An Examination of Elementary Students' Reasoning Ability via Inquiry-Based Project Designed by STEAM Integration

Hsuehi Lo, St. Cloud State University, United States

The European Conference on Education 2023
Official Conference Proceeding

Abstract
This study describes inquiry-based methods, taught in elementary school setting, integrated with STEAM courses sessions that teacher candidates work with individual children. I examine fifty-six students' (4^{th} and 5^{th} graders) reasoning ability, especially on mathematics and scientific justification, on teacher candidates' STEAM lessons through the theory of inquiry-based methods. I employed a quantitatively descriptive and quasi-experiential mixed model ANOVA and a qualitatively coding process on open-ended questions and letter-writing analysis on the field. A pre/post-test design was employed to determine levels of students' development in reasoning ability. Instead of telling students what, why, and how climate change occurred, all participants' learning processes are guided by play-based pedagogy, based on students' needs in real classroom settings. Students thus needed to hypothesize reasonable responses via online resources. The STEAM lessons culminated in students writing a letter to the local mayor about potential damage to their municipality stemming from climate change. The lesson structure required young people to propose policy changes. Results indicated that prior to the inquiry-based model's implementation students were primarily given pencil-paper tests. Under the inquiry-based models, students begin exploring knowledge through scientific inquiry. Using the processes in this study, students significantly improved their ability to measure their reasoning and argumentation skills.

Keywords: Inquiry-Based Methods, Play-Based Pedagogy, STEAM Curriculum, Teacher Candidates

Introduction

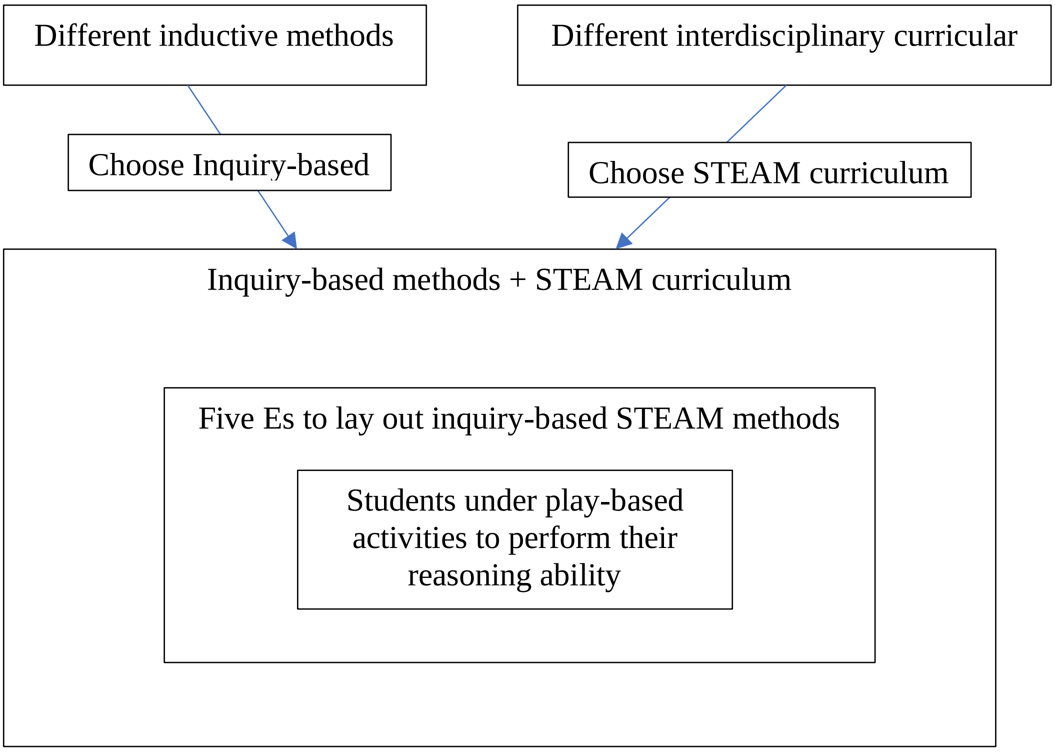
Four years ago, I began to introduce the theory of inquiry-based methods (Khalid & Mohammed, 2018) along with the play-based learning environment to my mathematics methods course. Teacher candidates implement the inquiry-based methods in the local elementary school at the same time so, as a method instructor and supervisor, I may observe and examine the practical performance of inquiry-based methods in real classroom settings. My intention to do this research, based on the pilot-observation in the four years, was to provide a scientific examination the validity of inquiry-based methods by elementary students' performance in the inquiry-based methods. Some research showed (Reinhardt, Robertson, & Johnson, 2021; Tan, 2019; Abramovich, Easton & Hayes, 2012) elementary teacher candidates may develop their signature pedagogy (Shulman, 2005) well when implementing inquiry-based methods in STEAM lessons. On the other hand, my pilot-observation showed that elementary students may develop their reasoning ability with STEAM-related activities under inquiry-based methods. This study is to examine if elementary students' reasoning ability can be developed well under inquiry-based STEAM methods.

