.

From a critical theory perspective, *Critical voice* is about giving students opportunities to question teachers' pedagogical methods and activities and empowering students to discuss restrictions that they encounter in their learning. Traditionally, mathematics teaching in the UAE has involved the teacher lecturing directly from a government-provided textbook and students completing all of the exercises contained within (Gaad et al., 2006). With the introduction of the educational reform and the implementation of IBL, teachers are encouraged to utilise various instructional strategies. Allowing students to have a voice in the classroom is a good indicator of change in pedagogy towards more IBL.

Table 1 Description and sample item for each LEIS scale

Scale	No. of items	Description
Personal relevance	6	The degree to which the learning is relevant to students' lives
Critical voice	6	The degree to which students are legitimately able to express a critical opinion
Student negotiation	6	The degree which the students are involved with other students in assessing the viability of new ideas
Shared control	6	The degree to which students participate in planning, conducting and assessing of the learning.
Involvement	8	The degree to which students have attentive interest, participate in discussions, do additional work and enjoy the class
Investigation	8	The degree to which skills and processes of inquiry and their use in problem solving and investigation are emphasised

The use of *Student negotiation* provides opportunities “for students to explain and justify to other students their newly-developing ideas, to listen attentively and reflect on the viability of other students’ ideas and, subsequently, to reflect self-critically on the viability of their own ideas” (Taylor et al., 1997, p. 4). The introduction of student negotiation indicates a shift in teacher–student roles in the classroom (Schoerning & Hand, 2013). Implementing IBL in Abu Dhabi involved students in working groups to present ideas and to come to a consensus about a task. All aspects of the exploration were completed collaboratively and primarily assessed on a group basis, making student negotiation an essential feature of the learning environment.

Shared control is about the “extent to which students are invited to share control of the learning environment with the teacher, including the articulation of their own learning goals, design and management of their learning activities and determining and applying assessment criteria” (Ozkal et al., 2009, p. 72). Shared control encourages students to participate and be active in the teaching–learning process. Teachers allow students to share control of their learning and the tasks involved (Sultan et al., 2011), making learning more motivating (Partin & Haney, 2012). Given the shift in the roles of the teacher and students, the shared control scale was included to examine the extent to which students felt that they could work with the teacher to decide what activities were best for them.

In mathematics, *Investigation* involves finding out about an issue about which we do not currently know the answer and using a process of formulating questions and then producing, testing, and refining conjectures about those questions. The final step is proving and communicating results (Magen-Nagar & Steinberger, 2017). A mathematical investigation is based on the pedagogical belief that students learn best when they can be active learners and construct personal understandings of mathematical concepts (Alt, 2018). When students explore and investigate concepts, they demonstrate deeper mathematical understanding (Polly et al., 2014). Given that investigations are an essential component of IBL, this scale was considered important.

Involvement is a distinguishing characteristic of classrooms where students exhibit more positive views towards their subject (Mäkelä et al., 2018). Students involved in their lessons are more willing to attempt mathematical problems, ask questions when clarification is required, and are more active in their learning (Nebesniak & Heaton, 2010). Within IBL, involvement includes discussions about the work or involvement in collaborative activities. Students work together towards a common goal, justifying this scale’s inclusion to assess how students feel involved or can participate in the classroom.

Validity of LEIS

To test the multivariate normality and sampling adequacy, Bartlett’s test of sphericity indicated that $\chi^2 = 4856.45$ and was statistically significant ($p < .001$), and the Kaiser-Meyer-Olkin measure of adequacy was high (0.918). These results indicated that the data were appropriate for further analysis.

The first step involved examining the factor structure using principal axis factor analysis with oblique rotation. Three items not meeting the criteria during factor analysis were removed from all further analysis. The loadings for the remaining 36 items were at least 0.40 on their *a priori* scale and no other scale (as recommended by Field 2016). The percentage of variance for different LEIS scales ranged between 3.77% and 31.33%, with the total percentage of variance being 57.27%. The eigenvalues for the LEIS scales were all above 1 (ranging from 1.36 to 11.28), thereby meeting Kaiser's (1960) criterion for a scale.

