Int J of Sci and Math Educ (2018) 16 (Suppl 1):S25–S45
https://doi.org/10.1007/s10763-018-9909-8

Do Teachers' Instructional Practices Moderate Equity in Mathematical and Scientific Literacy?: an Investigation of the PISA 2012 and 2015

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Received: 1 September 2017 / Accepted: 22 June 2018 / Published online: 12 July 2018

Abstract Many efforts have been made to reach educational equity, especially to reduce mathematics and science achievement gaps by students' socioeconomic status. Across countries, educators strive to reform traditional teacher-centered instructional approaches to more student-centered/inquiry-based instruction to improve equity in education. In this context, this study examines whether relationships between socio-economic status and scientific or mathematical literacy are moderated by student-centered instruction. Ten countries covering a wide range of achievement levels as well as equity in education are selected for an international comparison. A linear regression analysis is applied to student achievement, equity, and frequency of student-centered instruction data from the PISA 2012 and PISA 2015. We find mixed results: As student-centered instruction is offered more frequently, the gap in mathematical and scientific literacy between low and high socioeconomic status is generally narrowed or maintained. In most countries, students' mathematical and scientific literacy scores are expected to decrease across all socioeconomic status as student-centered instruction is given more frequently. The findings necessitate further scrutiny of how teachers implement student-centered instruction in various educational systems. This further research need to consider the complexity of implementation related to sociological and pedagogical aspects.

Keywords Equity in mathematics and science education · Inquiry-based instruction · International comparison study · PISA · Student-centered instruction

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Introduction

It has been well disseminated that students from high socioeconomic status (SES) families outperform their counterparts from low SES families (Lee, 2005). Students from low-income parents show lower mathematical and scientific literacy than those from high-income parents (Morgan, Farkas, Hillemeier, & Maczuga, 2009). In the Program for International Student Assessment (PISA) 2015, approximately three quarters of students with limited understanding of science are from low SES family background, while 65% of students with high-level mathematics achievement are from high SES families (Organization for Economic Co-operation and Development [OECD], 2016b). Moreover, Heckman (2011) reported that high SES students are 2 years advanced in mathematics competency compared to the lower SES students, and this earlier exposure would lead to inequality in students' learning outcomes. Equity in education becomes more critical because individual academic success is closely related to one's quality of life (OECD, 2008).

Educational reformers have attempted to reduce the learning gap between high and low SES students. One of many reformers' approaches to address this inequity in education is to emphasize student-centered learning environments (Acar, 2015; Mehalik, Doppelt, & Schuun, 2008). They point out that one main reason for achievement gaps in traditional classrooms is unequal access to educational opportunities in learning mathematics and science (Darling-Hammond, 1998). Reform-based instruction intends to provide equal learning opportunities in which all students actively engage in communicating their understanding of concepts. In such learning environments, students are more likely to bring their own ideas and prior understanding to learn mathematics and science, compared to traditional teacher-centered learning environments (Akkus, Gunel, & Hand, 2007; Cavagnetto & Hand, 2012; von Secker, 2002).

However, teachers sometimes implement student-centered learning approaches in ways different from the intentions of educational reformers (Lefstein, 2008). For example, secondary school mathematics and science teachers have a wide range of interpretations of student-centered learning environments (Anderson, 2002). Some teachers may not have solid understanding of what student-centered instruction is and how to implement such an approach when teaching. Moreover, Marshall (2009) reported that teachers only use 39% of instructional time to implement student-centered learning approaches throughout the school year. Wide variety in implementation may yield results different from reformers' expectation for the positive impact of student-centered learning approaches on equity in education.

The relationship of three important issues of education—student performance, equity in education, and instructional approach—is important to investigate to promote equal opportunities to learn and advance in mathematics and science for all students. In particular, we investigate how teachers' instructional practices moderate the relationships between students' socioeconomic background and learning of mathematics and science in different educational contexts. Focusing on teachers' student-centered instruction, this study aims to describe the moderated relationships between socioeconomic status and mathematical and scientific literacy in the PISA 2012 and 2015, respectively.

Theoretical Background

Equity in Learning Mathematics and Science

Definitions of equity depend on where researchers put their emphases in the process of explaining inequality (Bulkley, 2013). The American Library Association (2014) defined equity as keeping fairness and justice by removing uneven starting points or providing extra measurements to disadvantaged groups of people. In education, equity is referred to as equal access to learning resources, equality in learning outcomes, equal connections to family culture, and equal distribution of agency (Lynch, 2000). The PISA 2012 (OECD, 2013) conceptualized equity in education through the strength of the relationships between one's SES and academic performance. These definitions of equity in education agree that all students ought to have equal access to take advantage of educational opportunities regardless of their SES.

Due to the importance of equity in education, researchers have investigated and shown the influences of learners' background on mathematical or scientific literacy development. Socioeconomically and culturally disadvantaged students have lower mathematical and scientific literacy than advantaged students (Maerten-Rivera, Ahn, Lanier, Diaz, & Lee, 2016; Rodriguez, 1998). In particular, non-free/reduced lunch (Non-FRL) program students have higher performance than those in FRL programs; boys outperform girls; Whites and Asians are more proficient than Blacks and Hispanics; and native English-speaking students are better in mathematics and science than non-native English-speaking students. Atwater (2000) argued that underrepresented students' frequent misplacements into lower level classes contribute to their lower level scientific literacy. Moreover, students with access to limited home educational resources are less likely to perform well in assessments when they do not get enough support from schools (Darling-Hammond, 1998). Students could further lose interest and willingness to learn mathematics when they have both a lack of school supports and limited home resources (Martin, 2009).

Equity in education across different educational contexts has been investigated by international studies. Studies have revealed similar patterns in the relationships between SES and academic achievement. In addition, large-scale international comparison studies such as the PISA and the Trends in International Mathematics and Science Study (TIMSS) display achievement gaps between various student groups—social class, gender, and language across countries and educational systems. The PISA 2003 and 2009 showed that students' SES have strong influences on students' performance in mathematics and science (OECD, 2010; Schütz, West, & Wöbmann, 2007). The OECD (2009) suggested disparities in access to educational resources between those groups as a reason for the consistent achievement gap: Students with advantaged backgrounds are more likely to attend high-qualified schools and have sufficient interactions with teachers to verify their understanding compared to underserved students.

Classroom Instruction and Learning Opportunities

Educational reformers have pointed out possible relationships between instructional approaches and inequity in education. To discuss those relationships, two types of instructional approaches are compared: teacher-centered and student-centered instruction.

Teacher-Centered Instruction. Teacher-centered instruction is a traditional approach to teaching characterized as a monological learning environment. The teacher is the one who speaks most of the time in front of the class, while students are expected to sit quietly, take notes, and learn from what the teachers teach. In these environments, teachers transmit information to students, whose role is one of a passive information receiver in the classroom (National Research Council [NRC], 2000). Teacher-centered instruction rarely encourages students to communicate with teachers and classmates about what students do not fully understand. As a result, students' lack of opportunities to actively examine the given information prevents them from learning through critical thinking practices (Delpit, 1988; Townley, 1993).