To develop elementary students' reasoning ability in STEAM lessons, play-based pedagogy (Paterson, 2020), designed by teacher candidates, may be used to implement inquiry-based STEAM lessons for elementary students who have different learning needs. This means, based on elementary students' learning styles, levels of STEAM performance, and cultural background, teacher candidates may design meaningful games to develop their students' critical thinking skills. The focus of this study is students' reasoning ability in STEAM lessons, which may include elementary students' mathematical reasonings (Michael, Tammy, & Johna, 2010), scientific argument and reasonings (Zulkipi, et al., 2020; Berland & NcNeill, 2010). Through inquiry-based methods, used in STEAM interdisciplinary curriculum, I wonder how elementary students develop their reasoning ability through play-based pedagogy. The research question in this study is how elementary students develop their reasoning ability under play-based learning process through inquiry-based model.

Theoretical Framework

To aim at elementary students' reasoning ability, the content-related curriculum and pedagogy are discussed. First, I represent the difference between STEAM and STEM education, and why STEAM curriculum is the best lessons to examine and support students' ability. Secondly, I discuss students' reasoning ability performance in inquiry-based methods, and, thirdly, I explore how students use what, why and how to justify their reasoning in play-based learning pedagogy. Figure 1 may provide a picture of how pedagogy and content are considered together as Pedagogical Content Knowledge (Shulman, 1986) and how theoretical teaching models can be transformed to practical learning process.

Figure 1: Model of literature review



Students' Reasoning Ability in STEAM Curriculum

Students' reasoning ability can be developed by any creative activities in a disciplinary curriculum design like STEM education. Science education, under STEM curriculum, normally provides rich creative activities for students to observe facts, explore evidence, justifying the prediction based on their reasoning ability (Cabello et al., 2021). Researchers (Aguilera & Ortiz-Revilla, 2021) are aware that the component of "Arts" may need to be included in STEM curriculum in order to approach the essential meaning of education, not just for job preparation. Furthermore, standing on teaching through understanding, students can develop their critical thinking better when STEM curriculum adds art components than STEM only (Conradty & Bogner, 2018). By adding art into STEM curriculum design, students can show their critical thinking skills in reasoning ability (e.g., finding reasons, justifying the reasons, choosing meaningful reasons to conclude the hypotheses etc.) presented by the "art" activities (e.g., writing a letter to the city mayor, drawing pictures to share in the schools, or doing activities for community service. In this study, students are under STEAM education to develop their reasoning ability.

When focusing on students' reasoning ability performance, one concern is how students can develop their reasoning ability under inquiry-based STEAM lessons with wide different students' abilities and have different cultural backgrounds (Huo et al., 2020). Excellent STEAM lessons require teachers to be knowledgeable in domain-content subject with consideration of cultural or environmental differences. Students must feel that their teachers recognize their cultural strengths so they will feel worthwhile when representing their reasoning abilities (Zulkipi, et al., 2020). The research (Zulkipi, et al., 2020; Berland & NcNeill, 2010) showed it is easier to connect all students by environment-related art activities because these activities can be built together in the classroom which will provide a foundation that all students can relate to. In this study, under STEAM curriculum, students can represent their reasoning ability by writing a letter to their city mayor. This activity provided common ground for all students.

Students' Reasoning Ability Under Inquiry-Based Models

Within several inquiry models (Gunter, et al., 2011), STEAM curriculum can be designed under problem-based inquiry methods, based on the situation learning theory (Shulman, 2005; Putnam & Borko, 2000) as theoretical framework. Problem-based inquiry STEAM lessons provide students to examine the problem situation, so students need to ask themselves, what, why and how questions to learn new knowledge by themselves. The teachers' roles under problem-based inquiry STEAM lessons are to facilitate students' needs, not give answers, so students use their reasoning ability to guess, predict, and confirm new knowledge. In addition, Thunberg et al., (2018) showed that cognitive learning in inquiry-based STEAM methods can help students make a positive attitude to explore new knowledge by reasoning ability, and Vlassi and Karaliota (2013) studies in behavior science perspectives showed inquiry-based STEAM methods help students believe in their own capabilities to explore new knowledge.

Inquiry-based models can be represented by the five Es' (Engage, Explore, Explain, Elaborate, and Evaluate) in lesson processes (Duran & Duran, 2004) in STEAM curriculum. The Five Es may systematically support different kind of scientific activities for students to demonstrate their reasoning ability (Karpudewan et al., 2015). The goal of this study is to explore how students can use the questions of what, why, and how by themselves and answer their own questions by reasoning under situatedness inquiry-based learning in STEAM lessons.

