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Making sense of statistical and probabilistic information in the media texts: Pre-service teachers' critical thinking processes

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This study aimed to investigate the critical thinking processes that pre-service middle school mathematics teachers utilize when they intensely engaged with the media text based on statistical and probabilistic information. Data were collected through in-depth interviews with four pre-service middle school mathematics teachers in a public university. The findings of the study pointed out that pre-service middle school mathematics teachers progressed through different critical thinking processes, including comprehending, making connections, inferring ideas, critiquing, and self-reflecting about the information given in the newspaper article.

Keywords: Critical thinking, statistical literacy, media texts.

INTRODUCTION

Probability and statistics are regarded as the domains interrelated with critical thinking, which has a crucial role in scientific and social contexts, especially in newspaper articles. Newspaper articles present statistical results about various social and scientific issues such as health, finance, education, and culture and address these results by using numbers, probabilistic statements, or representing them with graphs or tables. Journalists or researchers, however, may release misleading information or use vague language of probability and statistics. To cope with such misleading information, people should make sense of probability and statistics in these contexts and think critically about them (Gal, 2004; Watson, 2006).

In the school context, most of the students do not have enough knowledge of statistical concepts to interpret media texts and blindly adopt one's one-sided ideas or information without questioning, which could prevent them to make efficient decisions about their life

(Watson, 2006). To help students in this sense, teachers themselves need be able to think critically about such information. However, teachers' lack of knowledge, as well as lack of critical perspectives could be an obstacle in providing such a help to students (Watson, Callingham, & Nathan, 2009). In mathematics teacher education programs, pre-service teachers complete statistics and probability courses. However, such courses do not usually stress critical use of statistical and probabilistic information in the contexts beyond the school. In this sense, this paper reports an investigation of pre-service mathematics teachers' uses of critical thinking processes to make sense of statistical and probabilistic information when they intensely engaged with a media text.

Critical thinking was conceptualized by various researchers (Ennis, 1985; Facione, 1990). Ennis (1985) defined critical thinking as "reflective and reasonable thinking that is focused on deciding what to believe or do" (p. 45) and conceptualized as a combination of certain cognitive skills (e.g., judging the credibility, analyzing arguments, drawing conclusions, or clarifying ideas) and dispositions toward critical thinking (e.g., being disposed to open different alternatives, to be informed, or to search for alternatives). In a further study, Facione (1990) worked on the conceptualization of critical thinking by forty experts in this subject. These experts had a consensus on two dimensions of critical thinking: cognitive skills (interpretation, analysis, evaluation, self-regulation, inference, and explanation) and affective dispositions (truth-seeking, open-minded, analytical, systematic, confident in reasoning, inquisitive, judicious). In the project of Jones and colleagues (1995), the framework proposed by Facione (1990) was reviewed by faculty, employers and policy makers to decide which aspects of critical thinking are more important for college students. The

conceptual frameworks of critical thinking proposed by Facione (1990) and Jones and colleagues (1995) could be applicable to various subject matter domains and contexts (Ten Dam & Volman, 2004). In the current study we made use of their frameworks as a starting point and a baseline in order to identify indicators of critical thinking processes in the data obtained from in-depth interviews through which the participants were intensely working on a media text that involve statistical and probabilistic information. It is important to note that we focused on the cognitive dimension of critical thinking rather than affective dimension in this study. Previous studies pointed out that critical thinking is transferable to different subject matters or contexts. On the other hand, it is a challenge for teachers to enable their students to transfer such critical thinking processes to the contexts beyond school. To provide transferability of critical thinking, newspapers or other media texts could be used in teacher education programs (Halpern, 1998). In the context of statistics, recent research suggested to use tasks that require thinking about complicated educational issues (Osana & Seymour, 2004), newspaper articles (Watson, 2011); tasks that require statistical literacy based on infusion approach (Aizikovitsh-Udi & Kuntze, 2014). In line with these studies, the current study investigated pre-service mathematics teachers' uses of critical thinking processes while intensely working on a media text that involved statistical and probabilistic information.

