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How Close Are Teachers to Think in a Scientific Manner?

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Abstract: Lately, The Ministry of National Education (Turkey) has announced '2023 Education Vision' for raising qualified generations equipped with a variety of skills and for meeting the needs of educators. Students, families, teachers and schools are four primary elements of the report. Especially upskilling teachers who appeal future generations and evaluating their skills are often referred in the report. In this regard, the present survey study aimed to determine and compare scientific thinking skills of teachers in accordance with their working experiences. Sampling of the study comprised of 62 teachers working in schools of Aegean region of Turkey from a variety of disciplines such as mathematics, science, and information technologies, and of working experiences from 1 to 28 years. Data of the study are gathered through sequential inquiry-based activity sheets administered simultaneously with the implementation of inquiry-based activities regarding electromagnetism. Findings of the study revealed that teachers had irrational and intuitive levels of thinking skills at the beginning and they could improve their level of thinking through activities and approached to think more in a scientific manner. However, this improvement differed as working experience changes. Novice teachers who have working career for less than 2 years could not show statistically significant improvement in their statements, in contrast, well-experienced teachers showed statistically significant increase in their scientific thinking scores. They could record their predictions and explanations consistently by considering variables, and evidence-data, they could make observations in an objective way which are the analyzing criteria determined by considering the literature. With the light of the findings, it is argued that especially novice teachers need support to improve their abilities and that they could be encouraged in a longer period with such inquiry-based activities fostering their thinking skills which eventually result in having scientific thinking generations as intended in 2023 education vision.

Keywords: Scientific thinking, Teacher experience, Evaluation, 2023 Education vision

Introduction

Attempts of understanding how an individual learns, proceeds the knowledge, decides on thinking pathways have been matter of interest amongst well known psychologists such as Piaget and Vygotsky who still enlighten today's research. This endeavor seems to remain on agenda with the increasing needs of improving education standards. Emphasis of meeting desired standards are widely discussed across the world, both in reports of National Research Council [NRC], and of Organization for Economic Co-operation and Development [OECD].

In a national point of view, Ministry of National Education [MoNE] of Turkey similarly dwells on addressing those standards to keep in pace with the fast-developing world. Lately, MoNE has announced '2023 Education Vision' for raising qualified generations equipped with a variety of skills and for meeting the needs of educators. Turkey's results in Programme for International Student Assessment [PISA] tests and the latest OECD (2019) report highlight the importance of taking steps for improving the qualities of education. In the 2023 Education Vision Report, students, families, teachers and schools are presented as the four primary elements. The interrelatedness of those elements is underlined because of the fact that they all directly affect teaching and learning processes. Especially upskilling teachers who appeal future generations and evaluating their skills are often referred in the report. Providing well qualified pre-service and in-service education for

teachers is stated to help fostering their teaching performance and thus students' academic development.

Skill acquisition these days come before solely memorizing of textbook information without any reasoning processes. It is believed by many researchers that skills are required to help an individual to see the meaning and worth of learning, and to reach full understanding of concepts. Scientific thinking skills which shaped existence and survival of many nations up till now is one of the thinking skills that are tried to be understood, improved and evaluated. The importance of the term 'scientific thinking skills' may not seem to be discussed as much as current focus on robotics and coding skills, or engineering and design skills addressed in STEM education, however, it forms a basis for those skill groups with regard to problem solving.

Societies needed to think scientifically even for hunting and gathering (Carruthers, 2002), making predictions and observations to raise and save their food, and maintaining welfare of their selves. 5 years lasting Halys Battle (28 th May 585 BCE) may be given as an instance regarding two scenarios in absence and presence of scientific thinking. The Halys Battle known as Battle of the Eclipse occurred around Halys River (Kızılırmak River of Anatolia). Battle between the Lydians and the Medes coincide with a solar eclipse according to Herodotus' recordings. 'The day was turned to night.' says, Herodotus and once seeing the sudden night sky, people quitted the battle because of thinking that gods were sending a message (Stephenson & Fatoohi, 1997). Thales of Miletos however, by doing accurate scientific observations and inferences, could predict the event and warned his people before it happens by pointing out that it is a natural phenomenon and there is nothing to be afraid of. This instance addresses the potential of scientific thinking on shaping the survival of communities.