Practical Play-Based Pedagogy/Activities for Students' Reasoning Ability

As Figure 1 represented above, inquiry-based methods provide a theoretical concept, and the play-based pedagogy may provide a practical concept for teachers to design meaningful STAEM learning activities for their elementary students to play. Here the play-based pedagogy is not based on free play-based curriculum (Pyle, 2017) for kindergarten and first grade. The play-based pedagogy, as Putnam and Borko (2000) states, is systematically designed for students as a group to choose STEAM activities to explore new knowledge. The formation can be different. For example, station teaching can be used so students play different STEAM games, but all aligned with the same learning objectives. It also can be under three prepared STEAM games; students can choose one of them to play individually or as a small group.

The goal of play-based pedagogy practically creates a game-based environment for students to explore new knowledge through the essential questions, what, what, and how to explore new knowledge by themselves. The games may come from technology (e.g., website like IXL, iPad apps, google exploration, etc.) integrating to the STEAM lesson objectives. The research (Lo & Hoover, 2022) showed through playing the games/activities with an "inquiry" or "unknown knowledge" in their mind, students represent that they have responsibility to find out the knowledge and they feel belonging in their learning process.

Method

Participants

Fifty-six students are qualified to participate in this study. These students are all in four classrooms in 4th and 5th grade at Lincoln Elementary School in the St. Clous School District, located in the central Minnesota. All of the teacher candidates in this study are well-trained and have proven their abilities in previous clinical settings. The school has 84% of students on free lunch and students' scores are consistently below the state average in standards test. The school principal and math coach are very supportive of this study because they are looking for different instructional models to implement their STEAM curriculum. Based on their observation, they found the play-based pedagogy in the real life under the theory of inquiry-based method helps students with different cultural background, students with limited English ability, and students with below average performance in STEAM lessons very well. Both would like to know the results of this inquiry-based method as it is implemented in the existing STEAM interdisciplinary curriculum.

Two of four teacher candidates are assigned to the 4th grade classrooms and the other two are assigned to the 5th grade classrooms. All four teacher candidates understand inquiry-based STEAM method concept, play-based pedagogy, and five Es lesson procedure very well. There are totally 98 students in the four classrooms, but the study eliminates students who are under special education plan (called IEP in the U.S.), who have extremely social emotional disabilities, and whose STEAM performance only reach to 2nd grade standards. To the end, only 56 students in these four classrooms are qualified to be participants in this study.

Instruments and Data Collection

The 5-likert-scale survey (see appendix A) with 5 items and three open-ended questions is designed as instruments for this study. This same survey is used twice as pretest (the 5 items) and posttest (the 5 items with three open-ended questions) in this study. Multiple data collections are implemented in this study. For the quantitative data, a quasi-experiential design with pre- and posttest survey to the 4th and 5th graders was collected to determine the levels of students' performance in their reasoning ability. The qualitative data is collected from the three open-ended questions in the posttest survey and students' performance in their persuasive letter writing project.

Procedure of This Study

The unit of climate changes was chosen to be an indicator of this study under inquiry-based methods because it is the unit covered in 4th and 5th grade science curriculum. Before the climate changes unit, all students took the pre-test survey. During the unit, students are required to write down their answers related to what, why, and how in their learning tasks. Most of time, the answers of these questions are represented in the "Explore", "Explain" and "Elaborate" steps in the five Es lesson process. The final project of this climate change unit is students wrote a persuasive letter to the local mayor. In the letter writing project, students are required to report their findings through math reasoning(what), cause/effect through scientific reasoning(why), and their reasoning of how to effectively do recycling in this city (how). After the unit, students take the posttest survey and teacher candidates collect students' persuaded letter.

Data Analysis

I analyzed quantitatively pre- and post-test survey by using mixed model ANOVA. Within 4 classrooms, one 4th grade and one 5th grade classroom are treatment group, in which students' reasoning performance is developed with the inquiry-based STEAM methods and plan-based pedagogy following five Es lesson process. The other two classrooms, one 4th grade and one 5th grade, acted as the control group in this study. Students in the control groups are under regular textbook-driven curriculum to complete their climates change unit. The mixed model ANOVA analysis is to compare the pre- and posttest results to see if students' reasoning ability performance shows a statistically significant difference.

I analyzed qualitatively students' answers to their open-ended questions and letter writing data by coding process (Elliott, 2018). I develop meaningful codes to categorize five criteria of reasoning abilities. The qualitative data may represent how play-based pedagogy through inquiry-based STEAM methods can facilitate students' reasoning ability in STEAM curriculum.

Research Question

How can 4th-5th grade students develop their reasoning ability under play-based learning process through inquiry-based STEAM methods?

Findings

Fifty-six students are qualified to represent their reasoning ability in this study. The following quantitative data report from the Mixed model ANOVA model is used to report if students' reasoning ability performance has statistically significant difference.

Reliability Indication

I relied on internal consistency statistics to interpret the reliability of the scales generated for the investigation, In the U.S, I designate grades 4-5 as "intermediate [elementary] level" (ages approximately 8-11). I intend to continue the development of an instrument that practitioners may find useful for tapping elementary students' attitudes toward their ability to engage in critical thinking. I have entered the pertinent results in Table 1.