METHOD

Participants

The study was conducted with four pre-service middle school mathematics teachers in the fourth year of Elementary Mathematics Education Program (EME) of a public university in Ankara, Turkey. The EME

program is a four year undergraduate program in which the enrolled students are trained to be mathematics teachers of grade levels 5 to 8 in middle schools. In this program, courses named "Introduction to Probability and Statistics" and "Research Methods" are required for all students. Participants were selected among 38 pre-service middle school mathematics teachers in the fourth year. Participants were selected on the basis of their potential to provide rich data. To select the participants, all of the fourth year students were given a newspaper article that was not used in the main study and were asked to write down a critical reflection about the statistical information in it. The participants were selected randomly among the ones who could produce significant reflections, had tendency to use valid quantitative procedures and mathematical language, as well as could detect points to criticize in the article.

Data collection

The major data source of the study was in-depth interviews. Participants were asked to read the newspaper article about cheating partners, claiming men are better at detecting a cheating partner than females. It was published in the Mercury newspaper in Tasmania ("Cheat radar better tuned in men, study finds", 2008) and proposed by Watson (2011) to be used in educational settings. The newspaper article includes some probabilistic and statistical statements that participants may pay attention while trying to make sense of the given results (Table 1). During the interviews participants were asked to think and reflect about the following main questions: What is the main idea of the newspaper article? What conclusions did researchers reach? What conclusions could you draw from the text? How could the researcher conduct the study reported in the newspaper article? (e. g. how to select sample, how to collect and analyze the data, how

Statement 1:	The results, published in New Scientist, show 29 per cent of men admitted they had cheated compared with 18.5 per cent of women.
Statement 2:	Researcher Paul Andrews said men were better at judging fidelity than women. 'Eighty per cent of women's inferences about fidelity or infidelity were correct, but men were even better, accurate 94 percent of the time' Dr. Andrews said.
Statement 3:	Men were more likely to catch out a cheating partner, picking up on 75 per cent of the reported infidelities compared with 41 per cent discovered by women.
Statement 4:	Men are better at detecting a cheating partner than females, and they are more likely to suspect infidelities that do not exist.

Table 1: Some of the probabilistic and statistical statements in the newspaper article

to reach reported findings) How would you evaluate reported findings? What do you think about generalizability of the reported statistics in the newspaper article? In addition, they were asked what they understand from four probabilistic statements in the newspaper article (Table 1). The duration of each interview was approximately forty five minutes and interviews were audio and video-recorded. Data were collected in the 2011–2012 spring semester.

Data analysis

The data were coded in order to identify expressions of the participants that indicate their critical thinking process. To determine possible indicators of critical thinking, we made use of the frameworks of Facione (1990) and Jones and colleagues (1995) as a starting point and a baseline in order to identify indicators of critical thinking processes in the interview data. To be precise, data were analyzed and searched for instances and processes in their thinking by making use of the frameworks suggested by Facione and Jones et al. as a base line. In some cases, certain dimensions of these frameworks could not be completely matched with any part of the data in this study. Thus, to make the dimensions of these frameworks more suitable with our data, we adapted and restated them as the data codes and categories of the current study, without making major alterations in their conceptual meaning. For

example, the critical dimension of “explanation” in the original framework of Facione was excluded in the current study, since it was not observed in the data. On the other hand, other dimensions of critical thinking such as interpretation, analysis, evaluation, and self-regulation were included, but revised and their explanations were restated to make them more suitable with our context. As a result of data analysis, five interrelated processes of critical thinking were identified (Table 2).

FINDINGS

Critical thinking about the bases of reported findings in the newspaper article

Bases of reported findings refer to the background of the study in the newspaper article, some of which are not explicitly given in the article such as selection of sample, data collection, data analysis, or reporting of the findings. Such information about the article was one of the dimensions that the participants reflected critically. They mostly attempted to use critical thinking processes of comprehending, critiquing, and self-reflecting. Regarding sampling, one participant (Ali) recognized the essential role of the sample and the need for sample to be representative in critiquing credibility of the study. He interrogated the extent to which sample size of the study is enough to make accu-

Comprehending	<ul style="list-style-type: none"> Identification of the main idea of the text (e.g. identifying extraneous ideas in the text) Organization of the contextual information (e.g. making use of graph, diagram, or table to organize the contextual information) Clarification of the information (e.g. defining the ambiguous or vague terms)
Making Connections	<ul style="list-style-type: none"> Examining link between ideas (e.g. identifying closely related statements) Identification of claims or arguments in the newspaper article (e.g. determining whether author states reason for supporting his claim)
Inferring	<ul style="list-style-type: none"> Examining evidence (e.g. seeking the background information or issue that needs to be addressed) Proposing alternatives (e.g. suggesting plans with the consideration of their pros and cons) Drawing conclusions (e.g. figuring out new meaning by making use of clues)
Critiquing	<ul style="list-style-type: none"> Detecting misleading information (e.g. detecting inconsistencies or author’s exaggerated generalization) Recognizing factors of credibility (e.g. appreciating sufficiency of information such as sample, data collection, or analysis processes)
Self-Reflecting	<ul style="list-style-type: none"> Expressing one’s own strengths and weaknesses of own thinking process (e.g. rereading sources to make sure that one has not overlooked important information; ask themselves questions about their beliefs or attitudes) Making corrections or revisions when they realized their mistakes or misunderstandings

