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A Multi-Level Analysis of Gender Disparities in Early Science Education: The Role of Teacher Beliefs, Motivation, and Exam-Oriented Systems in China

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Abstract. This synthesis article applies the multi-level framework to analyze how the macro-level factors (cultural norms and exam-oriented system) in China moderate the relationship between teachers' beliefs and gender bias (meso-level factor) and gender disparities (micro-level)in early science education. In the literature review, the author summarizes the evidence about how teachers' expectations, gender stereotypes, and instructional beliefs influence young children' s science learning opportunities. It also examines how the macro-level factors reinforce these beliefs. In the conclusion, the article indicates that teachers' beliefs are influenced by cultural norms about gender roles and systemic pressure like exam-oriented system. This impact continually affects how teachers design their instructional practices and provide differentiated feedback in the classroom. This review analyzes and connects findings across multiple levels of influence. The article concludes with implications and the goal of future studies on training programs for teachers, educational policy which can promote equitable science learning environments and eliminate gender disparities in early education.

Keywords: Teacher's belief, Early science education, Gender stereotypes, Chinese educational context, Multi-level framework

1. Introduction

Early childhood education plays a significant role in shaping children's cognitive, social, and emotional development. When children experience this critical developmental period, early education helps children foster their curiosity and provide opportunities for inquiry, observation, and resaoning. According to Alice et al. [1], young children should be viewed as active participants when they construct their own scientific understanding, instead of passive recipients of knowledge. This view shows that teachers should provide positive attitudes to children's ideas. Also, teachers in the ECE should provide equitable science instruction for all students in the classroom [2]. For instance, they should actively respond to children's questions, and help them develop a strong sense of self-efficacy which can make them keep long-term engagement with science. Moreover, this perspective can be used as a guide to redefine the understanding of researchers and teachers, which creates more inclusive and creative ways for children to learn in the classroom.

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People begin to pay more attention to early science education. However, the effectiveness of early science education depends mostly on teachers' attitudes, beliefs and instructional practices in the classroom. In this case, teachers should consider as the important factor in the early science education. For example, teachers' beliefs could shape the learning environment and increase children' s motivation in science. Based on motivational theories such as self-determination theory(SDT), students foster their motivation and engagement during the learning experiences if their needs in autonomy, competence, and relatedness are satisfied. In this case, teachers' beliefs directly influence these factors through the design of tasks, feedback on assignments , and learning opportunities in the classroom. For instance, when teachers offer students more independent exploration, challenging assignments, and positive reflections, students are more likely to experience high confidence and motivation in science learning. However, when teachers hold implicit biases such as gender bias, their expectations, treatment, and evaluation would be differentiated in the classroom [3].

As we acknowledged about the pathways of motivation(Self-determination theory), students may increase their motivation when they needs in autonomy, competence, and relatedness are satisfied. When it comes to teachers' beliefs, students' pathways of motivation may be influenced by teachers' design of instructional practices, feedbacks on assignments, and distributions of learning opportunities in classrooms. For instance, when we discuss about improvement children's motivation in early science education, independent exploration, challenging assignments, and positive reflections in the classroom can help children experience high confidence and motivations. In contrast, teachers may also differentiates their expectations, treatment, and evaluation when they affected by factors like implicit gender bias [3].

When we discuss about the gender bias in the educational settings, especially in science and STEM education, most literature is conducted in the Western contexts or at later stages of education. This gap seem reflect that there is little researches on how children can be influenced in the early science educational process if teachers hold the gender bias. In addition, researchers also may have limitations on how the teachers' gender bias works in different cultural contexts. For instance, in China's exam-oriented education system, The pressure from National College Entrance Examination and influences from cultural norms about gender roles could become external factors could reinforce the academic gender role for students. For instance, teachers are more likely to assume girls are good at memorization, while boys are good at logical reasoning to ensure that students could achieve great performance in the exams [4]. However, we still have limited valid evidences to indicate the interaction among cultural contexts, teachers' beliefs and students' engagement in early science education.

