Argument Mapping Method and Learners' Critical Thinking Dispositions in Physics

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Abstract

Argument mapping, which includes arguments or premises and contentions, presents ideas in a verbal-diagrammatical representation through boxes and arrows. This quasi-experimental study was conducted to determine the effect of argument mapping teaching method to the critical thinking dispositions of learners in Physics. The study participants were learners from a public high school in the Philippines for the School Year 2020-2021. The Critical Thinking Dispositions (CTD) of learners in Physics were determined using a researcher-made CTD Inventory. The Self-Learning Modules (SLMs) in Science 10 containing seven (7) SLMs implemented for seven (7) weeks for both groups containing the Most Essential Learning Competencies (MELCs) for Grade 10 learners as prescribed by the DepEd for the second quarter was used for the controlled group. The same SLMs were used in teaching the experimental group, which some parts have been modified to embed argument mapping activities. Pretest revealed that both groups have the same level of CTDs before implementing the intervention. However, posttest revealed that the CTDs of the learners exposed to Argument Mapping (AM) method of teaching group is significantly higher than that of the learners in the non-AM method of teaching group. The argument mapping teaching method had a positive effect on the critical thinking dispositions of learners. The researcher recommends that learners be exposed to activities requiring them to use their critical thinking, be given opportunities to collaborative works and communicate their ideas, and further studies be conducted to develop better instruments to measure the critical thinking dispositions of learners.

Keywords: Critical thinking dispositions, argument mapping, self-learning modules, quasi-experimental design

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INTRODUCTION

Critical thinking is becoming increasingly important in educational systems around the world (Enciso, Enciso, & Daza, 2017). It consists of a set of skills and dispositions that increases the likelihood of producing a logical solution to a problem or a valid conclusion to an argument (Dwyer, 2019). Dispositions, the habit of the mind or frame of mind that is necessary for exercising critical thinking, are not "arguments or judgements, but are affective states which include attitudes and a sense of psychological readiness of the human being to be critical" (Davies & Barnett, 2015). To use their critical thinking skills, students need the appropriate critical thinking dispositions (CTDs) (Bell & Loon, 2015; Davies & Barnett, 2015). If a student is to think critically, then it is a necessity to "utilize the dispositional aspect as a precondition for critical thinking which immensely influence critical thinking capability (Ghadi, Bakar, & Njie, 2015). In 2019, the National Achievement Test of the Department of Education revealed poor academic performance of students which was affirmed as PISA revealed close results (Department of Education, 2019; Malipot, 2019; Calderon, 2014). Moreover, results of the annually conducted competency-based local assessment in the public schools showed low achievement, which is in consonance with national and international achievement test results. The reports on low achievement is consistent in national and local scenarios even though critical thinking (CT) skill is embedded in the curriculum (DepEd Press Releases, 2018). This is because critical thinking dispositions may not have been reinforced or even practiced which may hinder the effective use in critical thinking (Bell & Loon, 2015). Critical thinking dispositions should be developed along with the skills since higher dispositions are likely to result in meaningful critical thinking that leads to problem solving, solutions, and decision-making (Irani, et. al., 2007 cited in Ghadi, et al., 2015).

Literature reviews show that few studies focused on CT dispositions, and there are very few strategies on enhancing them (Rauscher & Badenhorst, 2021; Redhana & Wahyuni, 2021; van Rensburg & Rauscher, 2021; Sulaiman, 2018). Popularly problem-based learning and inquiry-based learning were the strategies that provided effects to CTDs of students, yet the use of argument mapping (AM) in relation to CTDs is less utilized. This research, seeing the less utilization of argument mapping as a potential tool in fostering critical thinking dispositions, acknowledge a research gap Miles (2017) referred to as knowledge gap. Knowledge gap in research arises when the desired research findings do not or rarely exists. Argument mapping is a learning tool

that provides logically organized and structured argument, directed chains of propositions, which is made simpler and explicit using 'box-and-arrow' style (Dwyer, 2018). Furthermore, AMs helps one to organize and navigate around complex information, clarify reasoning, communicate quickly and effectively, and support critical thinking which may lead to improved critical thinking effects on learners (Dwyer, Morgan, & Stewart, 2012). Likewise, AMs can provide educators with valuable insights into a student's mental model of the argument in question (Butchart et al, 2009) which may be used to support teachers in offering feedback to students or scaffolding student learning from simple to complex levels or argument comprehension, analysis, and evaluation (Dwyer et al, 2012).