Table 2: Indicators used to code critical thinking processes of the participants

rate inferences about the study. He tried to support his evaluation by considering possible effect of extreme values in the data of a study with small sample size on drawing accurate conclusions from the data. On the other hand, the other participants just restated sample size of the reported study.

Regarding data collection, all participants focused on the issue of what was measured and how it was measured by clarifying the questions that were asked to the subjects of reported study. Meltem, for example, attempted to clarify question of “whether they [subjects in the study] had ever strayed” reported in the newspaper article, stating “...I mean, thinking of cheating in the past, [I thought that it was] a question such as ‘Have you ever cheated?’ The article could have just said like this: the young couple could have been informed that this study was about their current relationship.” She stipulated the condition of “current relationship”, which makes the meaning of question narrower and removing the ambiguity of the question that might lead readers to think about subjects’ current relationship or relationships in the past. It was only Ali, who reflected a different critical thinking process by critiquing misleading statement in the newspaper article, stating “Are men better confessors or do men deceive [their partners] more, it is unclear, some might deceive [their partners] and say they didn’t; that’s why, I think this may not give an idea about who deceives more.” He thought about the validity of the argument of “29 per cent of men admitted that they had cheated compared with 18.5 per cent of women” in the newspaper article with the consideration of the possible bias in measurement in which subjects might give misleading information about cheating of their partners.

Another finding was that all participants were in the process of comprehending by rethinking the categories in the article while considering about data analysis procedure of the study in the newspaper article. İrem was thinking about one of the statements in the newspaper article; that is “Eighty per cent of women’s inferences about fidelity or infidelity were correct, but men were even better, accurate 94 per cent of the time.”(Figure 1). By this table she analyzed women’s incorrect inferences about their partners’ fidelity. In this process, she organized the possible conditions to comprehend how the researchers could reach to the conclusions reported in the newspaper article and related raw data to percentages as a summary statistics.

K	E	
✓	X	0
✓	✓	1
X	X	1
X	✓	0

Figure 1: İrem's organization process regarding data analysis

Another finding was related to participants’ thoughts about results or conclusions reported in the newspaper article. While thinking about the main idea of article, they did not raised any concern about the results in the article that presents only correct inferences of men and women. They restated the statements in the newspaper article as the main idea of the text and did not consider men or women’s wrong inferences about their partners, which do not exist in the article. Moreover, while thinking about the results of the article, all of the participants attempted to critique the results in the article. However, their judgments were mostly subjective. Melek, for example, recognized the difference between the results given in the newspaper article to determine the reliability of the results or conclusions:

If numerical data are compared, it was found that 80 of women’s inferences were correct but 94% of men were right in these inferences. There is 14% difference; below [pointing the last paragraph of the article] there is much higher difference. It can have a difference of 75%; in the other one it can detect 41%, so that’s why I thought the test is really reliable.

She assumed observed differences in the results are large enough, especially in the case of numerical values of 75% and 41%, which are given in the statement of “Men were more likely to catch out a cheating partner, picking up on 75 per cent of the reported infidelities compared with 41 per cent discovered by women.” in the newspaper article. However, her judgment was subjective, indicating she might not be aware of statistical and practical significance of the results reported in the article. Supportively, in the process of critiquing of results and conclusions, two of the participants made self-reflection by reflecting their own thinking processes. Melek, for example, explained her subjective assessment in deciding if the study is reliable or not in the following:

[...]when assessing the test, I think I'm adding my own opinions a little too; but, for instance, when considering its reliability, I'm looking at the claims made at the beginning and the numbers below, I'm comparing them. So even if I am not doing calculations, may be because it fits my line of thought a little, I mean I believe in it more.

In summary, regarding the background of the study in the newspaper article, participants were mostly in the processes of comprehending, critiquing, and self-reflecting. During these processes, they mostly focused on the existing information (e.g. sample size and questions asked to subjects in the study) in the article. Only few of them attempted to interrogate information about the background of the study, which does not exist in the newspaper article.