Based on the limitations we discussed in the introduction, this synthesis paper would like analyze how gender bias influence children in the early science education within a theoretical framework. This paper will focus on how cultural norms and exam-oriented system in China moderate the influence of teachers' beliefs on children's engagement in early science education. This paper would apply the multi-level conceptual framework to explain how macro-level factors(cultural context) interact with meso-level factors (teachers' beliefs), and further influence young students' learning experiences.

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2. Literature review

2.1. Teachers' self-efficacy and beliefs in early science education

Teachers' self- efficacy has been widely examined as an important factor in the process of teaching and classroom practices. In the theory of Bandura, self-efficacy is a belief about one's capability to organize and execute actions required to achieve desired outcomes. When it comes to early science education, this concept can be considered as two dimensions: confidence in their own science knowledge and confidence in their ability to help young children develop a sense of science. It is important to differentiate these two dimensions since they can influence classroom practice in very different ways.

Teachers with high self-efficacy in science are more likely to present accurate scientific concepts and respond to children's scientific questions in the classroom. Moreover, when teachers show high pedagogic self-efficacy, they are more willing to hold exploring and creative tasks in the group activities. For instance, in the study of Duran et al. [5], teachers with stronger beliefs in inquiry-based instruction shows greater confidence and put more effort in their science teaching practices. The result in this study indicates that teachers' high self-efficacy have positive correlation with science teaching. It will affect how teacher design their scientific tasks and activities in the class. It also influence how they develop their dialogue with students. However, when teachers have lower self-efficacy may associate with more teacher-centered approaches which eliminate students' opportunities for more open-ended exploration and scientific reasoning. In addition, although some empirical studies show limited relationship with early science education, they still present evidence for impacts of teacher efficacy. Pan [6] found that higher teacher self-efficacy lead to greater student motivation and participation in physical education. This evidence indicates a broader mechanism about how teachers' beliefs affect students' quality of learning opportunities.

Motivation theory has been one of the important factors to explain students' engagement and persistence in learning. The Self-determination Theory (SDT) shows that motivation is increasing when learner's needs about autonomy, competence, and relatedness are satisfied. In the classroom, teachers act as a key role in enhancing students' motivation by course design, effective feedback, and interactions with students. The research found that SDT-based professional development courses help teachers increase their instructional self-efficacy and the use of student-centred STEM activities [7]. For example, when teachers are satisfied with their competence and autonomy in their inquiry-based approaches, they are more likely to design open-ended tasks, encourage the creative work, and offer detailed feedback. For young students, these practices make them ensure that their ideas are valued. The study of Hornstra et al. [8] also emphasizes the importance of supportive teaching behaviors such as offering choices, encouraging students' voices, and providing specific feedback. In early childhood science education, these behaviors help children develop a sense of scientific inquiry and the process of discovery. The authors also focus on expectancy-value and social cognitive perspectives which explain how motivational beliefs develop. This evidence shows that students are more like to attend practices when they expected to succeed and when they value the tasks. Teacher influence students' motivational belief through their evaluation practices, feedback, and expectations. As a result, motivation develop through social interaction rather than an individual trait.

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2.2. Gender bias in teachers' perceptions and interactions

In the Western context, most research demonstrates the implicit gender bias or stereotypes in the STEM field. This phenomenon indicates that teachers often unintentionally reinforce gender stereotypes in science subjects such as maths, physics, and chemistry. Some teachers may maintain their traditional view that boys are better in STEM fields than girls, while girls have talent in more emotional subject like Literature, Music and Art [9, 10]. Although these findings does not indicate that all teachers hold such beliefs, they still demonstrate that implicit gender stereotypes can influence the differential attitude and treatments of teachers in the classroom, especially in STEM courses.