Based on the Table 1, it showed that the five items sufficiently intercorrelated to produce Cronbach alphas (all are greater than 0.6) appropriate to the research effort and to justify combining the items to form a more reliable composite score.

Table 1: Reliability estimates

Scale	N Items	Description	α
A. Pre-Assessment	5	Initial Assessment of ability (of fourth and fifth graders) to think critically	**.73**
B. Post-Assessment	5	Same as above except collected ***following*** the treatment experience	**.79**
C. Pre-post taken as one tool	10	The alpha score across two administrations of the same items	**.66**

Descriptive and Inferential Results

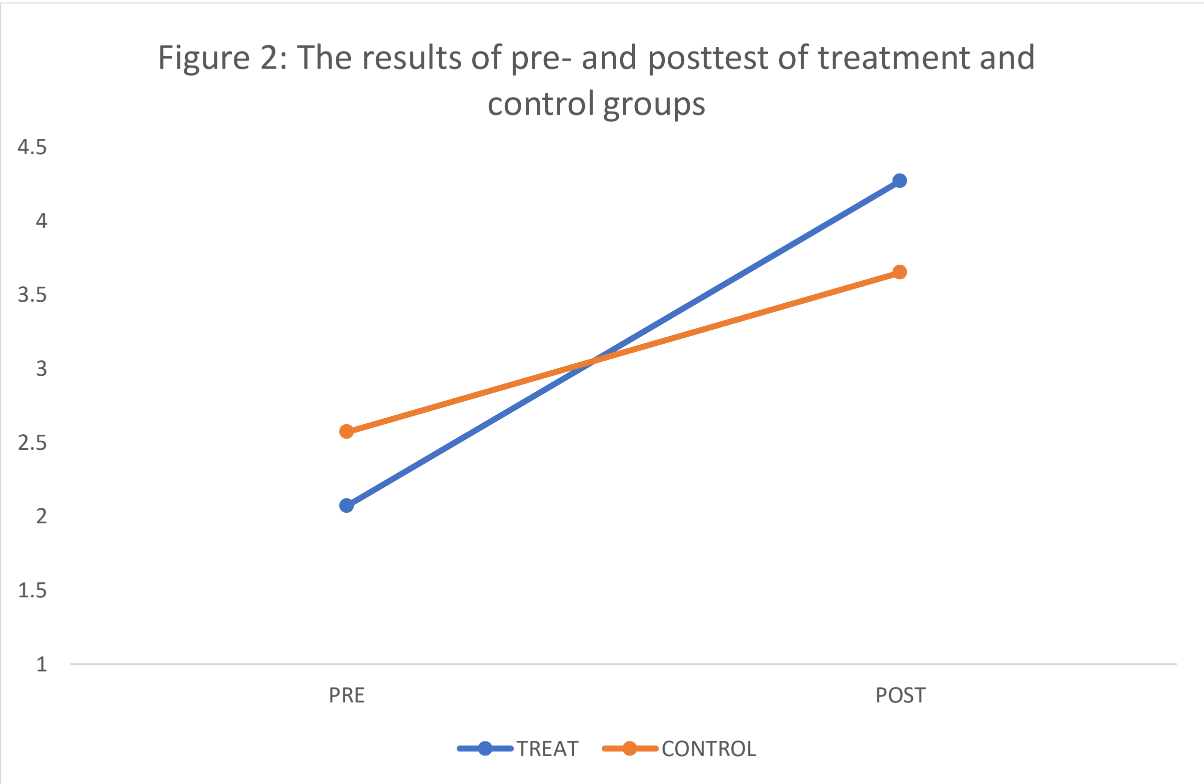
Descriptive Analysis. Based on the positive internal consistency metrics, I next constructed a composite score by averaging the pretest survey scores and, of course, the post treatment test survey values. As a starting point of the analysis, the mean values by pre- and posttest treatment levels are provided in Table 2 and transferred the Table 2 numbers into the Figure 2.

Table 2. Pre and post values across groups.

Pre vs. Post/ group	N	Mean	SD	d (Post-Pre)[1]	Effect Size[2]
Pre/ Treatment Group	30	2.07	.45	----	----
Post/ Treatment Group	30	4.27	.45	2.20	4.9
Pre/ Untreated Group	26	2.57	.41	----	----
Post/ Untreated Group	26	3.65	.27	1.08	3.1

[1]d = difference, post treatment mean – (minus) pretreatment mean.
[2]Rough estimate of pre-to-post effect size for each group (d/pooled SD's). Inferential results found below.

Figure 2 showed ordinal effect that before the units, the students in the treatment groups do performance reasoning ability lower than the control group. After using inquiry-based methods, the treatment group students perform higher reasoning ability than the control group in this unit.