Cronbach alpha coefficients for LEIS scales ranged from 0.75 to 0.88 with the individual as the unit of analysis and from 0.86 to 0.95 with the class mean as the unit of analysis. These results suggest that the scales of the LEIS have good levels of internal consistency based on Cohen, Manion and Morrison's (2000) criteria.

To determine whether the scales could differentiate between classes (as a measure of concurrent validity), analysis of variance (ANOVA) was used. The results indicated a statistically-significant difference ($p<.05$) between students' perceptions in different classes for all of the six scales of the LEIS, thus supporting concurrent validity. The eta^2 statistic, representing the proportion of variance attributed to class membership, ranged from 0.08 to 0.22 for different scales.

As a further indication of discriminant validity, the component correlation matrix indicated that correlations ranged from 0.11 to 0.40, which met the requirements of the threshold of 0.80 of discriminant validity (Kline, 2011). See Appendix 1 for the results.

Attitudes towards mathematics: SATMS

To assess students' attitudes towards mathematics classrooms, the Student Attitudes Towards Mathematics Survey (SATMS) was developed. For the purpose of this study, the focus was on three aspects of attitude: enjoyment; self-efficacy; and task value. The overarching aims guided the selection of the scales for the introduction of the inquiry approach in Abu Dhabi schools, which encourages students to enjoy mathematics, seek careers in mathematics and science fields, and develop a 'can do' attitude (self-efficacy) that would encourage independence, determination and perseverance, and see value in the work that they were completing to develop a sense of worth and propel them into long-term aspirations in mathematics and science endeavours. The constructs all had a sound theoretical foundation (see background section for more details).

The SATMS involves three constructs that were selected from existing instruments and developed into a new instrument to assess education reform in Abu Dhabi. One scale, enjoyment of mathematics classes, was modified from the Test of Mathematics Related Attitudes (TOMRA; Spinner & Fraser 2005) and two scales, self-efficacy and task value, were modified from the Student Adaptive Learning Engagement in Science questionnaire (Velayutham et al., 2011). See Table 2 for a brief description of each of these scales. Students responded to the items using a five-point frequency-response scale of almost always, often, sometimes, seldom, and almost never.

Table 2 Description and sample item for each SATMS scale

Scale	No. of items	Description
Enjoyment of mathematics classes	7	The degree to which students enjoy their mathematics lessons
Self-efficacy	8	The degree of confidence and beliefs that a student has in his/her ability to successfully perform mathematics-learning tasks
Task value	8	The extent that students believe the task they are completing is worthwhile, important, and useful

To ensure content validity, of the constructs selected were relevant to the setting and based on sound theoretical underpinnings. A short justification for the inclusion of each construct is provided below.

Self-efficacy is related to students' beliefs about their ability to do well in a subject. According to Velayutham and colleagues (2011, p. 4), "self-efficacy beliefs are powerful predictors of the choices that students make, the effort that they expend and their persistence in facing difficulties". Further, according to Bandura (1977), students are more likely to be motivated to learn if they believe that they can succeed. This 'can do' attitude is related to coping behaviours and extended bouts of effort in facing obstacles (Geyer, 2018). This is important given that, with the use of the new teaching, learning, and assessing techniques of IBL, students need to be able to persist for longer periods and use critical-thinking, creative, collaborative, and communicative skills to be successful. This supported the rationale for the inclusion of self-efficacy in the study.

Enjoyment of mathematics classes is the aggregated measure of whether a student likes or dislikes mathematics. Student enjoyment promotes problem-solving, increases resiliency and self-regulation, and supports behaviour in group work (Leavy & Hourigan, 2018). Research indicates that enjoyment is positively related to learning-related motivation, self-regulatory efforts, and performance (Pekrun, 2006). Students' enjoyment of learning forms the basis of interest (Schiefele, 1991) and enhances the willingness of students to re-engage in academic content over time (Hidi & Renninger, 2006). Of interest to this study was the finding that the use of inquiry methods increases student enjoyment (Makar, 2007). Furthermore, research indicates that students who enjoy a subject are more likely to pursue this area of education in their future careers (Lauermann et al., 2017). In order to examine students' enjoyment through the use of IBL, this scale was included in our study.