This quasi-experimental study determined the influence of argument mapping to the critical thinking dispositions of public high school students in the Philippines. Specifically, this study sought to answer the following questions: (1) What is the pretest and posttest Critical Thinking Skills and Dispositions of the learners taught using Argument Mapping and Non-Argument Mapping method? (2) What are the main gain scores in the learners' Critical Thinking Skills and Dispositions taught using Argument Mapping and Non-Argument Mapping method? (3) Is there a significant difference between the pre-test and post-test Critical Thinking Skills and Dispositions of learners taught using argument mapping and non-argument mapping method? (4) Is there a significant difference in the mean gain scores of Critical Thinking Skills and Dispositions of learners taught using argument mapping and non-argument mapping method?

This study may help teachers in creating activities that allows learner to use their CTDs, and on the process learners are given opportunity to enhance their CTDs. Moreover, curriculum makers may use the results of this study to design programs in the curriculum that promotes the use of CTDs. Other researchers may conduct further researches using this results and may develop better tools to describe CTDs.

METHODS

Research Design

This study utilized the quasi-experimental pre-test- post-test design. A quasi-experimental design is suited for studies that intends to measure the effect of an intervention in the absence of randomization (Miller, Smith, & Pugatch, 2020). This designs utilizes the already existing intact groups – control group that is close to the treatment group as possible in terms of pre-intervention characteristics, implying that it lacks randomization (White & Sabarwal, 2014). The participants in this study are two intact groups which cannot be randomized to form new groups, instead, only group assignments as to controlled and experimental groups were randomized using toss-coin method. Participants and Sampling.

Participants and Sampling

The participants of the study were the high school students in a public school in the Philippines. Since intact groups were used, pairwise matching was employed to ensure that the participants in both groups are equal. The outputs of learners without matches were still retrieved and recorded; however, they were not included in the research data and analysis. Matching was used based on the following criteria: (1) sex, (2) final grade in Science on the previous school year, and (3) first quarter grade on the current school year. Out of fifty (50) and forty-nine (49) Grade 10 students in each respective section in a public high school in the Philippines, only twenty-eight (28) matched pairs surfaced who were included in the study. Toss-coin method was used for the random assignment for the experimental group and the control group.

The implementation of the study was seven (7) weeks with the use of Self-Learning Modules (SLMs) for Grade 10 Science under the offline-print distance modality of learning. The SLMs distribution and retrieval is every two weeks.

Instrument

To gather the data needed in this study, the Critical Thinking Disposition Inventory (CTDI) and Argument Mapping (AM)-Embedded Self-Learning Modules (SLMs) were utilized.

Critical Thinking Disposition Inventory. The 77-item researcher-made Critical Thinking Disposition Inventory used was based on the CTDs

identified and described in the American Philosophical Association Delphi Report (Facione, 1990), the 12 Important Dispositions for Critical Thinking (Dwyer, 2019), and the California Critical Thinking Dispositions Inventory (The California Academic Press, 2016). The instrument measured the participants' dispositions through the use of a 5-point Likert scale where they may choose one from the agree - disagree continuum as follows: (5) strongly agree, (4) agree, (3) uncertain, (2) disagree, and (1) strongly disagree to indicate how closely each statement on critical thinking dispositions describes them with (5) describing tendency to very strong critical thinking disposition and (1) as the lowest tendency to CTD. The reliability test was administered to fifty-three (53) Grade 11 online STEM which yielded an alpha α of 0.904. This value indicates a very good level of reliability. The mean scores, verbal interpretations, and description are shown in the table below.

Table 1. Mean Scores, Verbal Interpretation, and Description of CTDs of Learners in Physics

Mean Scores	Verbal Interpretation	Description
4.51 – 5.00	Very Strong CTD	The learner shows a very strong CTD, an indication of strength in CTD
3.51– 4.50	Strong CTD	The learner shows a strong CTD, an indication of a positive inclination in CTD
2.51 – 3.50	Ambivalent CTD	The learner shows an ambivalent CTD, an indication of uncertainties towards CTD
1.51 – 2.50	Weak CTD	The learner shows a weak CTD, an indication of a negative tendency towards or unlikelihood to possess CTD unlikelihood to possess CTD
1.0 – 1.50	Very weak	CTD The learner shows a very weak CTD, an indication of a strong negative tendency towards or strong

Argument Mapping-Embedded Self-Learning Modules. The seven (7) Self-Learning Modules (SLMs) used in this study were from the Department of Education and included the Most Essential Learning Competencies (MELCs) prescribed for Grade 10 Science intended for the duration of the Second Quarter. These 7 SLMs were modified to embed argument mapping activities; however, the structure, the content and the competencies were retained. The researcher transformed the identified activities and tasks to argument map construction. The AM activities replaced specific activities in specific lessons wherever appropriate. There were a total of sixty-seven (67) AM activities in the whole duration of the implementation of this study.