One of empirical studies from Berekashvili [11] documents that teachers often encourage girls to be accurate, obedient, and caring, while boys are encouraged to be independent and creative. The findings demonstrate that teachers are more likely to view boys more independent and have high quality of cognitive skills in STEM which lead to differential feedback. In addition, Master et al. [10] suggest that differential feedback in the tasks can influence children's competence beliefs. Authors indicate that girls' science capability may be underestimated since they cannot receive equal opportunities for exploration and cognitively demanding questions.

Copur-Gencturk et al. [12] use attributional theory to determine whether teachers' attributional explanations for students' success and failure vary by gender. The study shows that teachers were more likely to attribute boys' success in mathematics to innate ability, while attribute girls' success to effort. The evidence from Leaper and Starr [13] suggest that women's motivation and persistence in STEM are shaped by long-term patterns of socialization, including subtle signals from teachers, parents, and peers. This finding further indicates the external factors could influence students' motivation. Attribution theory suggests that these explanations lead to important motivational consequences. In this case, when teachers attribute students' academic performance to ability, students would have a high level of competence and potential. Although attribution of effort can still be considered as positive feedback, teachers may underestimate students, especially girls', talent or ability in the STEM field.

However, most existing research is conducted in Western contexts about post-secondary or late stage students. In turn, researchers have less known about how these biases operate in early childhood settings. Researchers also know less about the factors like teacher beliefs and motivational processes interact with these biases. This limitation leads to difficulty to fully understand how gender disparities in science education emerge and develop over time.

2.3. Cognitive development, instructional practices, and gender

Despite the participation and motivation, teachers' bias also influences children's cognitive development. In psychology, critical thinking is the ability to analyze evidence and arguments, make logical reasoning, and consider different possibilities. These skills help children make new hypotheses, interpret results, and provide their own ideas in the science learning. Moreover, the quality of the instructional design improve the development of critical thinking in early science education. Teachers' gender bias affects their expectations for critical thinking in different children. In the article on how gender prejudice in education influences people's critical thinking, the author notes that one form of benevolent gender prejudice holds that women are less capable of critical thinking [14]. It claims that when teachers consciously or unconsciously perceive boys as more analytically capable, they may be more likely to direct higher-order reasoning questions toward them, encourage hypothesis testing, or challenge them with complex problem-solving tasks.

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However, the article shows that there is no support for the notion of male superiority in critical thinking; in fact, female students scored slightly higher overall on a measure of critical thinking disposition and significantly higher in open-mindedness and analyticity. This finding suggests that implicit gender bias could decrease girls' awareness and motivation in STEM fields and undermine their academic self-confidence. Although girls receive more support, they have fewer cognitively demanding interactions could decrease their opportunities for critical thinking and learning.

Moreover, Marni et al. [15] provide strong empirical evidence that gender is not a reliable predictor of a student's overall critical thinking capacity. Their work implies that educational expectations should not be differentiated by gender. When teachers hold biased expectations, they may challenge boys more frequently with reasoning questions or problem-solving tasks, while offering girls more supportive, yet less intellectually demanding, interactions. Instead, educators should pay more attention to developing all students' critical thinking skills since fundamental potential for critical thought is not gender-dependent.

In Shafer's study, the findings further emphasizes the importance of teachers in the classroom. The author discusses three approaches teachers would like to use to improving students' cognitive skills [16]. The first strategy is Dialogue-based approaches. These approaches target oral and written exchanges. Teachers would like to encourage positive interaction to improve students' reasoning skills. The Authentic instruction pays more attention on problem-based learning skills. In this instruction, teachers help students apply the concepts and theories to real situations. Students would improve their critical thinking and understanding of the concepts they learned in the classroom. The final strategy is Coaching. This approach focuses on a one-to-one approach. Teachers would provide specific feedback and assignments based on every student's situation. For instance, some students may have problems with critical thinking skills. Teachers may provide more critical thinking assignments to help them acquire important concepts in the classroom. These findings indicate that cognitive development mostly depends on teachers' effective instructional practices instead of gender differences. However, if teachers hold the implicit gender bias, these practices would have negative effects on students.