Considering the related research on the literature, researchers compromised on the fact that scientific thinking skills are needed to be improved and fostered even today to help individuals solve daily life problems encountered, ask further questions, inquire, consider important factors and variables, explain concepts in a meaningful way, and reach the scientific knowledge and conclusions. Teachers take an important place in teaching-learning processes in which they help students learn and comprehend new concepts, relate new concepts with the pre-conceptions, use data and evidence to explain scientific phenomena, consider variables, in short; think in a scientific manner. In addition, related findings of the literature indicate that teachers, especially novice teachers either do not possess or cannot efficiently use their thinking skills and it mostly depends on working experience (e.g. Borko & Livingston, 1989; Darling-Hammond & Schlan, 1996; Fantilli & McDougall, 2009; Haynes, 2011; Karataş & Karaman, 2013; Kim & Roth, 2011; Mirzaei Phang & Kashefi, 2014; Zimmerman 2017). For instance, Mirzaei, Phang and Kashefi (2014) compared expert and novice teachers' levels of reflective thinking through the use of questionnaires. Mirzaei et al. (2014) emphasize the differences of levels of reflective thinking between novice and expert teachers and they determined which reflective thinking skills do they have and use such as observation, social communication and cooperation. By pointing out the weaknesses of novice teachers' reflective thinking processes, researchers suggest tools for the purpose of improving inadequacy of thinking skills.

To this end, especially novice teachers having two or less years of working experience need to be supported for being well-equipped with scientific thinking skills (Windschitl 2003; Zimmerman, 2017). Findings of the literature also suggests that the pre-service teachers are not very different from those teachers in terms of their lacking of adequate thinking skills (As' ari, Mahmudi & Nuerlaelah, 2017), thus, they also need such support (pre-service education and master's programs) before they start to appeal students.

Method

Research Design and Sample Group

The present study has cross-sectional survey design with the aim of determining and comparing novice and expert teachers' level of thinking skills. Sample group of the study is comprised of 62 teachers from variety of disciplines such as mathematics, science, primary school, information technologies, et cetera (see detailed information regarding the sample group in Table 1). Teachers working in schools of Aegean region of Turkey had working experiences varying from 1 to 28 years. Participants' experience levels are determined in such a way that teachers having two or less years of working experiences have been labelled as novice, and participants having more than two years of working experiences are accepted as experts (Haynes, 2011). Convenience sampling method is used for selection of participants because of their being easily accessible by the researchers.

Table 1. Frequencies concerning gender, disciplines and working experiences of the teachers

		Frequency (f)	Percentage (%)
Gender	Female	37	59.68
	Male	25	40.32
	Total	62	
Discipline	Science	31	50.00
	Mathematics	16	25.82
	Technology and Design	4	6.45
	Information Technologies	5	8.06
	Preschool	1	1.61
	Primary School	5	8.06
Working Experience	Novice (0-2 years)	21	33.87
	Expert (2+ years)	41	66.13

Data Collection Procedure

In the present study, it is aimed to determine and compare novice and expert teachers' level of thinking through implementation of sequential inquiry-based activities, data were collected in spring semester of 2018-2019 academic year and it lasted three months. Data were collected through inquiry-based sequential activity sheets designed in accordance with implementation of sequential inquiry-based activities. Participants filled 11 sequential activity sheets simultaneously with the activities. In these activity sheets, sections for participants' noting their predictions, observations, and explanations down are provided. Participants' statements are analyzed and coded with specified criteria.

Data Collection Instrument

Data of the study were gathered through the use of 11 sequential inquiry-based activity sheets on a popular yet not well-known subject, electromagnetism. Activity sheets are designed in such a way that they are administered simultaneously with the sequential inquiry-based activities regarding electromagnetism. The implementation of the sequential inquiry-based activities is also utilized as a 'tool' rather than an intervention. Participants' way of thinking when encountering series of discrepant events on a novice topic is tried to be understood and to be evaluated with specified qualities of thinking.