Task value incorporates interest, which is engaging in a task: because of its appeal, enjoyment or attainment; to support one's identity or utility; or because of usefulness and cost, considering sacrifices associated with a task (Linnenbrink-Garcia et al., 2018). Importantly, when students see value in the work that they are completing in class, motivation increases (Eccles et al., 1983). In addition, in IBL tasks, research suggests that, when students perceive a task as useful for their future goals and aspirations, they will persevere and focus on attaining their targets (Miller & Brickman, 2004). For this reason, it was deemed important to examine the extent of value that students place on tasks that they were completing in the IBL classroom.

Validity of SATMS

The first step involved examining the factor structure using principal axis factor analysis with oblique rotation as with the LEIS. One item was found not to meet the criteria (Item 17 from the task value scale) during factor analysis, as it loaded more than 0.40 on another scale and was removed from all further analysis. All other items loaded at least 0.40 on their *a priori* scale and no other scale. The percentage of variance for SATMS scales ranged between 6.70% and 54.08%, with the total percentage of variance being 70.59%. The eigenvalues for SATMS scales were all above 1 (ranging from 1.47 to 11.90), thereby meeting Kaiser's (1960) criterion for a scale. See Appendix 2.

The Cronbach alpha coefficients, used as a measure of internal consistency, were high for all three scales, ranging from 0.92 to 0.95 with the individual as the unit of analysis and from 0.97 to 0.98 with the class mean as the unit of analysis. These results were considered acceptable levels based on Cohen, Manion and Morrison's criteria (2000).

The ANOVA results, used to ascertain the ability of each scale in the SATMS to differentiate between classes, showed a significant difference ($p < .01$) for all three SATMS scales, thus supporting concurrent validity. The eta² statistic, which represents the proportion of variance attributed to class membership, ranged from 0.15 to 0.22 for the scales.

Finally, the results generated using the component correlation matrix, used as a measure of discriminant validity, ranged from 0.52 to 0.59. These findings met the requirements of the threshold of 0.80 of discriminant validity as recommended by (Kline, 2011).

Translating the surveys

Given that the study's participants were all Arabic speakers, the surveys were translated into Arabic using a process of back-translation. Initially, the two instruments were translated into Arabic by a translator who specialised in translating documents that required an understanding of mathematical content and pedagogical approaches. Once translated, the instruments were then back-translated, as recommended by Ercikan (1998) and Warwick & Osherson (1973), into English by an independent specialist in both languages who had not been the translator of the original English versions of the surveys. The two English versions were compared to ensure that the intent remained the same. For example, the initial translation was "What I learn has nothing to do with my out-of-school life", whereas the back-translated version was "What I am learning has nothing to do with life outside school". In this case, the tense was changed to ensure that the translated meaning was the same. Another example required a wording change: the original was "It's ok for me to complain about teaching activities that are confusing", but the back-translation was "I am allowed to complain about the misleading activities". Where the English versions differed in the meaning of the statement, the first author sat with the second translator and altered the Arabic translation to match the intent of the English statement. Some work was also required to format the questionnaires as Arabic is a right-to-left language. So, tables and the frequency response format had to be reversed appropriately. Given that all students were native Arabic speakers, the Arabic version was administered without the English translation.

Data collection

The two instruments were presented to students in a single hard-copy booklet. This allowed the researcher to administer both surveys simultaneously and to ensure that students were clear to which classroom and teaching and learning experience they were responding. The administration was carried out in person by the first author to ensure that the process was consistent across all classes and allowed the classroom teacher to leave the room.

Prior to administration, a number of ethical considerations were made. First, informed consent was gained from the principal at each of the schools. The participation of teachers (the classes from which students were drawn) and the students was voluntary. Both teachers (although they did not provide data) and students were provided with detailed information about the study and its purpose in both English and Arabic. Students were informed that completion of the survey was voluntary and that they could withdraw from the study at any time. Students were also informed that their responses to the survey would remain anonymous. Ensuring that the teacher was not present in the room helped to avoid students feeling obliged or coerced in any way. Although data were collected during class time, student involvement in the collection of data was viewed as part of their evaluation of their IBL project, making it meaningful and useful to their course.