In this inactive and rigid classroom atmosphere, students might need to rely on home resources when they are not able to reach understanding in class. Students may or may not have a chance to catch or make up their deficit outside the classroom, depending on their available resources: Students with sufficient home resources will receive supplementary opportunities to learn and understand whereas students without such resources may not have additional chances. Thus, home resources play a significant role in students' learning, which leads to inequity in education (Lee & Luykx, 2007). Students without enough parental supports and home resources are likely marginalized from learning situations in the traditional classroom settings (Acar, 2015; Lee, Smith, & Croninger, 1997).

Student-Centered Instruction. Compared to teacher-centered instruction, student-centered instruction (e.g., inquiry-based and student-oriented instruction in this study) emphasizes students' active participation in the learning situation. Students are encouraged to communicate in classrooms by engaging in activities such as argument-based inquiry, designing an experiment (Ballenger, 1997), exploring mathematics tasks, or mathematical modeling (Artigue & Blomhøj, 2013). Student-centered instruction requires students to negotiate different ideas through verbal and written arguments and to use multiple representations to explain scientific theories or mathematical logic (Cavagnetto, 2010). In this learning environment, students are expected to have equal chances to share their ideas, ask questions, and develop understanding of new concepts. Active participation in classroom discussion invites student to establish critical thinking skills (Mistler-Jackson, & Songer, 2000; Richardson, 1996; Yore, Bisanz, & Hand, 2003).

Students who have little academic experience from out-of-school education can benefit from student-centered learning environments more than teacher-centered learning environments (Ballenger, 1997). In inquiry-based or problem-solving learning, students are encouraged to engage in making arguments, expressing their thoughts, and negotiating different opinions in the process of developing understanding. When participating in this process, students have opportunities to express misunderstandings and to catch up with what was not fully understood. This practice is particularly beneficial for students who do not have access to academic support outside of the classroom, as they have chances to learn and understand within the school, as opposed to the teacher-centered learning environments where students are less like to catch up with what they missed (Fraser, 2015; Roth, 1996). The NRC framework (2012) displayed the same notion of student-centered learning that values children's everyday experiences as the natural process of learning. Through student-centered learning experiences, supportive student-teacher relationships and learning ownership are consequently developed. In student-centered learning environments, non-school-related factors such as socioeconomic background may not play significant roles in the learning of mathematics and science, and students can instead utilize whatever resources they bring to their learning and develop their own voice. This could be more beneficial for all students, including the ones in low SES groups.

Difficulty of Implementing Student-Centered Instruction

Despite the potential benefits of student-centered instructional practices, it is difficult to say that teacher implementation of such practices is carried out with fidelity, which is related to the quality of instruction (Kirschner, Sweller, & Clark, 2006). This is because theoretical constructs and classroom materials for student-centered instruction struggle to capture the complexity of the realm of schools (Maaß & Artigue, 2013). Teachers shared their concerns about student-centered instruction, such as class time limitations and bigger efforts required compared to lecture-based instruction (Loughran, 1994; Mercer, 2008). Implementing student-centered instruction requires both teachers' and students' cognitive engagement more so than in teacher-centered instruction (Magnusso & Palincsar, 2005). Due to these difficulties, many science teachers still heavily rely on their "cook-book hands-on activities" for inquiry-based learning approaches (Akkus et al., 2007). They utilize traditional methods of classroom instruction when implementing inquiry-based learning by practicing learn to inquiry-structure activities, which follow the sequence of inquiry, but in a teacher-directed way and with limited student engagement. This indicates that students might not experience the core of student-centered instruction in their classrooms, especially when teachers' understanding is not aligned to theoretical constructs of student-centered instruction (Akkus et al., 2007).

In addition to teachers' practical concerns, implementing student-centered instruction is difficult because teachers need to provide learning materials in accordance with individual students' learning styles and culture: For example, some students prefer using technology when they learn new skills or ideas, while others prefer to learn through talking with peers. Teachers' awareness of student diversity influences students' learning through this type of instruction. This is because proper learning materials based on their understanding encourage students' multicultural and harmonious interactions and collaboration in the classroom (Atwater, 1996). Therefore, teachers' implementation of student-centered instruction requires understanding of sociocultural perspectives of learning (Banks, 1997; Barba, 1995). However, it could be very demanding to understand every single student's characteristics well. It might be further burdensome for teachers to select and provide distinctive and proper educational intervention matching a students' diverse background when implementing quality student-centered instruction (Oakes, 1990).

A review of literature on instructional approaches in relation to equity in education helps us hypothesize that student-centered instruction contributes to greater equity in learning mathematics and science. However, we also recognize that those contributions could be obscured depending on how teachers understand and implement such instruction. As discussed before, different educational contexts could further diversify the patterns of interactions between student-centered instruction and equity in education. Therefore, it is necessary to scrutinize how student-centered instruction moderates the relationships between students' SES and their learning outcomes in various educational contexts.

Using the PISA data, the purpose of this study is to investigate how mathematics and science classrooms embrace equity in education. The specific questions guiding this research are: (a) Does student-centered instruction broaden or narrow the achievement gaps between low and high SES students across different educational contexts? And (b) are students from high or low SES expected to have better achievement through student-centered learning environments across different educational contexts?

Method

Country Selection

Many countries have participated in the PISA: 65 countries participated in the PISA 2012 and 72 countries did in the PISA 2015. Scrutinizing all countries would be difficult and interpreting results would be even more complex in a single study. Thus, we purposively select ten countries participating in both PISA 2012 and 2015 data—Brazil, Chinese Taipei, Finland, France, Korea, Norway, Peru, Qatar, Singapore, and the United States of America (USA; alphabetical order) for the following reasons: to reduce such complexity in analysis, to cover a wide range of achievement and equity measured in the PISA (OECD, 2013, 2016b), and to find patterns by international comparison.

Particularly, the combination of students' performance and equity in education in Fig. 1 is used for this purposive selection of the countries (circled in Fig. 1). First, we consider countries with above-average achievement but below-average equity in either the PISA 2012 or 2015—this result in the selection of Chinese Taipei (Mathematics) and Singapore (Science). Second, we pay attention to above-average-achieving countries with above-average equity. Among such countries, Korea and Finland are selected. We then shift our focus to countries with average achievement in three levels of equity: France (below-average equity), USA (average equity), and Norway (above-average equity). Lastly, we select below-average-achieving countries with different degrees of equity—Peru (below-average equity), Brazil (average equity), and Qatar (above-average equity). Table 1 shows all selected countries with their equity and achievement levels. Although we have a sizable number of countries and students, we acknowledge potential limitations of generalizability due to the uniqueness of individual educational contexts and purposive selection.