2.4. Cultural and systemic influence in the Chinese context

Researchers consider cultural context and system structure as important factors in understanding implicit gender bias in education. They claim traditional Confucian values suggest the difference of gender roles could impact children's early science experiences and academic self-concepts. However, the gender difference in mathematical performance among Chinese young adolescents are relatively small or nonexistent [17]. Authors attribute this change to a highly standardized secondary education system and mathematics curriculum. It points out boys and girls offer equal opportunity and exposure to mathematics at school. However, Liu also showed that there is still a significant gap in Chinese middle school students' interests in science and engineering careers. The study showed that gender-math stereotypes were associated with biased self-assessments of mathematical competence. People who hold traditional gender stereotypes can influence students' beliefs about their abilities. Researchers also suggest that these stereotypes have a stronger influence on girls' confidence in mathematics and their future career choices. In this case, although students have equal access to learning opportunities in the STEM field, it still leads to different levels of confidence and future career choices. These internalized stereotypes can shape students' self-efficacy and have long-term effects in the STEM field.

Researchers conduct the study in kindergartens in Hong Kong to figure out whether the gender role expectations influences teachers' regular curriculum. In the research, authors find that teachers

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often apply practices which reinforce gendered routines in daily lives in the school [18]. The finding indicates that the teachers may reinforce the traditional gender roles for children at very young age. Also, one of researches showed that teachers in early science education may apply differential practice for students depending on their gender in STEM play practices [19]. Both studies indicate that teachers' perspective about traditional gender roles influence how they conduct everyday instructional practices in classroom. In addition, since these practices may emerge in early science education, these expectations can influence children's motivation and learning experience in STEM at a young age.

The National College Entrance Examination(Gaokao) highlights the significance of standardization and quantification [20]. In this article, authors mentions that teachers are encouraged to conduct effective teaching approaches to ensure students can achieve their highest scores in this exams. For example, teachers may connect the traditional gender roles with the subjects students will choose. Teachers are willing to encourage girls to choose subjects like Arts, and boys to choose STEM subjects. However, these unequal learning opportunities could influence female students' self-efficacy and motivation in STEM fields. These fingings indicate that teachers' cultural norms about gender roles could be reinforced when the systemic pressure emerges.

In this situation, teachers who have beliefs about standards and gender stereotypes, teachers would like to seek the most efficient ways to teach students. When they have gender bias, while girls have more talent in memorization and emotional study, boys have more talent in logical thinking, they will promote girls' choice in language and history, as they assume girls will have higher scores in NCEE and have a chance to enter a good university. The statistical evidence on career aspiration from Wang' s study [4] shows a significant difference in the STEM field between boys and girls (boys: 43.3%; girls:19.6%). However, these differences cannot contribute to personal performance. Authors suggest that these differences may be influenced by the broader sociocultural context. Girls who have lower science self-efficacy may reflect long-term experiences of gender bias, differential encouragement, and limited opportunity structures. When teachers expect boys to perform better in science, they may provide more attention, feedback, and advanced learning opportunities to them, further reinforcing achievement and confidence gaps.

In addition, some researchers argue that exam-oriented education places an overemphasis on scores, distorts students' learning purpose and motivation, overemphasizes exam tactics, intensifies training, and neglects the cultivation of students' abilities [21] The authors point out that when teachers pay more attention to "scores", they would adopt unscientific teaching methods to improve students' academic scores, leading to a tense, busy, and competitive atmosphere in primary and secondary schools, which also increases students' burden. Other research suggests that these negative patterns in the exam-oriented education system would reinforce teachers' gender expectations in decision-making and teaching methods. For instance, under examination pressure, teachers pay more attention to teaching academic knowledge and neglect students' attitudes, interests, and career planning [22].