Data analysis

Preparing the database

The data collected using the two surveys were entered into an excel spreadsheet by the first author. Prior to analysis the data was checked for missing and disengaged responses. First, for those surveys with more than 10% of data from a participant missing (e.g., incomplete survey responses), the data from that participant were omitted. Next, a check for disengaged responses was carried out on the remaining survey responses. For each participant, the standard deviation was calculated to determine whether there was sufficient variation in the responses. Cases with a standard deviation of less than 0.3 were omitted. During this process, data collected from 11 participants (3.6%) were removed from all analyses. For those surveys that remained, but had missing data, the class mean for that particular item (rounded to 2 decimal places) replaced the missing response.

Examining relationships

Simple correlation and multiple regression analyses were used to address the research objective. Simple correlations allowed us to investigate the relationship between two paired data sets. Calculation of the correlation coefficient (*r*) provides information about the strength of a relationship or degree of association between the variables. Multiple regression analysis was used to examine the relationships between all of the variables. A regression a coefficient (*β*) for each independent variable provided an estimate of the independent effect of each predictor on the dependent variable. For this analysis, the scales from the LEIS were the independent variables, and the scales from the SATMS were the dependent variables.

Table 3 Simple correlation and multiple regression analyses for associations between students' perceptions of their learning environment and their attitudes

Scale	Enjoyment of mathematics classes		Self-efficacy		Task value	
	r	*β*	*r*	*β*	*r*	*β*
Personal relevance	0.40**	0.11*	0.38**	0.08	0.48**	0.21**
Critical voice	0.42**	0.14*	0.32**	0.03	0.39**	0.06
Shared control	0.51**	0.21**	0.46**	0.06	0.53**	0.20**
Student negotiation	0.33**	−0.08	0.42**	0.08	0.42**	0.07
Involvement	0.50**	0.17**	0.54**	0.22**	0.46**	0.03
Investigation	0.51**	0.23**	0.61**	0.38**	0.54**	0.26**
Multiple correlation (*R*)		0.62**		0.66**		0.65**

N=291 students in 12 classes **p*<.05 ***p*<.01

Results

We examined whether students' perceptions of their inquiry-based classroom environment were related to their attitudes. The simple correlations reported in Table 3 indicate that associations between students' responses to the three SATMS scales (enjoyment of mathematics, self-efficacy and task value) and the LEIS were positive and statistically significant ($p < .01$) for all scales. Furthermore, the multiple correlation (R) between each SATMS scale and the learning environment was statistically significant ($p < .01$). According to these results, students' perceptions of the learning environment accounted for approximately 62% of the variance in students' enjoyment of mathematics lessons, 66% of the variance in students' self-efficacy, and 65% of the variance in task value.

The regression coefficients (β) indicated that different scales of the LEIS were predictors of different outcomes. For *Enjoyment of mathematics classes*, regression coefficients indicated that five of the six LEIS scales (personal relevance, critical voice, shared control, involvement, and investigation) were positive, independent, and statistically-significant ($p < .01$) predictors. The exception was that, for student negotiation, the relationship that was not statistically significant.

For *Self-efficacy*, regression coefficients indicated that two of the six LEIS scales (involvement and investigation) were statistically-significant ($p < .01$) predictors of self-efficacy when the other learning environment scales were mutually controlled. Both coefficients were positive in direction, suggesting that students perceiving more involvement and investigation reported more positive beliefs in their ability to do mathematics.

For *Task value*, regression coefficients (β) indicated that three of the six LEIS scales (personal relevance, shared control, and investigation) were statistically-significant ($p < .01$) predictors of task value. Again, all of these coefficients were positive in direction, suggesting that students reporting that lessons have more personal relevance, shared control, and investigation in the learning environment are likely to value the task more.

Discussion and recommendations

The strong positive relationships reported in this study (between students' perceptions of the learning environment and their attitudes) corroborate past research in the field of learning environments carried out across a range of subjects (Wolf & Fraser, 2008; Yang, 2015). The positive and statistically-significant ($p < .01$) correlations between the learning environment and the attitude scales support the notion that learning environments of IBL could improve girls' attitudes towards mathematics. Our findings are important given that a major aim of the mathematics reform effort is to promote student engagement in mathematics classes and the pursuit of mathematics after compulsory schooling (Al Murshidi, 2019). This section discusses these findings regarding the reform effort and their implications for girls in mathematics classes.