Variables

For students' mathematical and scientific literacy, we utilize all sets of plausible values: five sets of plausible values for mathematics literacy in the PISA 2012 and ten sets of

Fig. 1 Strength of the socioeconomic gradient mean performance in mathematics (PISA 2012, left; OECD, 2013, p. 27) and science (PISA 2015, right; OECD, 2016c, p. 218). The ten selected countries are circled

Table 1 Ten selected countries for data analysis

		Equity		
		Below-average	Average	Above-average
Mathematics performance	Above-average	Chinese Taipei	Singapore	Korea and Finland
	Average	France	United States	Norway
	Below-average	Peru	Brazil	Qatar
Science performance	Above-average	Singapore	Chinese Taipei	Korea and Finland
	Average	France	United States	Norway
	Below-average	Peru	Brazil	Qatar

plausible values for scientific literacy in the PISA 2015 as prior studies recommended (e.g., Laukaitye & Wiberg, 2017). Additionally, "using [multiple] plausible values will provide an accurate representation of [the] underlying relationships" of background information (Foy, Brossman, & Galia, 2012, p. 3). For socioeconomic status, we use the variable called the index of economic, social, and cultural status (ESCS) in both the PISA 2012 and 2015 database, which "provides a comprehensive measure of student socio-economic background, based on parents' education levels and occupational status and possessions in the home" (OECD, 2009, p. 32).

We select two different variables to represent student-centered instructional approaches: "teacher behavior: student orientation" (SO) for mathematics in the PISA 2012 and "inquiry-based science teaching and learning practices" (IB) for science in the PISA 2015. The selection of two different variables of the PISA is due to different focal disciplines in the PISA 2012 (Mathematics) and 2015 (Science). Detailed information about mathematics instruction is only available in the PISA 2012, while information about science instruction is only available in the PISA 2015.

Mathematical and Scientific Literacy. Through the PISA 2012 to 2015, the OECD (2016a) defined mathematical literacy as an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts. The capacity of formulate, employ and interpret mathematics is suggested by integrating mathematical modeling into the prior PISA frameworks. A half of the PISA items aim to measure students' employing mathematical concepts, procedures, and reasoning. The two quarters of them focus on formulating stations mathematically and interpreting mathematical outcomes, respectively.

The meaning of scientific literacy is explained as the ability to conduct scientific investigation and engage in a decision-making process through argumentation (Cavagnetto, 2010; OECD, 2013). Students, who inquire about the natural phenomena, construct a valid experimental design to test a hypothesis, and make claims by providing evidence, are regarded as "a reflective citizen" (OECD, 2016a, p. 20) who fostered scientific literacy. In accordance with the definition of scientific literacy, the PISA measured students' scientific literacy through problems that include analyzing socio-scientific contexts, understanding of science concepts, and evaluating scientific ideas using rigid scientific design.

Index of Economic, Social, and Cultural Status (ESCS). To represent students' socioeconomic status, the OECD (2017) constructs a composite score called the ESCS using principal component analysis (PCA). The ESCS is grounded on "the indicators parental education (PARED), highest parental occupation (HISEI), and home possessions (HOMEPOS) including books," which are constructed from responses in the student questionnaire (OECD, 2017, p. 339). All participating countries equally contributed to the PCA for the estimation of the ESCS scores. However, to report the ESCS scores, this scale is "transformed with zero being the score of an average OECD student and one being the standard deviation across equally weighted OECD countries" (OECD, 2017, p. 340). Because the ESCS is considered as a representation of SES, we will use only the term SES in the rest of this article.

Teacher Behavior: Student Orientation (SO). The variable labeled TCHBEHSO in the PISA 2012 database (SO in this article) is used for data analysis to investigate how student-centered mathematics instruction moderates the relationships between SES and mathematical literacy. The OECD (2013) built the SO from the questions in the students' survey in Table 2. The SO variable represents students' perceptions of teachers' behaviors related to student-oriented instruction. Response

Table 2 Item and statements for "Teacher Behavior: Student Orientation" in the PISA 2012 (cite) and "Inquiry-Based Science Teaching and Learning Practices" in the PISA 2015 (cite)

Teacher Behavior: Student Orientation (SO)	Item	How often do these things happen in your mathematics lessons?
	ST79Q03	The teacher gives different work to classmates who have difficulties learning and/or to those who can advance faster
	ST79Q04	The teacher assigns projects that require at least 1 week to complete
	ST79Q07	The teacher has us work in small groups to come up with joint solutions to a problem or task
	ST79Q10	The teacher asks us to help plan classroom activities or topics
Inquiry-Based Science Teaching and Learning Practices (IB)	Item	When learning <school science> topics at school, how often do the following activities occur?
	ST098Q01TA	Students are given opportunities to explain their ideas.
	ST098Q02TA	Students spend time in the laboratory doing practical experiments.
	ST098Q03NA	Students are required to argue about science questions.
	ST098Q05TA	Students are asked to draw conclusions from an experiment they have conducted.
	ST098Q06TA	The teacher explains how a < school science> idea can be applied to a number of different phenomena (e.g., the movement of objects, substances with similar properties).
	ST098Q07TA	Students are allowed to design their own experiments.
	ST098Q08NA	There is a class debate about investigations.
	ST098Q09TA	The teacher clearly explains the relevance of <broad science> concepts to our lives.

categories are “Every lesson,” “Most lessons,” “Some lessons,” and “Never or hardly ever.” Responses to the survey questions are scored so that higher values of the SO indicate that students perceive such teachers’ behaviors more frequently. The SO is scaled to have an international metric with the mean of zero and the standard deviation of one. The range is from − 1.60 to 3.31.

Inquiry-Based Science Teaching and Learning Practices (IB). To examine how student-centered science instruction moderated the relationships between SES and scientific literacy, the variable labeled IBTEACH in the PISA 2015 database (IB in this article) is used for data analysis. As seen in the description of the IB, this variable denotes students’ perceptions of how often teachers enact actions relating to inquiry-based instruction. The IB is constructed using the eight questions in Table 3. Higher values of the IB indicate teachers’ behaviors more frequently perceived by students. This variable also has an international metric with the mean of zero and the standard deviation of one. The range of this variable is from − 3.341 to 3.183.

Data Description

The PISA target population is 15-year-old students enrolled in educational institutions in each country. The OECD (2014, 2017) collected the data for all participating countries (except for the Russian Federation) using a two-stage stratified sample design. Because our research interests are at the student level, this design requires the incorporation of student weights in data analysis. This application helps to ensure the representative of sampled students (OECD, 2017) and statistical results such as means and regression outputs in this research are weighted by “final trimmed nonresponse adjusted student weight” in the database. Descriptive statistics by country are reported in Table 3. Furthermore, we utilize Fay’s method of balanced repeated replication suggested in the PISA to estimate sampling variances (OECD, 2017). Using variables “final student replicate BRR-Fay weights” in the databases, we could overcome the issue that “the variance estimator can be unstable” relying on the sample design (OECD, 2017, p. 123).