Taken together, the reviewed literature demonstrates that teachers' beliefs, motivational frameworks, gender bias, and cultural contexts are deeply interconnected in shaping early science learning. Although prior studies often examine these factors separately—focusing on self-efficacy, motivation, gender stereotypes, or systemic pressures in isolation—their findings collectively point to a set of underlying mechanisms through which early educational experiences become gendered. In order to reduce the descriptive review and work toward deep comprehensiveness, the following themes synthesis will focus on how the key mechanisms like teachers' belief system, motivational

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processes, access to cognitive learning opportunities, and cultural and systemic conditions interact to influence early science education in China.

3. Themes

3.1. Theme 1: teachers' beliefs shape the foundations of early science learning

In the multi-level framework, teachers are one of the critical roles in the meso-level. They work as a bridge that translates macro-level factors like cultural context and systematic influences into classroom practices. Teachers' beliefs have been influenced by these macro-level factors, which lead to the consequence for the design of learning environments, attitudes, and access to different opportunities for young learners.

Beliefs about children's competence play a central role in early science instruction. Based on a cross-sectional survey to explore pre-service early childhood education teachers' (PT) beliefs, Ata Akturk and Cetin [23] found that although teachers widely acknowledged the importance of early science education, many held a narrow view of its scope such as natural topics. In addition, teachers who reported low self-efficacy for teaching science have correlation with limited hands-on experiences, insufficient theoretical knowledge, and inadequate university preparation. Therefore, when teachers have less self-efficacy, their own competence would decrease. In this case, teachers are more likely to depend on more teacher-directed activities. They may also reduce practices that allow children to investigate, explore, and generate ideas, such as complexity tasks. These findings explain how beliefs about one's teaching competence affect the access to learning opportunities for children in science education.

Similarly, teachers' beliefs about their own self-efficacy also influence how they design instructional practices in the classroom. Part et al. [24] used survey data from early childhood teachers and indicated that many educators avoid early STEM teaching courses since they think that children are developmentally inappropriate or more suitable for secondary education. Teachers who avoid science teaching not only reduce children access to early exposure to STEM knowledge, but also decrease teachers' opportunities to practice which could lead to less confidence. Authors also found that teachers with more teaching experience and with specific professional development had higher levels of readiness beliefs and were more willing to implement STEM activities. This suggests that beliefs are not fixed dispositions but fluid mechanisms that may expand or constrict instructional possibilities according to contextual reinforcement.

The two studies emphasize the significance of recognizing that teachers' beliefs do not operate in isolation but are part of a network that impacts early science learning environments. Beliefs about children influence what we expect young learners to be able to do, and beliefs about the competence of teachers influence the extent to which instructional approaches can be ambitious or limited. If both sets of beliefs are constrained, classrooms are likely to rely on low-level, teacher-directed activities. In contrast, teachers with higher self-efficacy and broader conceptions of science are more likely to provide rich inquiry-based learning opportunities.

The pattern suggests, analytically, that teacher beliefs serve as a gate-keeping mechanism that regulates access to high quality learning experiences. Beliefs do not directly affect student outcomes; rather, they affect the conditions under which learning happens. These conditions include the material's difficulty, students' freedom, and the extent to which their ideas are valued. In this sense, self-efficacy can be seen as a mediating variable between teacher cognition and instructional practice, and thus affect the extent to which children's engagement with science is fostered or inhibited in the classroom.

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Also, what teachers believe children can do is equally important in shaping learning environments. If teachers believe that some students are better at science or "ready" to learn it, they may provide them with more challenging tasks, better feedback, and more opportunities to explore on their own. By comparison, students who are seen as less able may be given simpler lessons or feedback that is more about behaviour than reasoning. These minor differences in expectations, however, result in unequal access to learning opportunities within the same classroom.