Data Collection

Prior to the start of the 2nd Quarter, all learners were given pretest using the CTDI to determine their CTDs in Physics. All received Self-Learning Modules on weekly basis as scheduled by the school for the duration of the whole quarter. In the randomly assigned controlled group (section), learners received the regular Science 10 Self-Learning Modules while all learners in the experimental group (section) received the AM-embedded Self-Learning Modules. In AM-embedded SLMs, a scoring rubric is used for the specification of the criteria for scoring the output. All responses were recorded; however, only the outputs of those with matched pairs were included and analyzed for this study. A post-test using the same CTDI was given to all learners at the end of the quarter.

Data Analysis

The statistical techniques used in the analyses of data were mean, standard deviation, mean gain, and t-test for related and independent samples. All significance levels were set to alpha of 0.05. Statistical data were analyzed with the aid of SPSS.

Ethical Considerations

Research tools/instruments were subjected to structure and content validation by identified experts in the field. Learners and parents were properly oriented with regards to their participation to the study. Also, proper communications were done prior to the implementation of the study. Moreover, participants and data collected were treated confidentiality. Lastly, results were communicated to the school were the study was conducted so that it may be utilized as baseline data in conducting parallel activities related to this study.

RESULTS

Pretest and Posttest Scores in Critical Thinking Dispositions in Physics of the Learners. The CTD in Physics pretest mean scores results as measured by the researcher-made Critical Thinking Dispositions Inventory (CTDI) for both groups revealed "ambivalent critical thinking dispositions", indicating that the participants have uncertainties towards CTDs and that they are not inclined to using CTDs. This also means that both groups have the same level of CTDs prior to implementation of the intervention. After the seven-week treatment period, showed both groups had an increase in mean scores in CTDs. Further, posttest results revealed that the argument mapping

method of teaching group have a "very strong CTD", an indication of the strength in CTDs while the non-argument mapping method of teaching group revealed "strong CTDs", indicating the learners' positive inclination in CTDs. Table 2 below shows the data on the pretest and posttest scores in CTDs in Physics of the learners taught using argument mapping and non-argument mapping method.

Table 2. Pretest and Posttest Mean Scores in Critical Thinking Dispositions in Physics of the Learners.

Grouping	Variable	N	SD	M	Descriptive Rating
Argument Mapping Method of Teaching	Pretest Result - CTDs	28	.53	3.49	Ambivalent CTD
	Posttest Result - CTDs	28	0.10	4.70	Very strong CTD
Non-Argument Mapping Method of Teaching	Pretest Result - CTDs	28	.51	3.47	Ambivalent CTD
	Posttest Result - CTDs	28	0.53	3.91	Strong CTD

Mean Gain Scores (Pretest-Posttest Scores Difference) in the Learners' Critical Thinking Dispositions in Physics

The mean gain of the learners in the AM method of teaching group was higher than that of the learners in the Non-AM method of teaching group. This means that the increase of mean scores in CTDs in the AM method of teaching group was higher than that of the non-AM method of teaching group. Below is the table showing the mean gain scores between the two groups.

Table 3. Mean Gain Scores in CTDI of Learners

Group	N	M		SD	Mean Gain
		Pretest	Posttest		
Argument Mapping Method of Teaching Group	28	3.49	4.70	0.55	1.21
Non- Argument Mapping Method of Teaching Group	28	3.47	3.90	0.70	0.43

Difference in the Posttest Scores between the Learners Taught Using Argument Mapping and Non-Argument Mapping Method of Teaching

The t-test for independent samples revealed that a significant difference exists between the posttest scores in CTDI of the learners in two groups with $t(54)=7.84$, $p=0.00$ favoring the AM method of teaching group. This shows that the CTDs in Physics of the learners in the AM method of teaching group is significantly higher than that of the non-AM method of teaching group

which may be attributed to the intervention implemented. Consequently, argument mapping method may have positively affected CTDs implying that argument mapping may be used in classroom teaching to enhance the critical thinking dispositions of learners. Below is Table 4 showing the t-test for independent samples for the posttest results of CTDs of the learners in Physics.