Data Analysis

We conduct two steps of data analysis. At the first step, we apply a linear regression analysis separately to each country to describe how teachers’ student-centered instruction moderated the relationships between mathematical or scientific literacy and socioeconomic status. The linear model for each country includes mathematics or science literacy scores as a dependent variable, an intercept, single variables—SES and IB or SO—, and the interaction between the variables as independent variables in Eqs. 1 and 2. At the second step, we construct the specific linear models by substituting the SO or IB with − 2 (two-standard-deviation-below-mean), − 1, 0 (the international mean), 1, and 2 (two-standard-deviation-above mean) into the first-step outcomes. We exclude the case that SO is − 2 because this is out of the range of SO. Finally, we construct graphical representations of the linear models to

Table 3 Descriptive statistics of the variables by country

PISA 2012	Country	Number of students	Weighted mean Mathematical literacy	SO	SES	Scale reliability for SO	Correlations between mathematical literacy and SES
	Brazil	12,176	390.998	−0.428	−1.186	0.670	0.415
	Chinese Taipei	04003	560.191	−0.016	−0.403	0.690	0.435
	Finland	05660	523.255	−0.061	−0.389	0.640	0.276
	France	02991	498.335	−0.410	−0.040	0.630	0.463
	Korea	03348	554.328	−0.168	−0.001	0.760	0.307
	Norway	03008	490.987	00.237	−0.472	0.630	0.267
	Peru	03817	371.679	−0.600	−1.191	0.650	0.467
	Qatar	06606	382.860	−1.082	−0.440	0.790	0.244
	Singapore	03656	575.749	−0.082	−0.261	0.740	0.376
	USA	03256	484.224	−0.297	−0.187	0.680	0.367
PISA 2015	Country	Number of students	Weighted mean Scientific literacy	IB	SES	Scale reliability for IB	Correlations between scientific literacy and SES
	Brazil	14,360	418.946	−0.046	−0.829	0.870	0.353
	Chinese Taipei	07056	538.821	−0.453	−0.189	0.902	0.374
	Finland	05581	536.282	−0.304	−0.269	0.832	0.308
	France	05325	510.779	−0.156	−0.080	0.838	0.436
	Korea	05122	523.411	−0.614	−0.165	0.899	0.296
	Norway	05096	503.809	−0.026	−0.493	0.877	0.280
	Peru	06021	405.655	−0.694	−0.994	0.867	0.457
	Qatar	09803	431.262	−0.472	−0.599	0.903	0.228
	Singapore	05687	562.417	−0.009	−0.064	0.865	0.390
	USA	05094	502.177	−0.337	−0.136	0.890	0.345

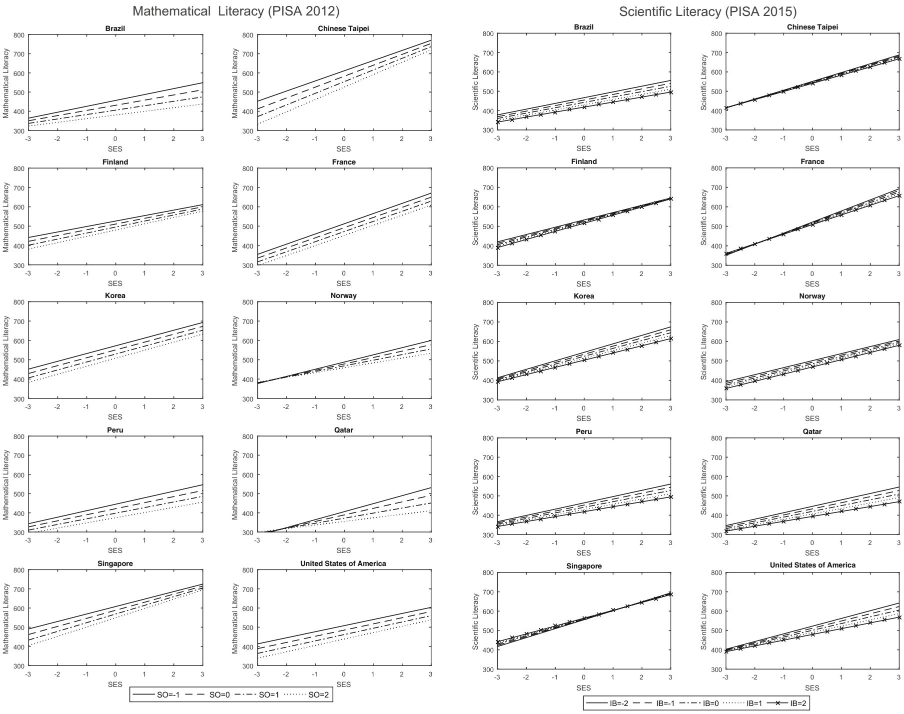

Fig. 2 The relationships between SES and Achievement moderated by student-centered instruction in PISA 2012 and 2015

show how the SO or IB moderated the relationships between SES and achievement in Fig. 2.

The linear regression models of the PISA 2012 and 2015 data are evaluated based on the following equations:

$$MATH = (\beta_{\mathrm{m0}} + \beta_{\mathrm{m1}} \times \mathrm{SO}) + (\beta_{\mathrm{m2}} + \beta_{\mathrm{m3}} \times \mathrm{SO}) \times \mathrm{SES} + e_m \quad (1)$$

$$SCIE = (\beta_{\mathrm{s0}} + \beta_{\mathrm{s1}} \times \mathrm{IB}) + (\beta_{\mathrm{s2}} + \beta_{\mathrm{s3}} \times \mathrm{IB}) \times \mathrm{SES} + e_s \quad (2)$$

where *MATH* and *SCIE* represent the plausible values of mathematical and scientific literacy, respectively; β_{m0}, β_{m1}, β_{m2}, β_{m3}, β_{s0}, β_{s1}, β_{s2}, and β_{s3} are regression coefficients; and e_m and e_s represent error terms.

Results

Linear model estimation output for mathematics and science are reported in Table 4 in the "Results" section. As seen in Eqs. 1 and 2, the constant terms, β_{m0} and β_{s0} represent expected scores of students with the average SES, which means SES = 0. The regression coefficients β_{m1} and β_{s1} indicate the degree of changes in students' expected achievement scores with SES of zero as they perceived student-centered instruction

Table 4 Estimation results of mathematics and science linear models

	Country	R square	Constant (β_{m0})	SO (β_{m1})	SES (β_{m2})	Interaction (β_{m3})
Mathematics PISA 2012	Brazil	0.247***	431.315***	−25.338***	26.893***	−3.887***
	Chinese Taipei	0.255***	582.878***	−28.335***	56.834***	−3.905***
	Finland	0.098***	510.765***	−15.553***	29.757***	−1.446***
	France	0.252***	492.185***	−20.081***	52.490***	−0.152***
	Korea	0.139***	550.771***	−21.397***	40.617***	−0.445***
	Norway	0.083***	478.247***	0–9.850***	33.123***	−4.032***
	Peru	0.271***	421.517***	−23.437***	31.559***	−2.272***
	Qatar	0.127***	389.133***	−16.983***	34.002***	−7.673***
	Singapore	0.183***	588.440***	−19.500***	42.092***	−3.166***
	USA	0.191***	485.109***	−23.257***	32.228***	−0.535***
	Country	R square	Constant (β_{s0})	IB (β_{s1})	SES (β_{s2})	Interaction (β_{s3})
Science PISA 2015	Brazil	0.142***	442.537***	−12.182***	27.784***	−0.949***
	Chinese Taipei	0.141***	546.109***	0–2.513***	43.934***	−0.845***
	Finland	0.096***	524.370***	0–4.297***	39.539***	1.024***
	France	0.191***	515.585***	0–3.236***	53.243***	−1.874***
	Korea	0.103***	524.061***	−10.077***	40.257***	−1.649***
	Norway	0.085***	485.588***	0–8.075***	36.526***	0.237***
	Peru	0.225***	441.000***	−11.390***	28.986***	−1.726***
	Qatar	0.079***	419.976***	−13.029***	29.830***	−1.704***
	Singapore	0.152***	559.737***	−01.986***	43.455***	−1.415***
	USA	0.134***	501.196***	−10.699***	34.793***	−2.519***

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

more frequently (see Eqs. 1 and 2). In addition, β_{m2} and β_{s2} show the degree of changes in expected achievement scores as SES changes for students with the average SO or IB.