Our findings suggest that five LEIS scales were positive, independent, and statistically-significant ($p < .01$) predictors of girls' enjoyment of mathematics, with the exception being student negotiation. These findings replicate positive relationships between the learning environment and enjoyment in past studies of mathematics (e.g., Afari et al., 2013; Vandecandelaere et al., 2012) and other subjects such as science (Allen & Fraser, 2007;

Wahyudi & Treagust, 2004a) and the arts (Radovan & Makovec, 2015). These findings suggest that, when students' enjoyment of a subject increases, so too does their willingness to engage in or re-engage with a subject over time (Hidi & Renniger, 2006). Given that girls, when compared with boys, are less likely to re-engage with mathematics past compulsory education (Anaya et al., 2021), these findings are particularly important.

Our findings also suggest that two LEIS scales (involvement, and investigation) were statistically-significant ($p < .01$) independent predictors of girls' reports of self-efficacy. These findings support a growing body of research that reports relationships between learning environment perceptions and self-efficacy in mathematics (Afari et al., 2013; Aldridge et al., 2012; Dorman, 2001). Of importance, these findings also support other studies carried out in the Gulf region, including Qatar (Qureshi et al., 2017) and the UAE (Afari et al., 2013; Aldridge et al., 2012).

Finally, our findings suggest that three LEIS scales (personal relevance, shared control, and investigation) were statistically-significant ($p < .01$) predictors of task value. This finding supports those of previous research (Khalil & Aldridge, 2019; Liu et al., 2012).

Of interest is the finding that student negotiation was not related to any of the SATMS scales. Considering the collaborative nature of IBL classes, it is surprising that students did not consider negotiation between themselves and their peers to be linked to their enjoyment, self-efficacy, or task value. Based on the first author's knowledge of the Middle Eastern educational context, possible reasons could be related to cultural differences and the nature of hierarchy in differing cultures. The implementation of inquiry-based learning required a change in the role of the teacher from a source of all knowledge and prestige at the front of the room to a facilitator. This dynamic was very different from the traditional roles within teaching and learning and particularly for cultures such as this, with a high power-distance index as for the UAE (Hofstede, Hofstede, & Minkov, 1991, 2010). This change in hierarchical structure required students to negotiate with peers rather than being directed by the teacher and could be a source of the impact on attitudes.

Overall, our results suggest that the learning environment of inquiry-based classes could promote important attitudinal outcomes for girls in mathematics classes. First, the investigation scale was a predictor of all three attitude scales, suggesting that girls who perceive more opportunities to incorporate skills and processes related to inquiry (as assessed by the investigation scale) also report higher enjoyment, self-efficacy, and task value. This finding provides important implications for teachers involved in the UAE reform effort, given that investigations are at the core of IBL and are an essential element of inquiry cycles, often incorporating experimentation and data interpretation (Pedaste et al., 2015), and allowing students to explore, discover and construct knowledge. The finding also provides government officials and policymakers with important information about the possible efficacy of the change in pedagogy to meet long-term aims.

Second, the two learning environment scales of critical voice (providing opportunities to question the pedagogy and activities) and shared control (giving input into the goal setting, design, management, and assessment of learning activities) provided information about students' agency during the mathematics lessons. This finding suggests that empowering girls over what and how they learn could improve their mathematics enjoyment and task value. Incorporating IBL practices requires that teachers give autonomy to students regarding decisions about establishing hypotheses and questions, pathways for research, and presentation of findings. IBL allows differing approaches and conclusions within a class, with students developing skills that encourage deep and transferable learning, set within a safe environment enabling them to have a voice and personal perspective.

Third, our findings suggest that, for girls, personal relevance is a predictor of their enjoyment of mathematics lessons and the degree to which they value the task. Personal relevance involves making connections between the task and students' everyday life outside school. In classes using IBL, students select their own tasks, increasing the likelihood of being relevant to their lives. Further, the nature of IBL requires that students use mathematics in an applied context, providing opportunities to apply their learning to relatable, real-world experiences. Our findings suggest that girls value and enjoy tasks more when they perceive the learning to be relevant to their lives. This finding is important because improving these two attitudinal qualities is likely to increase girls' engagement in mathematics lessons (Velayutham & Aldridge, 2013).