Sequential Inquiry-Based Activity Sheets

The first 10 activity sheets involved *prediction* section with multiple choices and one open-ended choice to ensure participants' expressing their thinking freely, open-ended *observation* and *explanation* section. They are asked to make scientific predictions before the demonstration of the sequential inquiry-based activities and justify their predictions by stating their reasons. After they state their predictions and justifications, they record their observations and based on their observations, thy try to make interpretations to explain the logic behind the observed phenomena. In the last and 11^{th} activity sheet, a table is provided for students so that they record and consider all their data (observations in our case) in a holistic point of view, and lastly a final interpretation section is provided for participants to let them compare data gathered and make inferences accordingly.

Analysis of Data

Statements on sequential inquiry-based activity sheets are both analyzed individually, focusing on a horizontal development and also intragroup comparisons between novice and expert teachers. For the analyses, SPSS (Statistical Package for Social Sciences) with descriptive statistics and inferential statistics test (Friedman Test) was used. Specified thinking levels are coded and labelled in SPSS as 1,2, and 3. It is mainly investigated whether participants think with variables, support their claims with evidence and data, and whether they justify their explanations in a consistent way. Based-on those requisites, statements of participants were coded under three main headings; *irrational thinking*, *intuitive thinking* and *scientific thinking* with the lights of related research on thinking skills (i.e. Kember et al., 2000; Korthagen, 2001; Perschbach, 2006; Husu Toom &

Partikanien, 2008).

Results and Discussion

In the present study, raised research questions are as follows:

RQ1-) In which way the levels of scientific thinking of teachers' change during inquiry-based activities?

Findings of the study revealed that in overall point of view, teachers had thinking levels between irrational and intuitive thinking at the beginning of encountering discrepant events and different variables of electromagnetism (M = 1.82), and they approached to think scientifically at the end of the activities (M = 2.10), and they had mean scientific thinking score of M = 1.94, SD = .299 (See Figure 1).

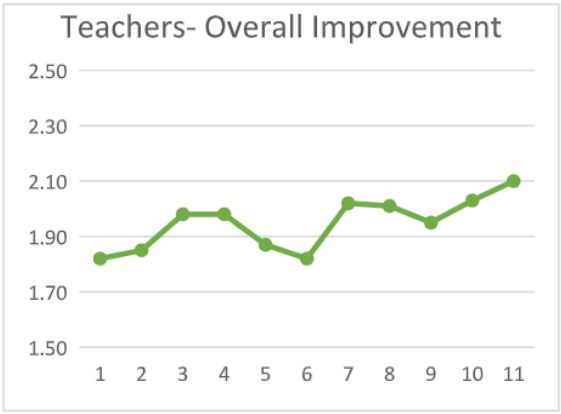

Figure 1. Overall improvement of teachers in their thinking skills

RQ2-) Is there any statistical difference of scientific thinking levels of participants (novice and expert teachers) in their predictions, observations and explanations through sequential inquiry-based activities?

Teachers showed statistically significant difference in levels of scientific thinking in their predictions through 10 sequential inquiry-based activity sheets $\chi 2$ (9, n = 62) = 578.31, $p < .05$. Inspection of mean values showed an increase in level of scientific thinking from the first activity sheet (M = 1.68) to the 10th activity sheet (M = 2.00), they also showed statistically significant difference in levels of scientific thinking in their observations through 10 sequential inquiry-based activity sheets $\chi 2$ (9, n = 62) = 41.11, $p < .05$. Inspection of mean values showed an increase in level of scientific thinking from the first activity sheet (M = 1.85) to the 10th activity sheet (M = 2.03), teachers also improved their explanations through 11 sequential inquiry-based activity sheets $\chi 2$ (10, n = 62) = 99.37, $p < .05$. Inspection of mean values showed an increase in level of scientific thinking from the first activity sheet (M = 1.98) to the 11th activity sheet (M = 2.10). However, as findings revealed, these improvements depended on the working experiences of the teachers.