The values and significance of the regression coefficients β_{m3} and β_{s3} need to be interpreted with other regression coefficients collectively because those coefficients are related to the interaction terms of SO × SES and IB × SES. Positive values of β_{m3} and β_{s3} respectively indicate that the slope coefficients of SES of Eq. 1 and SES of Eq. 2 would become greater as SO or IB increases. If β_{m3} or β_{s3} is statistically significant, the relationships between SES and mathematical or scientific literacy depend on students' perception of student-centered instruction. Brazil, Chinese Taipei, and Qatar show significant interaction terms in the results about mathematical literacy ($p < 0.1$ for all; see Table 4): the relationships between SES and mathematical literacy were moderated by the perceived frequency of student-oriented instruction in mathematics classrooms. The science literacy result of Peru and USA shows significant interactions between IB and SES with p values less than 0.1 (see Table 4). The relationships between performance and socioeconomic status of these two countries are contingent on students' responses about the frequency of inquiry-based instructions.

As mentioned in the method section, we substitute IB or SO in the regression equations with the specific values of −2, −1, 0, 1, and 2 to reflect the perceived frequencies of IB or SO implementation in classroom, and so that the results would be

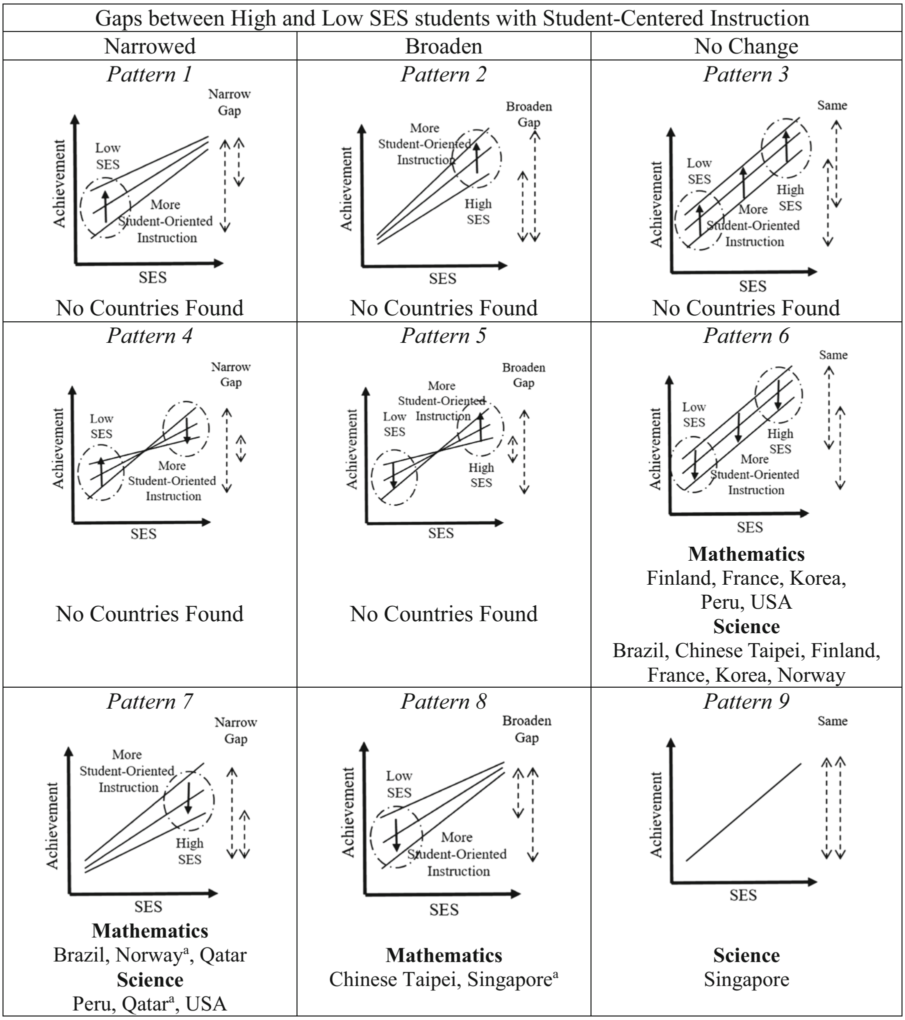

Fig. 3 Summary of the findings in the ten countries. The nine patterns in this figure are *generalized* and specific slope coefficients and achievement levels for each country could differ from the generalized graphs. [a] Classifications heavily rely on visual representations in Fig. 2 than statistical significances in Table 4 while considering the interaction coefficients

more interpretable with graphical representations. Calculated linear graphs are displayed in Fig. 2, and all slopes of SES and intercepts are reported in Tables 5 and 6. In Fig. 3, nine *generalized* patterns are presented and ten countries' mathematics and science patterns are categorized into each generalized pattern.

Mathematical literacy scores in all ten countries are likely to decrease as students perceive frequent student-oriented instructions in mathematics classrooms. However, the mathematical literacy gap between high and low SES students is likely to be reduced in two countries, Brazil and Qatar, which have significant interactions between SO and SES (pattern 7 in Fig. 3). Norway also shows this pattern throughout the graphs although such a significant interaction is not found. In these three countries, as students perceived student-oriented instruction more frequently, students with high SES are likely to decrease mathematics literacy scores and, in turn, the literacy gap between low SES and high SES narrow. Students across all SES levels in Finland, France, Korea, Peru, and USA (pattern 6) tend to have lower scores of mathematical literacy as the frequency of student-oriented instruction increased. On the other hand, the achievement gap is likely to be broaden in Chinese Taipei and Singapore (pattern 8): Students from low SES are expected to have lower achievement with more student-oriented instruction.

The results about scientific literacy in the PISA 2015 also show the two main patterns, patterns 6 and 7, compared to the results about mathematical literacy. Overall, students' scientific literacy scores are generally expected to decrease as inquiry-based instruction is given more frequently. For the one unique case of Singapore (pattern 9), the relationships between students' achievement in scientific literacy and SES are expected to remain in constant with more inquiry-based instruction. In terms of equity in education, we find that the achievement gap in scientific literacy between high and low SES levels decreases in Peru, Qatar, and USA (pattern 7). In these three countries, as inquiry-based instruction is offered more frequently, expected scores of students from high SES decrease while those from low SES seem to be remain unchanged. In the other six countries (Brazil, Chinese Taipei, Finland, France, Korea, and Norway for pattern 6), inquiry-based science instruction does not change the achievement gap in scientific literacy between high and low SES students as the expected scores of all SES groups decrease.