Finally, our findings suggest that involvement in mathematics learning is related to girls' enjoyment of mathematics and task value. In the context of Vygotsky (1978) and social construction, allowing students to participate in collaborative work and discussions (involvement) is important. IBL functions best when students participate in collaborative processes and encourage and learn from each other. Therefore, the findings suggest that, through IBL, teachers promote involvement in discussions and shared idea development that is likely to lead to more-positive attitudes towards their learning.

There were some limitations to the study. First, although the sample size was sufficient for the analyses used, given that participants were drawn from only four schools within Abu Dhabi city, generalising the findings to other schools outside of the city confines should be

Table 4 Improving the learning environment using strategies related to IBL

Learning environment construct	Strategies to enhance the learning environment
Personal relevance	♣ Demonstrating to students how theory can be applied in practice ♣ Relating the content taught to everyday applications ♣ Linking current newsworthy issues to applications of content ♣ Providing explicit opportunities for students to discuss, for each new topic, why it is worth studying, how it operates in the real world, why it makes sense, and make connections to what students already know ♣ Provide utility value answering the student question "where am I going to use this?"
Critical voice	♣ Building positive relationships and establishing trust, promoting an environment where students feel safe to share and have a voice ♣ Providing opportunities for student feedback and then enact the feedback so students can see that their opinions and suggestions are valued
Shared control	♣ Provide students with choices on topics, activities and methods for developing and presenting work ♣ Allow students to use self- and peer-assessment to enable them to have some 'control' in the assessment process
Involvement	♣ Provide opportunities for students to be actively involved in their learning, by allowing them to ask questions seeking clarification ♣ To allow for group work, where students are involved, participating and working together towards a shared goal
Investigation	♣ Use open-ended questions that promote exploration and investigation of concepts ♣ Explicitly teach the inquiry cycle ensuring students understand the steps involved in investigating ♣ Encourage students to make predictions about the outcomes of their investigations and then proceed to establish the findings

undertaken with caution. Given this limitation, it is recommended that future studies examine whether the results are replicated in other Middle Eastern countries. Second, the sample included only students from middle school; therefore, generalising the results to other year levels requires caution. Third, given the study's correlational nature, the data were collected at only one time, making it impossible to examine whether IBL impacts girls' attitudes and career aspirations differently over time. Therefore, it is recommended that future research involves a longitudinal design to establish benefits over time. Finally, because the nature of the study did not establish causal relationships, it is recommended that future studies involve a mixed-methods approach.

Our findings lend support and justification for the continued mandated implementation of IBL in mathematics classes in the context of the education reform. Given the strong and positive associations between the learning environment and attitudes towards mathematics, it is likely that the learning environment promoted through IBL has the potential to improve girls' attitudes towards mathematics. Beyond the scope of this study, it is likely that more-positive attitudes would increase participation in future mathematics courses and mathematics-related career fields.

Given these statistically-significant associations between factors of the learning environment important to IBL and girls' attitudes, it is recommended that professional development opportunities, including both initial training and ongoing mentoring and support, are provided to help teachers. This professional development could build teachers' capacity to implement strategies associated with IBL to improve the learning environment. Table 4 summarises some possible strategies and skills that could provide a focus for such professional learning.

Our research is significant as the only study to examine the use of IBL in mathematics classes in Abu Dhabi. The findings suggest that the learning environment developed using IBL techniques could improve girls' attitudes towards mathematics. Consideration should be placed on the potential importance of utilising IBL to improve outcomes for girls, particularly as a vehicle for achieving some of the aspirations of the education reform efforts in the UAE.

Appendix 1 Factor loadings, eigenvalues and percentages of variance for the LEIS.