Inferential Analysis. A mixed model ANOVA was developed. Via this model, I sorted variability of the dependent measures into three interacting independent variables, TRIAL (two levels Pre vs. Post, repeated measures) and GROUP (two levels, treated vs. controlled). The potential independent variable GRADE (between grades within classes) was ignored as no a priori reason existed to assume that the fourth-grade class would perform differently from the fifth-grade class. In fact, in a preliminary study, this proved to be the case, GRADE did not interact with TRIAL, nor did it interact with GROUP. I treated the TRIAL effect and TRIAL * GROUP interaction as within-subjects effects with inter-subject variability designated as the error term. GROUP served as a between-subjects factor, with within-group variability serving as the error term. The resulting mixed model ANOVA table is shown below in Table 3.

Table 3. Mixed model ANOVA inferential results

Variability Source	Pillai's Trace	F	df	*p*	Partial Eta[2]
PRE-POST Assessment (Within Subjects)	.94	779.2	1	<.001	.94
PRE-POST X Group (Treated vs. Controlled, Within Subjects) Trial by Group	**.62**	**89.8**	**1**	**< .001**	**.63**
GROUP[1] (Between Subjects	----	.451	1	.51	----

[1]Between-Groups SS = .106, 1 df yields a MS of .106. Error = 12.73 df = 54 = MS_{error} =.236 (.45, see above)
[2]Eta-squared indicates the strength of an effect—roughly in SD units. For example, the pre-post by GROUP effect here is about 2/3 of an sd.

The most central effect related to the questions posed for the study's is the PRE-POST X GROUP interaction effect. I chose to emphasize this result because it best answers the research question about whether the treatment worked as planned. In other words, one might pose the following query: Did the treatment group improve more than did members of the untreated group? The answer is a resounding yes. Not only was the GROUP X PRE-POST effect significant, but it produced a reasonably strong effect, $F (1, 56) = 89.8$, $p < 0.001$, the effect size (η^2) = 0.63.

Oddly, both the treated and controlled group changed significantly as a function of time, e.g., TRIAL, evincing a sizeable effect size of .94 (partial eta^2). This probably occurred because of subjects' prior exposure to items, e.g., during the pre-treatment phase of the study. Perhaps exposure to the topic of critical thinking produced contemplation of the topic that impacted post test results. In my view, this is a form of difficult-to-manage error variance that probably undermined the interaction effect by some degree. In other words, this is a measurement issue that needs to be addressed in future studies, perhaps via analysis of covariance.

Table 4 contains results (treatment group only) by item (pre vs. post). This allows for an examination of which items produced the largest pre-to-post differences.

Table 4. Mean values by item/ treated group only (descending order by gain: post-pre)

Item (short title)/ Arranged in descending order by size of pre-post change (difference)	Mean	SD	Mean	SD	Post-Pre Difference	Rank By Gain[1]
1. I can use my own words to describe what global warming is and how greenhouse gases (HCFs) trap the sun's heat.	2.23	.63	3.87	.63	1.64	5
2. I can justify evidence to explain global warming under natural factors or human factors.	2.23	.86	4.30	.65	2.07	4
3. I can examine the city data report and decide which parts need to reduce their HCFs emission.	2.10	.61	4.57	.63	2.47	2
4. I can explore effective strategies through information online to reduce HCFs emission in the city.	**1.87**	**.57**	**4.57**	**.57**	**2.70**	**1**
5. I can write a persuasive letter to our mayor persuade him by using scientific reasoning.	1.93	.74	4.07	.58	2.14	3

[1]Item #4 produced the largest gain (pre-to-post), followed by, in order, items 3, 5, 2, and 1.

Based on the table 4 report, it obviously showed students in the treatment groups can explore effective strategies by themselves online and produce new knowledge "to reduce HCFs emission in the city" by self-learning process. The findings showed students can use their own reasoning ability to build their new knowledge.

The Qualitative Findings

The following qualitative data from students' answers to open-ended questions and their persuasive writing project is used to report how play-based pedagogy through inquiry-based STEAM methods can facilitate students' reasoning ability in STEAM curriculum.

Theme one: Students prefer to have more time to do self-learning under inquiry-based STEAM method.

From the open-ended question number 2, it showed students would like learning lessons by themselves under inquiry-based methods. Instead of a lecturing process in science lessons, they prefer to play related-scientific games online to explore new knowledge. They feel confident to ask themselves what, why, and how questions. Here are two quotations from a student.

> "Our group choose to play an online game under global warming lessons on the website of IXL. After the greenhouse video clip, we have a plenty of time to explore what greenhouse gases are, why carbon dioxide trapped the heat from the sunlight. I feel so proud that I learn new knowledge by myself." (4th grader, Reid)

"I like the inquiry-based learning environment because I have more time to explore meaningful information about why climate change cause global warming." (5th grader, Mohammad)