Critical thinking about the reported statistics

This part includes participants' critical thinking processes about descriptive or summary statistics (percentages and probabilistic statements), which already exist in the newspaper article. Participants reflected different critical thinking processes such as comprehending, making connections, inferring, and self-reflecting. One of the main findings was that participants dealt with clarifying the meanings of Statement 2 and Statement 3 (see in the data collection part of this study). For example, İrem had confusion with the meaning of "fidelity" concept and tried to define the terms of fidelity and infidelity:

I think I don't know the meaning of the concept 'fidelity'. I can't distinguish these two conditions [Statement 2 and Statement 3]. I think predicting [fidelity] correctly means when they say that they don't think their partner cheated on them and actually they [their partner] hadn't; and predicting infidelity correctly means when they say that their partner definitely must have cheated on them and their partner had done so.

After developing an idea about these terms, she reasoned through proportionality and calculated the number of female and male who made correct inferences about her/his partner's fidelity or infidelity, stating "162 women predicted correctly whether or not their partner cheated on them. And I understood that 190 men accurately predicted whether their partner cheated on them." Although she expressed her difficulty understanding the difference between

Statement 2 and Statement 3, she did not make clear the difference between them. When asked what she understood from the Statement 3, she stated "41 per cent of 203 couples; so, 83 women detected that their partner cheated on them.", which can be considered as an evidence that she did not recognise the condition of cheating immediately. After that, she realized Statement 1 in the newspaper article, which gives information about the number of people cheating their partners. She made connections between two related statements (Statement 1 and Statement 3). In this process, she overviewed the newspaper article and read statements again if she overlooked anything, which can show us her self-monitoring process. Then, he corrected her mistake, stating "men noticed 75% of the cheatings done by their partner. I mean, it seems that 75% of cheating partners were noticed". Surprisingly, Ali and Melek have such a recursive process of thinking in a similar way. In addition, during this process Ali and İrem constructed a table or diagram to organize the findings of the study reported in the newspaper, which also shows their making connections among reported statistics in the newspaper article. On the other hand, Melek and Meltem could not go further, which could be due to the fact that they could not make explicit the differences between the statements in the newspaper article, especially Statement 2 and Statement 3 whereas Ali and İrem advanced their categorization of the reported findings by examining closely related statements and drawing new conclusions from the newspaper article (see Figure 2).

Another finding of the study was that they had difficulty in detecting misleading statements in the newspaper article, especially regarding Statement 4, which require understanding of the conditional probability. For example, İrem tried to critique the Statement 4, which is "Men are better at detecting a cheating partner than females, and they are more likely to suspect infidelities that do not exist". In this critiquing process, İrem dealt with the clarification of the Statement 4. She proposed two alternative meanings for the concept of "being suspicious": Male/Female says that his/her partner is cheating, Male/Female says that his/her partner is cheating when his/her partner is not cheating in real world. The ambiguity about the meaning of this concept and having difficulty in conditional probability might have prevented her to draw an improper conclusion about Statement 4 and partially critiquing it, stating as "I think it [Statement 4] is wrong...1.4% [3/203] and for women, 2.8% [6/203].

I think this is the opposite of [Statement 4]. If we consider the first meaning [Male/Female says that his/her partner is cheating], it becomes true...it depends on the meaning of "being suspicious". If we think the second meaning that I believe in, women are more suspicious, that is, anyway women are suspicious unnecessarily."

Critical thinking about the generalizability of the reported findings

During interviewing, participants were encouraged to think about the generalizability of the reported findings. While thinking about this issue, all participants attempted to critique the arguments reported in the newspaper article with recognition of relevant factors to determine if it was generalizable to population or other similar contexts. In this process, they differ from each other by focusing on different factors such as sample size, sampling method, and cultural factors. Two participants (Ali and İrem) also reflected the process of inferring (examining evidence) regarding what background information about sample characteristics needs to be addressed to critique generalizability of the reported findings. For example, İrem discussed generalizability as following:

Well, I don't know if 203 couples are enough. I don't think it can be generalized. My usual opinion, you can't imagine something big from a small sample. If I ask each of the 203 men or if I get 58 men, in this case, will only 23 of 58 of all their wives predict correctly? It seems that this will not be correct all the time...You know, different results will be obtained from different samples; well, here the 203 couples don't have any characteristic features anyway. I mean, where do

they live, in which country, I don't know how long they have been married; maybe there are many influential factors. It has only mentioned that they are young couples [...]