Table 4. *t-test* for Independent Samples for the Posttest Results of CTDs of the Learners in Physics

Variable	Group	Mean	Mean Difference	95% Confidence Interval of the Difference		t value	df	Sig (2 tailed)
				Lower	Upper			
Posttest in CTDs	AM	4.70	0.8	0.59	1.00	7.84*	54	0.000
	Non-AM	3.90						

*Note: *p <0.05*

Difference Between the Pretest and Posttest Scores in Critical Thinking Dispositions in Physics of Learners Taught using Argument Mapping Method of Teaching

The t-test for paired samples showed a significant difference between the pretest and posttest mean scores in the CTDs in Physics of learners in both groups. In the argument mapping of teaching group, the significant increase of mean scores in CTDs from pretest to posttest, ($t(27)=11.61$, $p=0.000$) may be attributed to exposure of the learners to argument mapping activities which may have caused them to have higher critical thinking dispositions in Physics. Moreover, significant increase of mean scores in CTDs ($t(27)=3.25$, $p=0.003$) from pretest to posttest of the learners in the non-argument mapping of teaching group may be due to the features of the SLMs and the maturation of learners. This implies that argument mapping may be a better strategy to enhance the critical thinking dispositions of learners. The t-test for paired samples showing the significant differences in the pretest and posttest CTDs of learners in Physics is described in the table below.

Table 5. *t-test* for Paired Samples Showing the Significant Differences in the Pretest and Posttest CTDs of Learners in Physics

Group	Variable	Mean Scores	Mean Difference	95% Confidence Interval of the Difference		t value	df	Sig (2 tailed)
				Lower	Upper			
Argument Mapping Group	Pretest	3.49	1.21	1.00	1.43	11.605*	54	0.000
	Posttest	4.70						
Argument Mapping Group	Pretest	3.47	0.44	0.16	0.70	3.251*		0.003
	Posttest	3.91						

*Note: *p <0.05*

Difference in the mean gain scores in Critical Thinking Dispositions in Physics of Learners

The mean gain difference between the two groups was significant (t(54)=4.63, p=0.00) which means that the increase in the mean scores of the learners in the argument mapping method of teaching group was significantly higher than that of the non-argument mapping method of teaching group. This implies that the use argument mapping may have caused the learners in the controlled group to frequently use their critical thinking dispositions; hence, the increase in CTDs. Further, Cohen's d suggested that argument mapping method of teaching had a large effect on the CTDs in Physics of learners. It can be implied that regardless of the group size, argument mapping had a positive effect to the critical thinking dispositions of learners in the controlled group.

Table 6. *t-test* for Independent Samples for the Pretest and Posttest Results of CTDs of Learners

Group	Mean Gain	95% Confidence Interval of the Difference		t value	df	Sig (2 tailed)	Cohen's d
		Lower	Upper				
AM method of teaching group	1.21	0.44	1.12	4.63**	54	0.000	1.24
Non AM method of teaching group	0.43						

*Note: *p <0.05*

DISCUSSION

The pretest CTD in Physics of learners taught using argument mapping method of teaching revealed an "ambivalent CTDs" signifying that they had uncertainties towards CTDs. While posttest results revealed "very strong CTDs" which indicated the learners' strength in CTDs. This means that these learners were able to use their critical thinking dispositions. The same CTDI was also administered as pretest in the controlled group which showed an "ambivalent CTDs". This indicates that they have uncertainties towards CTDs and may imply they are not inclined to using critical thinking dispositions. For the posttest, "strong CTDs" was found indicating the learners' positive inclination in dispositions. Looking into literature, Palavan (2020) reported that the CTDS of learners have increased from pretest to posttest after exposing them to argument mapping activities. Similarly, Temel (2014) reported an increase in the scores from pretest to posttest for the critical thinking dispositions of tertiary students after giving them problem-based learning sessions.

The mean gain of the learners in the AM Group was higher than that of the Non-AM Group. It indicates that the increase of mean scores from pretest to posttest CTDs in the AM group was higher than the increase of means scores from pretest to posttest CTDs in the non-AM group. This result was affirmed by Abrami et al., (2015) wherein they cited argument mapping as one of the effective strategies for teaching CT skills and dispositions at all educational levels and across all disciplinary areas. Mamood (2016) also suggested that argument mapping facilitate in visualizing thinking, increasing interest, building opportunities for collaboration and group work and learning to build 'valid and credible' arguments". Likewise, argument mapping-infused critical thinking instruction caused a significant increase in the learners' reflective judgement performance (Dwyer, Hogan, & Stewart, 2015). In a study of comprehension and memory, it was found that student who studied argument maps scored higher than those who studied using text (Dwyer, Hogan, & Stewart, 2010).