Discussion

This study aims to investigate the relationships between socioeconomic status and mathematical or scientific literacy of ten participating countries in the PISA 2012 and 2015. We explore whether inquiry-based or student-oriented instruction moderates those relationships by analyzing student data of ten countries covering wide ranges of achievement and equity levels in education. The literature review indicated that, in theory, student-centered instruction has the potential to improve equity in education, particularly by providing students from low SES equal opportunities to learn and understand mathematics and science within the classroom. However, it is also possible that those contributions vary depending on teachers' understanding and implementation of student-centered instruction as well as on different educational contexts.

Some countries aligned with the theoretical assumption that achievement gaps become narrower when student-centered instruction was offered more frequently. This assumption was empirically shown with one pattern for mathematical and scientific literacy across different educational contexts—pattern 7 in Fig. 3. However, the reduced gap only comes from the decreasing scores of students from high SES: Brazil, Norway, and Qatar, for mathematical literacy; and in Peru, Qatar, and USA for scientific literacy. Equity in mathematical literacy is worsened in Chinese Taipei and Singapore (pattern 8): Student-centered instruction increased the mathematics achievement gap between groups of high and low SES students.

The results in Fig. 3 indicate that our theoretical hypotheses do not always reflect a move in a positive direction based on our findings. There is no country that reduced the gap by low SES students' taking advantages of student-centered instruction while high SES students' scores remained the same (pattern 1 in Fig. 3). Furthermore, in many countries, the more frequently student-centered instruction is implemented, the lower scores students across all SES levels are expected to achieve in both mathematical and scientific literacy.

The findings of this research suggest that doing more student-centered instruction might not be a panacea for relieving inequality in academic achievement. Although the findings do not always support the positive impacts of student-centered instruction, we do not attribute this failure to the problem of student-centered instruction itself. There are certainly successful cases in other studies as we hypothesize (e.g., von Secker, 2002) and we do not examine all countries in the PISA 2012 and 2015. Instead, we would like to suggest a few possible explanations for the results based on several issues in relation to the survey, implementation, and educational policies in different educational contexts.

First, in the PISA 2012 and 2015, student-centered instruction is examined through the student survey, not the teacher survey. The questions in the student survey (see Tables 2 and 3) could only explain a partial dimension of student-centered instruction in classrooms. It is possible to find varied results using other measurements for student-centered instruction, such as teachers' evaluations of their own teaching practices. Student-centered instruction may be perceived differently depending on who responds to questions about the instruction. For example, with teachers' self-evaluations on their instructional practices, von Secker's (2002) reported a positive impact of inquiry-based instruction on students' achievement. This suggests considerable cautions in interpretation of our findings.

Moreover, the survey questions in Tables 2 and 3 may not assess the quality of the instruction (Kirschner et al., 2006). These questions are rather about *how often* students experienced teachers' behaviors related to student-centered instruction. Although frequency of student-centered instructional practice is certainly one indicator of high fidelity of implementation, the student survey does not address other important aspects of instruction: For instance, how students make decisions in their experimental design in science classrooms or how well mathematics tasks with high cognitive demands are implemented. Results might be different with qualitative information reflecting more dimensions of student-centered instruction.

Second, as discussed in the literature review, the benefits of student-centered instruction might not be observed due to teachers' difficulties in understanding and implementing student-centered instruction. Student-centered instruction places a higher demand on teachers' cognitive process, in that teachers must turn on their intellectual vigilance to provide active scaffolding and challenging questions to students. Such interactions in classrooms necessitate that teachers instantly modify knowledge about students as they make sense of what has happened and what is expected during lessons (Simon, 1995). Because of this complexity in student-centered instruction, "teachers ignore, resist, subvert, misinterpret, selectively adopt, or otherwise distort reformers' intentions. Changes tend to be superficial, seldom penetrating the core of instructional practice" (Lefstein, 2008, p. 701). For example, if teachers misunderstand inquiry-based instruction in science classrooms as a "minimal guidance," it is more likely to generate "abandoned students" or "behavioral freedom" in science class. In this misunderstood student-centered instruction, students are less likely to be engaged in conceptual understanding and argumentation even though students experience classroom discussions and hands-on activities.

Third, we pay attentions to similarities and differences among educational contexts at the national level, namely educational policies discussed in the PISA reports. For example, we find a similarity between the findings about mathematical and scientific literacy, and teacher responsibility for curriculum measured by the three dimensions as shown in the PISA report (OECD, 2016d): choosing textbooks, deciding which courses are offered, and determining course content.

In general, students in countries where teachers have more responsibilities for their curriculum (more than 50% of responsibility is on teachers: Finland, France, and Korea) tend to show lower performance across all SES levels in both mathematics and science when student-centered instruction is frequently implemented (see pattern 6 in Fig. 3). On the other hand, in the educational systems that allow relatively low autonomy for teachers in curriculum (about less than 40% of responsibility is on teachers: Brazil, Norway, Peru, Qatar and USA), more frequent student-centered instruction negatively influence on achievement of high SES students in mathematics or science while students with low SES are affected minimally. Singapore has a distinctive system as the school board has 40% of the responsibility for curriculum, which is unusually high compared to other participating countries in the PISA. And Singapore is the country in which more inquiry-based instruction in mathematics and science classrooms have minimal effects on equity in mathematical and scientific literacy. However, it should be noted that this parallel between our findings and curriculum policy is not perfect: there are simultaneously countries like Chinese Taipei in discord with this argument for mathematical and scientific literacy.

Discussions about the responsibility for curriculum encouraged us to reconsider teachers' difficulties in instruction to speculate possible explanations for our findings of somewhat negative effects of student-centered instruction on students' mathematical and scientific literacy in the PISA 2012 and 2015. The demanding process for teachers to prepare and implement this type of instruction could be exacerbated when they take more responsibility for curriculum. Unlike teacher-centered instruction, student-centered instruction has variations of implementation among teachers since it requires teachers' active, simultaneous decision making through cognitive and epistemic negotiation (Akkus et al., 2007; Luft, 2001). Students are expected to do more than reproduce and repeat what they learned from teachers in student-centered instructional approaches. This means that teachers need to be experts of creating learning environments based on their understanding of national standards, school curriculums, students' learning levels, and the instructional approaches (Luft, 2001). Furthermore, inquiry-based/student-oriented instruction is difficult to standardize as it entails dynamic modes and patterns based on teachers' understanding on learners and school cultures (Keys & Bryan, 2001). There is no specific guide for student-centered instruction, which results in science teachers' struggling to implement such instruction appropriately (Newman , Abell, Hubbard, McDonald, Otaala, & Martini, 2004). Given these challenging environments for teachers, heavy responsibility for curriculum might increase the probability that teachers misguide students' learning through student-centered instruction.