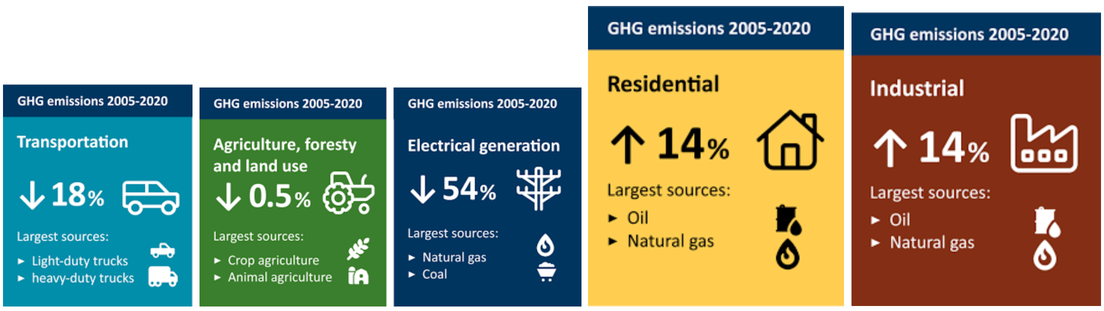
It showed students enjoy having enough time to work together. In the beginning, they might start with divergent perspectives to answer questions or make a hypothesis. Students will use their critical thinking skills to examine information, examine evidence, justify their reasoning, and keep asking meaningful questions to approach convergent perspectives.

"Our group evaluates information and make a reasoning justification for our conclusion. So, we know better how to write a letter to our city major." (4th grader, Ayan)

Theme two: The "Arts" in STEAM showed students' reasoning ability better

The findings are based on the coding analysis from writing a letter. Through students' persuasive letter performance, it showed students do a better job to combine STEAM reasoning ability with their language art performance. The final task in the climate change unit, the writing task, students use the online resource (https://www.pca.state.mn.us/sites/default/files/lraq-2sy23.pdf) to find the data (see Figure 3) and use the data to write a persuasive letter to their city mayor. The coding on the letter writing is to explore students' use the questions of what, why, and how, as scientific reasoning, to compose their letter. It showed students can develop their reasoning ability from STEAM requirement to apply in the real-life situation. The project helped students begin to learn how to appropriately represent their scientific reasons and argument to other persons.

Figure 3: Data for writing a persuasive letter



Resources are from the website: https://www.pca.state.mn.us/sites/default/files/lraq-2sy23.pdf

The following is the quotation from students' persuasive writing project.

"…because residential and industrial GHG are still increase 14% from 2005 to 2020, we suggest you increasing solar energy for houseowner and manufacture to reduce the use of oil and natural gas." (4th grader, Abdi)

"After we explore global warming, dear Mr. Kleis, I think you need to make a recycling policy in each school and show recyclable materials as explicit as possible." (4th grader, Sara)

Writing a letter in a group can be one of play-based activities. After that, each group may present their letter and explain what they write, why they represent this way, and how better they think your performance as self-evaluation under the last step of five Es process.

Conclusions

Inquiry-Based Methods in Diversity Classrooms

Students' reasoning ability is current K-12 education focus, especially in schools with complicated social environments. There is a constant debate about what kind of education models and training models can help our students the best. Several studies (Mark, et al., 2021; Kang & Kim, 2014) showed the inquiry-based methods perform well for gifted and talented students. After implementing the study in the elementary school, where 89% of students remain eligible for free/reduced lunch and 45% are designated as students of color, the study represented the opposite result of the previous studies that students of color in the multi-cultural background classrooms actually can also perform well. Survey question number 4 "I can explore effective strategies through information online to reduce HCFs emission in the city." The difference between post and pretest means have the largest gain. It means students of color have the ability and students who come from poverty have the ability to do critical effective learning under inquiry-based STEAM method. They showed they can provide self-learning attitude in each learning task.

Play-Based Pedagogy and Five Es

One conclusion of this study is about students' motivation and their attitude to each learning tasks in the STEAM lessons. Obviously, the play-based pedagogy plays a practical role effectively to motivate students' learning attitude without worrying about their possible STEAM content deficiency. Play-based pedagogy are required to use scaffolding to lay out the STEAM games. In addition, teacher candidates must be well trained to change easy games to be more challenge, to change competitive games to be cooperative games, or change individual games to be group-playing games.

Play-based pedagogy motivate students to participate in the science unit on climate change, so they enhanced their reasoning ability and other critical thinking. This means that under educative models, inquiry-based methods, students can practice how to use their own words to ask meaningful question, to justify meaningful evidence (for example global warming in this study), to examine their justification of their reasoning, and to explore the best strategies to report all reasoning they made to others.

Five Es play a big role in making a regulation for students to play STEAM games in each lesson. Under play-based pedagogy, students, individually or in a small group, are easy to lose the direction during their own playing time. When teacher candidates use five Es lesson process in each single STEAM lesson, it may help students to create an environment-awareness schema (Thunberg et al., 2018) in their mind. Normally under inquiry-based methods, teacher candidates act as a facilitator in STEAM lessons to go around the classroom to help different kinds of students' learning needs. During the "Explore" time, students know the next step is "Explain" section so they will do meaningful exploration to aim at their explanation in the next step of each lesson.