İrem was not sure about to what extent sample size is sufficient for generalizability from deterministic point of view, stating "you can't imagine something big from a small sample." Conversely, Meltem made somewhat immediate comments regarding generalizability and did not provide enough evidence to support his evaluation. She considered factor of the sample size of the study enough to generalize the conclusions and tended to relate the generalizability of the study to the clear presentation of the findings in the newspaper in the following quote:

203 is actually a good number; in statistics when we, for example, carry out a study, we say it's a good result when it is over 30, or 100, for instance. Well, 203, compared with that, is good, that's why...it can be generalized because everything is clear [...]

In summary, all participants attempted to critique findings in the article when they were asked to think about the generalizability. However, they did not reflect comprehensible reasoning to make sound assessment about the generalizability.

FINAL REMARKS

One of the main conclusions arising from this study is that pre-service mathematics teachers mostly focused on the existing information rather than on the missing or misleading information in the newspaper

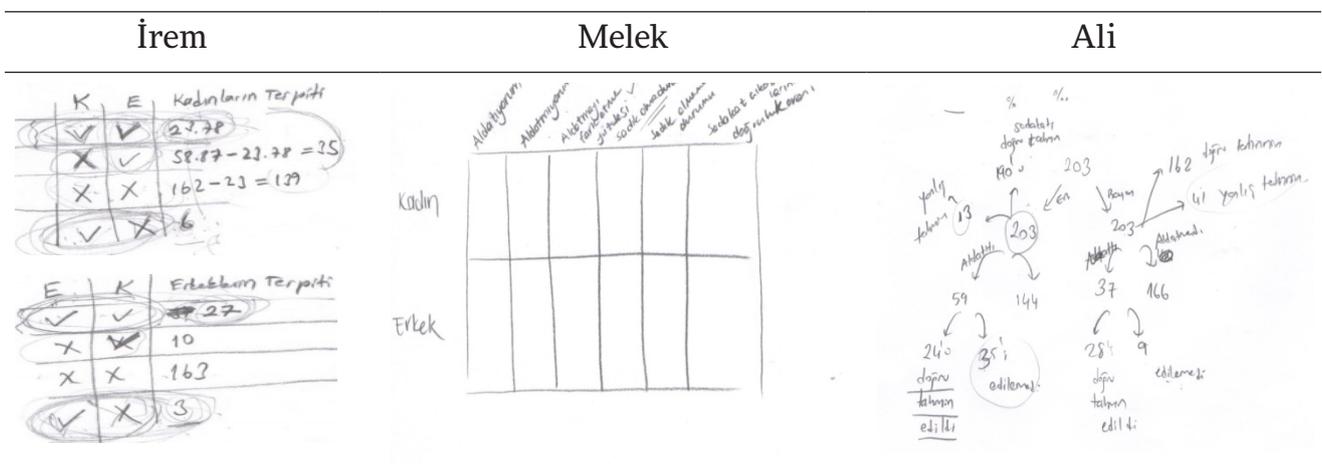


Figure 2: Three participants' thinking processes about the reported findings

article, which might have prevented them to detect one-sided arguments (Watson, 2006). Moreover, they mostly attempted to comprehend the statements in the newspaper article by clarifying their meanings and make immediate comments or overgeneralizations like “it is good” or “the results of the study is generalizable” without enough evidence to support their ideas, which contradicts with the nature of critical thinking that requires skeptical thinking, and inquiry on the basis of evidence (Facione, 1990). Another important conclusion is that they had difficulty in comprehending conditional probability statements, which might prevented them to make appropriate inferences and critique the reported findings in the newspaper article. These results are consistent with the findings of Ozen and Cakiroglu (2013). This indicates their lack uses of critical thinking processes regarding conditional probability in the media texts even though they have already studied about this concept in their statistics courses. This study contributes to our understanding pre-service mathematics teachers' engagement in the media contexts, which might lead us to reconsider the content of statistics courses in the teacher education programs regarding how these courses really address the issue of uses of critical thinking processes regarding the statistical and probabilistic information in real life contexts. Media texts could be used as a mediator to contribute their critical thinking process in designing of statistics courses in which they could be encouraged to think about both proper and improper examples of newspaper articles about diverse topics, rather than just focusing on the computational procedures.

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