In addition to the teachers' overall improvement in their level of thinking (from M = 1.82 to M = 2.10), both novice and expert teachers' thinking improvement on activity sheets is analyzed horizontally with the Friedman Test. Findings revealed that novice teachers could not improve their level of scientific thinking in their predictions $\chi 2$ (10, n = 62) = 7.88, $p > .05$, observations $\chi 2$ (10, n = 62) = 10.00, $p > .05$ and explanations significantly $\chi 2$ (10, n = 62) = 11.89, $p > .05$. However, expert teachers' improvement in level of scientific thinking on prediction ($\chi 2$ (9, n = 62) = 16.66, $p < .05$ and observation ($\chi 2$ (9, n = 62) = 24.01, $p < .05$ were statistically significant, improvement of expert teachers on explanations however, was not found to be statistically significant ($\chi 2$ (10, n = 62) = 17.51, $p > .05$ (See Tables 2, 3 and 4).

Table 2. Improvement in thinking - predictions from the 1st activity sheet to 10th activity sheet

	N	3
	Chi-Square	7.744
	Df	9
	Asymp. Sig.	.560
0-2 years (Novice Teachers)	N	2
	Chi-Square	7.875
	Df	9
	Asymp. Sig.	.547
2+ Years (Expert Teachers)	N	20
	Chi-Square	16.663
	Df	9
	Asymp. Sig.	.054

Table 3. Improvement in thinking - observations from the 1st activity sheet to 10th activity sheet

	N	5
	Chi-Square	10.077
	Df	9
	Asymp. Sig.	.344
0-2 years (Novice Teachers)	N	3
	Chi-Square	10.000
	Df	9
	Asymp. Sig.	.350
2+ Years (Expert Teachers)	N	41
	Chi-Square	24.018
	Df	9
	Asymp. Sig.	.004

Figure 4. Improvement in thinking - explanations from the 1st activity sheet to 11th activity sheet

0-2 years (Novice Teachers)	N	4
	Chi-Square	11.892
	Df	10
	Asymp. Sig.	.292
2+ Years (Expert Teachers)	N	26
	Chi-Square	17.507
	Df	10
	Asymp. Sig.	.064

These data support the findings of related literature that expert teachers perform and improve their selves better on specific tasks when compared to novice teachers having two or less years of working experiences (e.g. Borko & Livingston, 1989; Darling-Hammond & Schlan, 1996; Fantilli & McDougall, 2009; Haynes, 2011; Karataş & Karaman, 2013; Kim & Roth, 2011; Windschitl 2003; Zimmerman, 2017). This finding may be interpreted as an urgent need for improving the pre-service and in-service programs to help novices keep in pace with the new trends in education (Huang, 2015). Consistent with the related research, expert teachers having more years of working experience, are able to modify and improve their thinking in a shorter time to more of a scientific manner. Considering their considerable impact on learning processes, especially for children in younger ages, scientifically thinking teachers are required for the aims and intended standards mentioned in 2023 Education Vision Report.

Last but not least, author, physicist and futurist Michio Kaku in his speech on ISTE 2016, warns people about the digitized future in which development of technology that human power will no longer be needed as much as today's, especially in medicine and engineering areas. However, Kaku underlines the fact that teaching profession does not seem to be disappear although with the improvements on technology, even in underdeveloped countries, people can learn through distant education. The reason of teachers' remaining on the agenda is that learners still will need to be guided and be supported to comprehend concepts, therefore teaching will change its form more into a guidance and facilitator, rather than a transferring of information as Kaku suggests. Considering Kaku's insights into future, the presence of scientific thinking teachers, guides, or facilitators seems to be crucial even more.

Conclusion

In sum, with the light of the findings of the study, it is concluded that:

- Sequential inquiry-based activities helped teachers getting closer to think scientifically.
- Expert teachers who have working experience more than two years showed more consistent improvement through the activities, when compared with novice teachers.
- Novice teachers who have working career for less than 2 years could not show statistically significant improvement in their statements on *prediction, observation and explanation sections*, in contrast, well-experienced teachers showed statistically significant increase in their scientific thinking scores.
- Especially novice teachers need support to improve their abilities and that they could be encouraged in a longer period with such inquiry-based activities fostering their thinking skills.

Future Research

In the future research, it is planned to compare of different participant groups in a longer period of data collection. Further, it is intended to investigate if other groups of skills addressed in the 2023 Education Vision are related with scientific thinking skills.

Recommendations

It is recommended repeating the study into other contexts (other participant groups or other concepts to be covered) in a purpose of increasing the validity of data collection tool.

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