Technology Roles in the STEAM Curriculum

Technology in this study plays a big role to establish the inquiry-based STEAM methods so even though in the diversity classrooms, students still can develop their reasoning abilities corresponded with different kinds of learning styles (Darmayanti, et al., 2022). The traditional textbook-driven through lecturing teaching process may need to be used to integrate some benefits from technology application. Technology also provides effective STEAM games online or iPads for students to play with each other. Multiple STEAM games online, representing the same learning objectives, may fit into different students' needs. Technology can be a huge resource under play-based pedagogy. Students can choose online games to play for making some math procedure fluency or choose other online games for understanding (for example to google what HCF, why greenhouse gases trap the sun's heat, or to reduce HCF emission). Students with access to technology can feel a great sense of belonging in their learning environment.

Limitation and Further Research

This study presented the research question that the theoretical inquiry-based methods can develop elementary students' reasoning ability. During the whole STEAM curriculum, students frequently use what, why, and how questions to explore knowledge as their reasoning ability evidence. Students' critical thinking skills and performance in this study is limited by the four indicators and three open-ended questions (see Appendix A). Further research may develop students' reasoning ability performance based on different critical thinking skills in STEAM curriculum.

Inquiry-based methods play as a theoretical framework to implement in STEAM curriculum. The play-based pedagogy performed very well to motivate students' self-learning attitude in the real-life learning environment. It showed the transformation from theorical to practical methods works very well, especially under clinical teacher preparation program. The study also showed teacher candidates receive benefits from implement what they learn in the program, and they can implement what they learn into other methods. For the further research, the inquiry-based methods may be implemented in different subject matters designed by student-centered curriculum.

Appendix A

Consideration of Students' Reasoning Ability

A. **<u>Response Format/ Disagree-Agree</u>**: Please read each item carefully and record your degree of agreement or disagreement with the statement. Do this by circling either 1, 2, 3, 4, or 5 in the space provided, as follows:

1=Disagree; 2=Tend to Disagree; 3=Neutral; 4=Tend to Agree; 5=Strongly Agree
(Leave items blank if you have no opinion.)

B. **<u>Response Format/ Written</u>**: At the end of the survey, you will find a few short-answer items. It will be a great help to the project if you write a short paragraph in response [to them], without consulting outside sources. We want to know about your thinking right now.

C. **Circle**: Please circle the order of this questionnaire administration

FIRST TIME SECOND TIME

D. **<u>Agree-disagree items.</u>**

No.	**Survey questions**	**Disagree-Agree Choices** **1 Disagree,** **2 Tend to Disagree,** **3 Neutral,** **4 Tend to Agree** **5 Strongly Agree**				
1	I can use my own words to describe what global warming is and how greenhouse gases (HCFs) trap the sun's heat.	1	2	3	4	5
2	I can justify evidence to explain global warming under natural factors or human factors.	1	2	3	4	5
3	I can examine the city data report and decide which parts need to reduce their HCFs emission.	1	2	3	4	5
4	I can explore effective strategies through information online to reduce HCFs emission in the city.	1	2	3	4	5
5	I can write a persuasive letter to our mayor persuade him by using scientific reasoning.	1	2	3	4	5

E. Very Short Answer Items.

1. Please share an example of how you justify a scientific reasonings to agree with a hypothesis you made in any science lessons—especially in terms of making a hypothesis and how you accept or deny the hypothesis (e.g., a statement like "Climate change is affected by human beings releasing to much carbon dioxide" and you may share your reasoning by writing "I agree with this statement because …").

2. You may know we use five Es in our STEAM lessons. Please provide a short paragraph about how you use "*what*", "*why*", and "*how*", in your critical thinking section to make a justification of your reasonings in your science lessons.
3. Please provide a short description of how **you** feel about the inquiry-based learning environment and integrate STEAM subjects together in your science lessons.

References

Abramovich, S., Easton, J., & Hayes, V. (2012). Parallel structures of computer-assisted signature pedagogy: The case of integrated spreadsheets. *Computers in the Schools. 29*(1-2),174-190. https://doi.org/10.1080/07380569.2012.651425

Aguilera, D. & Ortiz-Revilla, J. (2021). STEM vs. STEAM education and student creativity: A systematic literature review. *Education Sciences, 11*(7), 331. https://doi.org/10.3390/educsci11070331

Berland, L. K. & McNeill, K. L. (2010). A learning progression for scientific argumentation: Understanding student work and designing supportive instructional contexts. *Science Education*, *94*(5), 765-793. https://doi.org/10.1002/sce.20402

Cabello, V., Moreira, P., & Griñó Morales, P. (2021). Elementary students' reasoning in drawn explanations based on a scientific theory. *Education Sciences, 11*(10), 1-19. https://doi.org/10.3390/educsci11100581

Conradty, C. & Bogner, F. (2018). From STEM to STEAM: How to monitor creativity. *Creativity Research Journal, 30*(3), 233-240. https://doi.org/10.1080/10400419.2018.1488195