This study suggests several paths for future research. The findings provide general ideas about the relationships among instruction, socioeconomic status, and achievement. To have a better understanding of the findings, additional research emphasizing a specific educational context or geographically adjacent countries in detail will be beneficial (e.g., Bos & Kuiper, 1999). Moreover, we are only able to speculate possible factors from similarities and differences among educational systems. Further investigations on possible influential factors (e.g., quality of student-centered instructions) would help better understand the influences of instructional behaviors on the relationships between socioeconomic status and achievement.

This study confirms suggestions provided by previous international comparison studies that policymakers and administrators should not blindly mimic others' educational contexts that have shown positive outcomes (Hatano & Inagaki, 1998). The findings in this research demonstrate that understanding the relationships between socioeconomic status and achievement are not straightforward, but potentially related to sociological, pedagogical, and even psychological factors. Educational context should be accounted for by more international comparison studies before adopting educational practices in different countries. Then better understanding from those studies can help each country to improve students' learning science and mathematics through student-centered instruction.

Appendix

Table 5 Linear models of the relationships between mathematical literacy and index of economic, social, and cultural status moderated by student-oriented instruction in PISA 2012

	SO = − 1		SO = 0		SO = 1		SO = 2	
	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope
Brazil	456.653	30.780	431.315	26.893	405.977	23.006	380.639	19.119
Chinese Taipei	611.213	52.929	582.878	56.834	554.543	60.739	526.208	64.644
Finland	526.318	28.311	510.765	29.757	495.212	31.203	479.659	32.649
France	512.266	52.642	492.185	52.490	472.104	52.338	452.023	52.186
Korea	572.168	40.172	550.771	40.617	529.374	41.062	507.977	41.507
Norway	488.097	37.155	478.247	33.123	468.397	29.091	458.547	25.059
Peru	444.954	33.831	421.517	31.559	398.080	29.287	374.643	27.015
Qatar	406.116	41.675	389.133	34.002	372.150	26.329	355.167	18.656
Singapore	607.940	38.926	588.440	42.092	568.940	45.258	549.440	48.424
USA	508.366	31.693	485.109	32.228	461.852	32.763	438.595	33.298

Table 6 Linear models of the relationships between scientific literacy and index of economic, social, and cultural status moderated by inquiry-based instruction in PISA 2015

	IB = − 2		IB = − 1		IB = 0		IB = 1		IB = 2	
	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope
Brazil	466.901	29.682	454.719	28.733	442.537	27.784	430.355	26.835	418.173	25.886
Chinese Taipei	551.135	45.624	548.622	44.779	546.109	43.934	543.596	43.089	541.083	42.244
Finland	532.964	37.491	528.667	38.515	524.370	39.539	520.073	40.563	515.776	41.587
France	522.057	56.991	518.821	55.117	515.585	53.243	512.349	51.369	509.113	49.495
Korea	544.215	43.555	534.138	41.906	524.061	40.257	513.984	38.608	503.907	36.959
Norway	501.738	36.052	493.663	36.289	485.588	36.526	477.513	36.763	469.438	37.000
Qatar	463.780	32.438	452.390	30.712	441.000	28.986	429.610	27.260	418.220	25.534
Peru	446.034	33.238	433.005	31.534	419.976	29.830	406.947	28.126	393.918	26.422
Singapore	555.765	46.285	557.751	44.870	559.737	43.455	561.723	42.040	563.709	40.625
USA	522.594	39.831	511.895	37.312	501.196	34.793	490.497	32.274	479.798	29.755

References

Acar, O. (2015). Examination of science learning equity through argumentation and traditional instruction noting differences in socio-economic status. *Science Education International, 26*(1), 24–41.

Akkus, R., Gunel, M., & Hand, B. (2007). Comparing an inquiry-based approach known as the science writing heuristic to traditional science teaching practices: Are there differences? *International Journal of Science Education, 29*(14), 1745–1765.

American Library Association (2014). *Equality and equity of access: What's the difference*. Retrieved April, 25, 2014 from http://www.ala.org/advocacy/intfreedom/equalityequity.

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education, 13*(1), 1–12.

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

Atwater, M. M. (1996). Social constructivism: Infusion into the multicultural science education research agenda. *Journal of Research in Science Teaching, 33*(8), 821–837.

Atwater, M. M. (2000). Equity for Black Americans in precollege science. *Science Education, 84*(2), 154–179.

Ballenger, C. (1997). Social identities, moral narratives, and scientific argumentation: Science talk in bilingual classroom. *Language and Education, 11*(1), 1–14. https://doi.org/10.1080/09500789708666715.

Banks, J. A. (1997). *Educating citizens in a multicultural society*. New York, NY: Teachers College Press.

Barba, R. H. (1995). *Science in the multicultural classroom: A guide to teaching and learning*. Needham Heights, MA: Allyn and Bacon.

Bos, K., & Kuiper, W. (1999). Modelling TIMSS data in a European comparative perspective: Exploring influencing factors on achievement in mathematics in grade 8. *Educational Research and Evaluation, 5*(2), 157–179. https://doi.org/10.1076/edre.5.2.157.6946.

Bulkley, K. E. (2013). Conceptions of equity: How influential actors view a contested concept. *Peabody Journal of Education, 88*(1), 10–21. https://doi.org/10.1080/0161956X.2013.752309.

Cavagnetto, A. R. (2010). Argument to foster scientific literacy: A review of argument interventions in K–12 science contexts. *Review of Educational Research, 80*(3), 336–371. https://doi.org/10.3102/0034654310376953.

Cavagnetto, A. R., & Hand, B. (2012). The importance of embedding argument within science classrooms. In M. S. Khine (Ed.), *Perspectives on scientific argumentation: Theory, practice and research* (pp. 39–53). New York, NY: Springer.