Item	Factor loading					
	Personal relevance	Critical voice	Shared control	Student negotiation	Involve-ment	Investigation
1 I learn about the world outside of school.	0.72					
2 My new learning starts with problems about the world outside of school.	0.77					
3 I learn how Mathematics can be part of my out-of-school life.	0.47					
4 I get a better understanding of the world outside of school.	0.75					

Item	Factor loading					
	Personal relevance	Critical voice	Shared control	Student negotiation	Involve-ment	Investiga-tion
5 I learn interesting things about the world outside of school.	0.67					
7 It's ok for me to ask the teacher "Why do I have to learn this?"		0.67				
8 It's ok for me to ques-tion the way I'm being taught.		0.77				
9 It's ok for me to complain about teach-ing activities that are confusing.		0.71				
10 It's ok for me to complain about anything that prevents me from learning.		0.56				
11 It's ok for me to express my opinion.		0.53				
12 It's ok for me to speak up for my rights.		0.48				
13 I help the teacher to plan what I'm going to learn.			0.67			
14 I help the teacher to decide how well I am learning.			0.65			
15 I help the teacher to decide which activities are best for me.			0.81			
16 I help the teacher to decide how much time I spend on learning activities.			0.80			
17 I help the teacher to decide which activities I do.			0.76			
18 I help the teacher to assess my learning.			0.69			
19 I get the chance to talk to other students.				0.47		
20 I talk with other stu-dents about how to solve problems				0.67		
21 I explain my un-derstandings to other students.				0.60		
22 I ask other students to explain their thoughts.				0.74		
23 Other students ask me to explain my ideas.				0.62		
24 Other students explain their ideas to me.				0.78		

Item	Factor loading					
	Personal relevance	Critical voice	Shared control	Student negotiation	Involve-ment	Investiga-tion
25 I discuss ideas in class.					0.66	
26 I give my opinions during class discussions.					0.71	
27 The teacher asks me questions					0.73	
28 My ideas and suggestions are used during classroom discussions.					0.64	
29 I ask the teacher questions.					0.61	
31 Students discuss with me how to go about solving problems.					0.54	
32 I am asked to explain how I solve problems.						0.51
33 I carry out investigations to test my ideas.						0.48
34 I am asked to think about the evidence for statements.						0.76
35 I carry out investigations to answer questions coming from discussions.						0.82
36 I explain the meaning of statements, diagrams and graphs.						0.75
38 I carry out investigations to answer the teacher's questions.						0.57
39 I find out answers to questions by doing investigations.						0.59
Eigenvalue	1.88	2.55	1.95	1.61	11.28	1.36
% variance	5.24	7.04	5.41	4.47	31.33	3.77
Cronbach alpha	0.75	0.83	0.88	0.82	0.83	0.86
ANOVA	0.09**	0.08**	0.08*	0.10**	0.08*	0.22**

N=291 students in 12 classes Factor loadings smaller than 0.40 have been omitted. * $p<.05$ ** $p<.01$

Appendix 2 Factor loadings, eigenvalues and percentages of variance for the SATMS

Item	Factor loading		
	Enjoyment	Self-efficacy	Task value
1 I look forward to lessons in this subject	0.91		
2 Lessons in this subject are fun	0.88		
3 Lessons in this subject interest me	0.65		
4 This subject is one of my favourite school subjects	0.88		
5 There should be more lessons in this subject	0.82		

Item	Factor loading		
	Enjoyment	Self-efficacy	Task value
6 I enjoy the activities that we do in this subject	0.72		
7 These lessons increase my interest in this subject	0.74		
8 I can master the skills that are taught		0.79	
9 I can figure out how to do difficult work		0.78	
10 Even if the mathematics work is hard, I can learn it		0.75	
11 I can complete difficult work if I try		0.78	
12 I will receive good grades		0.81	
13 I can learn the work we do		0.72	
14 I can understand the contents taught		0.78	
15 I am good at this subject		0.83	
16 What I learn can be used in my daily life			0.73
18 What I learn is useful for me to know			0.78
19 What I learn is helpful to me			0.85
20 What I learn is relevant to me			0.73
21 What I learn is of practical value			0.88
22 What I learn satisfies my curiosity			0.59
23 What I learn encourages me to think			0.58
Eigenvalue	11.90	2.16	1.47
% variance	54.08	9.82	6.70
Cronbach alpha	0.95	0.92	0.92
ANOVA	0.22**	0.15**	0.17**

N=291 students in 12 classes. Factor loadings smaller than 0.40 have been omitted

* $p<.05$ ** $p<.01$

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