Darmayanti, R., Sugianto, R., & Muhammad, Y. (2022). Analysis of students' adaptive reasoning ability in solving HOTS problems arithmetic sequences and series in terms of learning style. *Numerical: Jurnal Matematika Dan Pendidikan Matematika*, *6*(1), 73–90. https://doi.org/10.25217/numerical.v6i1.2340

Duran L. & Duran, E. (2004). The 5E instructional model: A learning cycle approach for inquiry-based science teaching. *The Science Education Review, 3*(2), 49-58. https://files.eric.ed.gov/fulltext/EJ1058007.pdf

Elliott, V. (2018). Thinking about the coding process in qualitative data analysis. *The Qualitative Report, 23*(11), 2850-2861. https://doi.org/10.46743/2160-3715/2018.3560

Gunter, M., Estes, T. & Mintz, S (2011). *Instruction: A models Approach*. (7^{th} ed.). Pearson.

Huo, L., Zhan, Z., Mai, Z., Yao, X., Zheng, Y. (2020). A case study on C-STEAM Education: Investigating the effects of students' STEAM literacy and cultural inheritance literacy. In Lee, LK., U, L.H., Wang, F.L., Cheung, S.K.S., Au, O., Li, K.C. (Eds) Technology in Education. Innovations for Online Teaching and Learning. ICTE 2020. Communications in Computer and Information Science, vol 1302. Springer, Singapore. https://doi.org/10.1007/978-981-33-4594-2_1

Kang, H., & Kim, T. (2014). The development of the STEAM project learning program for creative problem-solving of the science gifted in elementary school. Journal of Gifted/Talented Education, 24, 1025–1038.

Karpudewan, M., Roth, W., Abdullah, M. (2015). Enhancing primary school students' knowledge about global warming and environmental attitude using climate change activities. *International Journal of Science Education, 37*(1), 31-54. https://doi.org/10.1080/09500693.2014.958600

Khalif, B. & & Mohammed Zin, Z. (2018). Traditional and inquiry-based learning pedagogy: A systematic critical review. *International Journal of Instruction, 11*(4), 545-564. https://doi.org/10.12973/iji.2018.11434a

Lo, H. & Hoover, J. (2022). Investigating formative strategies to support differentiation via digital technology in elementary math classes. *Proceedings of the European Conference on Education, London, UK.* https://papers.iafor.org/submission63632/

Mark, S., Lee, C., ; & Azmani, P. (2021). Growing capacity in gifted and talented education through science, technology, engineering, arts, and mathematics (STEAM). *Kentucky Teacher Education Journal: The Journal of the Teacher Education Division of the Kentucky Council for Exceptional Children*, *8*(1), Article 3. https://digitalcommons.murraystate.edu/ktej/vol8/iss1/3

Michael, B., Tammy, L. & Johna, F. (2010). The NCTM process standards and the five Es of science: Connecting math and science: math and learning processes. *School Science and Mathematics*, *110*(5), 262-276. https://doi.org/10.1111/j.1949-8594.2010.00033.x

Paterson, A. (2020). The play paradox: A systematic literature review of play-based pedagogy applied in the classroom. *Educational & Child Psychology*, *37*(4), 96-114 Dec 2020.

Pyle, A. & Danniels, E. (2017). A Continuum of play-based learning: The role of the teacher in play-based pedagogy and the fear of hijacking play. *Early Education and Development, 28*(3), 274-289. https://doi.org/10.1080/10409289.2016.1220771

Putnam, R. T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher, 29* (1), 4-16. https://doi.org/10.3102/0013189X029001004

Reinhardt, K., Pobertson, P., & Johnson, R. (2021). Connecting inquiry and universal design for learning (UDL) to teacher candidates' emerging practice: Development of a signature pedagogy. *Education Action Research, 31*(3), 437-454. https://doi.org/10.1080/09650792.2021.1978303

Shulman, L. (2005). Signature pedagogies in the professions. *Daedalus,134*(3). 52-59. https://www.jstor.org/stable/20027998

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14. https://www.jstor.org/stable/1175860?origin=JSTOR-pdf

Tan, C. (2019). A signature pedagogy for initial teacher education in singapore. *The New Educator*, *15*(3), 226-245. https://doi.org/10.1080/1547688X.2019.1626670

Thunberg, H. M., Salmi, H. S. & Bogner, F. X. (2018). How creativity, autonomy and visual reasoning contribute to cognitive learning in a STEAM hands-on inquiry-based math module. *Thinking Skills and Creativity*, *29*, 153-160. https://doi.org/10.1016/j.tsc.2018.07.003

Vlassi, M. & Karaliota, A. (2013). The comparison between guided Inquiry and traditional teaching method: A case study for the teaching of the structure of matter to 8th Grade greek students. *Procedia – Social and Behavioral Sciences*, *93*(21), 494-497. https://doi.org/10.1016/j.sbspro.2013.09.226

Zulkiplil, Z., Yusof M., Ibrahim, N., & Dalim, S. (2020). Identifying scientific reasoning skills of science education students. *Asian Journal of University Education 16*(3), 275-280.