Darling-Hammond, L. (1998). Unequal opportunity: Race and education. *The Brookings Review, 16*(2), 28–32.
Delpit, L. (1988). The silenced dialogue: Power and pedagogy in educating other people's children. *Harvard Educational Review, 58*(3), 280–299.
Foy, P., Brossman, B., & Galia, J. (Eds.). (2012). *Scaling the TIMSS and PIRLS 2011 achievement data*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College and International Association for the Evaluation of Educational Achievement (IEA).
Fraser, B. (2015). Encyclopedia of science education. In R. Gunstone (Ed.), *Classroom learning environments* (pp. 154–157). Dordrecht, The Netherlands: Springer.
Hatano, G., & Inagaki, K. (1998). Cultural contexts of schooling revisited: A review of "the learning gap" from a cultural psychology perspective. In S. G. Paris & H. M. Wellman (Eds.), *Global prospects for education: Development, culture, and schooling* (pp. 79–104). Washington, DC: American Psychological Association.
Heckman, J. J. (2011). The economics of inequality: The value of early childhood education. *American Educator, 35*(1), 31–35.
Keys, C. W., & Bryan, L. A. (2001). Co-constructing inquiry-based science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching, 38*(6), 613–645. https://doi.org/10.1002/tea.1023.
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. https://doi.org/10.1207/s15326985ep4102_1.
Laukaityte, I., & Wiberg, M. (2017). Using plausible values in secondary analysis in large-scale assessments. *Communications in Statistics - Theory and Methods, 46*(22), 11341–11357. https://doi.org/10.1080/03610926.2016.1267764.
Lee, O. (2005). Science education with English language learners: Synthesis and research agenda. *Review of Educational Research, 75*(4), 491–530.
Lee, O., & Luykx, A. (2007). Science education and student diversity: Race/ethnicity, language, culture, and socioeconomic status. In S. Abell & N. Lederman (Eds.), *Handbook of research on science education* (Vol. 1, pp. 171–197). Mahwah, NJ: Erlbaum.
Lee, V. E., Smith, J. B., & Croninger, R. G. (1997). How high school organization influences the equitable distribution of learning in mathematics and science. *Sociology of Education, 70*(2), 128–150.
Lefstein, A. (2008). Changing classroom practice through the English National Literacy Strategy: A micro-interactional perspective. *American Educational Research Journal, 45*(3), 701–737. https://doi.org/10.3102/0002831208316258.
Loughran, J. (1994). Bridging the gap: An analysis of the needs of second-year science teachers. *Science Education, 78*(4), 365–386.
Luft, J. A. (2001). Changing inquiry practices and beliefs: The impact of an inquiry-based professional development programme on beginning and experienced secondary science teachers. *International Journal of Science Education, 23*(5), 517–534. https://doi.org/10.1080/09500690121307.
Lynch, S. J. (2000). *Equity and science education reform*. Mahwah, NJ: Erlbaum.
Maaß, K., & Artigue, M. l. (2013). Implementation of inquiry-based learning in day-to-day teaching: A synthesis. *ZDM Mathematics Education, 45*, 779–795. https://doi.org/10.1007/s11858-013-0528-0.
Maerten-Rivera, J., Ahn, S., Lanier, K., Diaz, J., & Lee, O. (2016). Effect of a multiyear intervention on science achievement of all students including English language learners. *Elementary School Journal, 116*(4), 600–624.
Marshall, J. C. (2009). *The creation, validation, and reliability associated with the EQUIP (Electronic Quality of Inquiry Protocol): A measure of inquiry-based instruction*. Paper presented at the annual meeting of National Association of Researchers of Science Teaching (NARST), Garden Grove, CA.
Magnusson, S., & Palincsar, A. (2005). Teaching to promote the development of scientific knowledge and reasoning about light at the elementary school level. In J. Bransford & S. Donovan (Eds.), *How students learn: History, mathematics, and science in the classroom* (pp. 421–474). Washington, DC: National Academies Press. https://doi.org/10.17226/10126.
Martin, D. B. (2009). Researching race in mathematics education. *Teachers College Record, 111*(2), 295–338.
Mehalik, M. M., Doppelt, Y., & Schuun, C. D. (2008). Middle-school science through design-based learning versus scripted inquiry: Better overall science concept learning and equity gap reduction. *Journal of Engineering Education, 97*(1), 71–85. https://doi.org/10.1002/j.2168-9830.2008.tb00955.x.
Mercer, N. (2008). Changing our minds: A commentary on 'conceptual change: A discussion of theoretical, methodological and practical challenges for science education'. *Cultural Studies of Science Education, 3*(2), 351-362.

Mistler-Jackson, M., & Songer, N. B. (2000). Student motivation and internet technology: Are students empowered to learn science? *Journal of Research in Science Teaching, 37*(5), 459–479.
Morgan, P. L., Farkas, G., Hillemeier, M. M., & Maczuga, S. (2009). Risk factors for learning-related behavior problems at 24 months of age: Population-based estimates. *Journal of Abnormal Child Psychology, 37*(3), 401–413.
National Research Council [NRC]. (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, DC: National Academies Press.
Newman Jr., W. J., Abell, S. K., Hubbard, P. D., McDonald, J., Otaala, J., & Martini, M. (2004). Dilemmas of teaching inquiry in elementary science methods. *Journal of Science Teacher Education, 15*(4), 257–279.
Oakes, J. (1990). *Multiplying inequalities: The effects of race, social class, and tracking on opportunities to learn mathematics and science*. Santa Monica, CA: RAND.
OECD. (2009). *Highlights from 'education at a glance 2008'*. Paris, France: OECD Publishing.
OECD. (2010). *PISA 2009 results: Overcoming social background–equity in learning opportunities and outcomes* (Vol. 2). Paris, France: OECD Publishing. https://doi.org/10.1787/9789264091504-en .
OECD. (2013). *PISA 2012 results: Excellence through equity giving every student the chance to succeed* (Vol. 2). Paris, France: OECD Publishing.
OECD. (2014). *PISA 2012 technical report*. Paris, France: OECD Publishing.
OECD. (2016a). *PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic and Financial Literacy*. Paris, France: OECD Publishing.
OECD. (2016b). *PISA 2015 results in focus*. Paris, France: OECD Publishing.
OECD. (2016c). *PISA 2015 results (volume I): Excellence and equity in education*. Paris, France: OECD Publishing.
OECD. (2016d). *PISA 2015 results (volume II): Policies and practices for successful schools*. Paris, France: OECD Publishing.
OECD. (2017). *PISA 2015 technical report*. Paris, France: OECD Publishing.
OECD. (2008). *Ten steps to equity in education*. Paris, France: OECD Policy Brief. Retrieved November 3, 2015, from http://www.oecd.org/education/school/39989494.pdf .
Richardson, T. (1996). Foucauldian discourse: Power and truth in urban and regional policy making. *European Planning Studies, 4*(3), 279–292.
Rodriguez, A. J. (1998). Busting open the meritocracy myth: Rethinking equity and student achievement in science education. *Journal of Women and Minorities in Science and Engineering, 4*(2–3), 195–216.
Roth, W. M. (1996). Teacher questioning in an open-inquiry learning environment: Interactions of context, content, and student responses. *Journal of Research in Science Teaching, 33*(7), 709–736.
Schütz, G., West, M. R., & Wößmann, L. (2007). *School accountability, autonomy, choice, and the equity of student achievement international evidence from PISA 2003* (OECD Education Working Papers, No. 14). Paris, France: OECD Publishing. https://doi.org/10.1787/246374511832 .
Simon, M. A. (1995). Reconstructing mathematics pedagogy from a constructivist perspective. *Journal for Research in Mathematics Education, 26*(2), 114–145.
Townley, B. (1993). Foucault, power/knowledge, and its relevance for human resource management. *Academy of Management Review, 18*(3), 518–545.
von Secker, C. (2002). Effects of inquiry-based teacher practices on science excellence and equity. *Journal of Educational Research, 95*(3), 151–160. https://doi.org/10.1080/00220670209596585.
Yore, L., Bisanz, G. L., & Hand, B. M. (2003). Examining the literacy component of science literacy: 25 years of language arts and science research. *International Journal of Science Education, 25*(6), 689–725.