This theme demonstrates that the beliefs of teachers are not only personal attributes but also within the educational system that affects the distribution of opportunities. These beliefs determine what is considered valid knowledge, who is considered competent, and how learning should occur. They also set the stage for other processes including motivation, engagement, and cognitive development. To understand early science inequality, we need to look beyond teachers. And we have to think about the beliefs that make those things possible.

3.2. Theme 2: gender bias as an implicit force influencing engagement and motivation

Based on the idea that teachers' beliefs are a structural mechanism, gender bias can be conceived as one specific means of enacting teachers' beliefs in the classroom. In the multi-level framework, the micro level is where the gender bias is mainly manifested, affecting students' daily experiences of feedback, encouragement and participation. Gender bias is about changing the way people view things and also about encouraging students to think about their skills and how they learn science.

One of the key relationships in most literature is teachers' implicit gender assumption and their expectations and interactions with students. In this case, boys have more access to open-ended questions or exploring challenges since they are viewed as excellent talent in logical reasoning and problem-solving. However, girls always need to put more effort and accuracy to prove their ability in STEM fields. As a result, this differential treatment would influence their motivation in the long term.

By using large-scale quantitative data (the ECLS-K dataset), Robinson et al. [25] found that teachers' implicit gender biases in mathematics decrease girls' engagement, motivation, and achievement in early elementary school. The research also found that teachers often underestimate girls' math success compared to boys, even girls achieve high math scores on tests and behave better in the classroom. In this situation, girls need to put in more effort and achieve higher scores to be viewed as the same mathematically competent as boys. In turn, girls' competency in maths need to be proven continually to ensure they can have the equal access to tasks and prizes from teachers. Based on a motivational perspective, such conditions may reduce students' sense of autonomy and intrinsic interest since their engagement becomes tied to external validation rather than internal confidence.

Importantly, these processes are strongly related to different motivational theories, such as self-determination theory and expectancy-value theory. If students are exposed to fewer signals that their ideas are valued or that they can succeed, their tasks competence and value may decrease. In early childhood education, students are especially sensitive to these kinds of cues, these experiences can have a lasting effect on their self-concepts. Therefore, gender bias is not simply a short-term influence on students' behaviours in class, but a long-term influence on their future motivational dispositions in science.

At the same time, although teachers provide approaches to address gender bias in classrooms, they are not always effective. Janssen et al. [26] explain this process in early elementary classrooms. Based on the qualitative interviews, the authors found that many teachers rely on minimizing strategies such as "anyone can do anything," which suggests that everything is equal. However,

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these approaches may oversimplify the issue and fail to address the underlying mechanisms through which bias operates. Although they exclude the influence of gender, teachers' implicit expectations still influence how they treat students differently.

In short, gender bias is a long-term process that shapes students' motivational experiences from an early age. This bias may happen in the classroom interactions, teacher feedback, and teachers' differential expectations. As a result, gender bias would influence students' science abilities and motivation.

3.3. Theme 3: differential cognitive opportunities and the development of critical thinking

Based on the previous theme about how gender bias influences students' engagement and motivation, this theme would further examine how this process continually affects students' cognitive development through differential access to learning opportunities. In the multi-level framework, this process is the result of cumulative meso-level teacher beliefs and micro-level interaction patterns, both of which determine how tasks in the classroom are cognitively demanding. As a result, disparities in learning outcomes emerge not from inherent differences in ability, but from systematic differences in the quality and complexity of learning experiences.