Further, the critical thinking dispositions of the learners in both groups were the same – equal or comparable - prior to the implementation of the intervention. Luele (2018) reported that no significant difference was found in the pretest scores in critical thinking dispositions of college students in a university prior to the introduction of problem-based English writing. Dwyer et al., (2012) affirmed a non-significant difference between AM and non-AM groups, implying an "adequately matched CT ability" prior to the

AM intervention. Similarly, Yu, Zhang, Xu, Wu,& Wang (2013) reported comparable pretest scores in critical thinking dispositions between problem-based learning and lecture-based learning groups prior to the implementation of intervention.

A significant difference exists between the posttest scores in CTDI of the learners in the AM and Non-AM groups favoring the AM group. This shows that the critical thinking dispositions in Physics of the learners in the AM group were significantly higher than that of the non-AM group. This increase may be attributed to argument mapping method which positively affected the CTDs. This is in congruence with the results of Dwyer, Hogan, & Stewart (2011) whose report suggested that critical thinking can be potentially enhanced though AM training. Further, on two studies conducted among nursing students, critical thinking dispositions was found to be significantly enhanced by problem-based learning (Yu et al., 2013; Naber & Wyath, 2014), yet reflective writing interventions was emphasized (Naber & Wyath, 2014).

Moreover, a significant difference exists between the pretest and posttest mean scores in the critical thinking dispositions in Physics of learners in the argument mapping group indicating that the increase of mean scores from pretest to post test is significant. Argument mapping may have caused the learners to have higher critical thinking dispositions in Physics. In agreement to this results, Karami, Pakmehr, & Aghili (2012) reported a significant increase in posttest in the critical thinking dispositions of high school students after implementing the collaborative learning method. Likewise, Butchart et al., (2009) reported a significant increase of mean scores from pretest to posttest in critical thinking skills after exposing the students in a course of argument mapping exercises for a semester. Further, critical thinking disposition was also found to significantly increase from pretest to posttest when students were exposed to problem-based English writing instruction (Luele, 2018). Collaborations and discussions during collaborative classroom activities promote students' opportunities to express themselves, engage into discussions and to think critically.

Going further, a significant difference exists between the pretest and posttest mean scores in the critical thinking dispositions in Physics of learners in the non-argument mapping group surfaced. The results mean that the increase in the mean scores in critical thinking dispositions in Physics of the learners in the non-argument mapping group was significant. This may mean that the non-argument mapping method of teaching employed to this group could have caused the learners to show a positive increase in their critical

thinking dispositions in Physics. This can be accounted to the maturity of the learners and the potential of the existing learning materials to make the learners use the dispositional aspect of critical thinking.

Lastly, the mean gain difference between the two groups was significant implying that the increase in the mean scores of the learners in the argument mapping was significantly higher than that of the non-argument mapping. Similarly, Dwyer, et al. (2012) reported that the critical thinking of the students in the AM group had a significantly higher mean score gain from pretest to posttest than those in the control group and that participation in the course taught through AM significantly enhanced critical thinking performance. A qualitative study on integrating argument-based science inquiry with argument mapping in Physics also suggested the potential of argument mapping in promoting students critical thinking (Nurudin, n.d.).

This study is only limited to the responses of Grade 10 learners in a school in Capiz in the Philippines. The exposure to argument mapping method was limited to only one grading period (8 weeks) through modification of the self-learning modules used by the learners in a distance learning modality.

CONCLUSION

Argument mapping method of teaching seemed to have a positive effect to the critical thinking dispositions of learners in Physics. Also, argument mapping method of teaching may be used to increase the CTDS of learners. Using argument mapping method in the classroom may give the learners the opportunity to communicate and express their ideas in working collaboratively with their peers, encouraging them to use critical thinking as they justify the argument maps they construct.

Learners may be exposed to argument mapping activities and other similar activities requiring them to use their critical thinking dispositions, and be given opportunities to collaborative works and communicate their ideas. Likewise, further studies may be conducted to develop better instruments to measure the critical thinking dispositions of learners.

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Conflict of Interest

No conflict of interests is declared by the researcher.

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