Both Li [14] and Marni et al. [15] figure out there are no support for gender difference in critical thinking skills. These findings suggest that cognitive difference is not biological and highlight that educational expectations should not be differentiated by gender. In a qualitative study, authors used semi-structured interviews to examine how teachers' expectations influence students in the classroom. Mirza et al. [27] shows that teachers' expectations have a relationship with a child's psychological, cognitive development, and their academic behaviors in the classroom. When teachers view students as more intelligent, capable, and talented, they are more likely to offer students more challenging tasks and supportive feedback which emphasizes students cognitive skills development. In an analytical perspective, although students may begin with similar abilities, their skill could develop differently in the long-term. For example, when students are exposed to complex reasoning tasks and detailed feedback, they have more opportunities to enhance their cognitive skills and confidence in their ability. However, if teachers provide repeated simplified tasks to students, they will hardly develop even if they may have talent initially. Moreover, these differences would influence long-term skill development, confidence in reasoning, and willingness to engage with complex problems.

Azizi et al. [28] 's outcome-based studies further support this interpretation. They found that both gender apply the similar critical strategies when they solve the cognitive tasks. This indicates that critical thinking skills relevant to external factors like explicit strategy instruction, task complexity, and access to practices instead of biological sex. Take both literature together, girls and boys may demonstrate similar critical thinking outcome in the short term. However, their ability would be different when they receive long-term differential instructional strategies for cognitive tasks and feedback.

All these studies show that cognitive inequality emerges through external factors such as teachers' expectations and gender biases which translate into differentiated opportunities and support. This also shape how students come to see themselves as thinkers. Thus, the development of critical thinking is not merely an individual cognitive process but a socially mediated outcome of instructional distribution. In conclusion, educators should focus on explicitly and inclusively teaching critical thinking strategies to all learners, rather than on gender considerations.

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3.4. Theme 4: cultural and systemic pressures shaping gender bias in the Chinese context

In the previous themes, most of them focus on how the meso-level and micro-level factors influence students' self-efficacy and motivation in early science education. In this part, it will discuss how these process are influenced and reinforced in the broader macro-level cultural and systemic context. In the China, the exam-oriented system and cultural gender norms interact to impact how the instructional practices apply in the classroom, and then influence teachers' beliefs. In this case, gender disparities in early science education emerge through multi-level and cumulative processes rather than isolated influences.

A key pattern of this context is the influence of culturally embedded gender expectations. Research used a multiple-case qualitative design to examine early childhood educators' perceptions and practices regarding gender differences in STEM play within China. The study found that most teachers uphold the social norm that girls should pursue "soft" or domestic roles, thereby lowering their own and others' expectations for girls' STEM engagement from an early age [4]. Such early signals and low expectations foster girls' self-perceptions and contribute to early disengagement from STEM-related learning when they enter high school.

These cultural norms also can reinforced by China's exam-oriented edcuation system. In the research analysis about Gaokao system, the author claims that high-stakes testing discourages risk-taking, exploration, and decision making [29]. In this system, teachers are likely to encourage students, especially girls, to choose "safe" subjects like History, Literature, and Language when they are in Grade 11. Also, the cultural norms about gender roles moderate this situation. Teachers may consider that girls are good at these subjects and they can be easier to achieve high scores in the exam. Although these beliefs occur in the high school and secondary school, the reinforced gender bias could happen in the early stages of education. As mentioned in previous literature, gender biases and differentiated classroom practices influence children in the kindergarten. In this case, when students face the choices of subjects in the high school, they are already influenced by accumulated instructional practices and gender bias from the early stages.

Similarly, Li and Zhang [30] provide empirical evidence that China's high-stakes education system interacts with cultural norms to enhance the gender bias in academic outcomes. The quantitative analysis examines how multiple-choice questions(MCQs) influence students of different genders. In the finding, the authors point out that these kinds of questions could disadvantage girls because of gender differences in risk avoidance. While the scores are viewed as the important and even only standard, a small influence on motivation and confidence would lead to a large reaction and negative consequences, especially in STEM subjects. Moreover, these assessments impact the distribution of classroom practice. Teachers would like to distribute more subjective or theory-based questions in the classroom practice. Teachers believe this approach can protect students' confidence and reduce the failure that influences their motivation. Although these solutions could protect girls and ensure they can achieve high scores in the exams, they can also unintentionally reduce girls' attendance in the logical thinking and problem-solving process, which is the basis of STEM learning. In conclusion, this assessment would also limit the access to opportunities for girls to improve their abilities in STEM learning.

In conclusion, these findings figure out how cultural norms about gender roles connect with systemic pressure to increase the emergence of gender disparities in the STEM learning process in the Chinese context. Girls choose to avoid STEM subjects not because of personal interests. However, the systematic pressure mediates the influences of teachers' expectations and implicit social norms to reduce girls' opportunities for STEM learning. In this case, the macro-level cultural

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norms and exam-oriented norms influence teachers' beliefs about subject selection and their teaching approaches and their evaluation of students' abilities based on different genders. These beliefs further influence students' motivation and self-efficacy in STEM subjects. The analysis ranges from micro-level factors to macro-level factors clearly show the process of how gender disparities happen in the STEM field.

4. Conclusion

This synthesis paper provides an analysis of how gender disparities emerge in early science education. It suggests that it happens because of interaction among teachers' beliefs, implicit gender bias, motivational patterns, differentiated cognitive learning opportunities, and cultural context. By analyzing these factors, this review provides a clear process of how the macro-level factors mediate the meso-level factors to influence a person at the micro-level.

The main contribution of this synthesis is to show how these factors function as a system. Based on the theoretical perspective, the findings suggest that gender difference in early science education should be viewed as the outcome of an integrated system instead of independent factors.Science learning process is inquiry-based or teacher-directed based on teachers' self-efficacy and beliefs about children's capabilities. Gender bias would influence the interpretations of equivalent performances, which lead to conditional agreement. Although underlying abilities like cognitive learning abilities vary between different people, the gap between abilities is further reinforced by differential distribution of complex tasks. The view provides another explanation that cognitive development happens in the classroom and is reinforced by teachers' beliefs and practices. This highlights how teachers' expectation and practices in early science educational experience influences long-term academic and cognitive development for children.

This synthesis from both systematic and practical perspectives shows that the effect of improvement in educational resources and curriculum is not enough for early science educational equity. In this case, the interventions should focus on how to improve teachers' belief systems and instructional practices to help students build high self-efficacy and confidence in STEM fields at an early stage. In addition, the improvements need to provide professional training programs to teachers. These programs can provide guidance about how to improve the design of classroom instruction. For example, the guidelines should include how to provide students with equal learning opportunities to complete cognitive tasks in the classroom. This suggestion helps ensure that every student can engage in the critical thinking process. Importantly, such classroom level processes are established in higher-level institutional contexts. In an exam-oriented system like China, typical assessments and choices of subjects which are based on efficiency could reinforce small difference in confidence and performance into larger gaps over time. In this case, equity in learning opportunities depends not only on teaching practices, but also on system-level structures and classroom dynamics.

In future study, researchers may need to focus on two main questions. First of all, researchers should focus on how early teacher beliefs relate to later academic choices through longitudinal study. In addition, researchers should consider the non-Western and exam-oriented educational systems as important mediated factors. Moreover, most of the literature discusses how the oriented exam systems influence students and teachers in developed areas of China, such as Shanghai and Hong Kong. Future studies should consider how different levels of SES influence the relationship between exam-oriented systems and teachers' beliefs in developing areas. Also, developed areas in China may have more resources in educational settings, and developing areas have limited resources in early science education. Researchers should pay more attention to how different policies and

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abundant educational resources interact with traditional cultural norms and the exam-oriented system to influence teachers' beliefs about early science education and gender differences.

In conclusion, when people consider increasing equity in early science and STEM education, they should consider how to make educators' expectations, instructional decisions, and assessments match children's potential instead of factors such as gender, cultural assumptions, and social norms. In this case, early science education can offer greater benefits and opportunities in classroom settings. Such changes provide a specific direction toward reducing gender disparities and supporting more inclusive STEM trajectories from the early stage of education.

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