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Investigation of pre-service science teachers' epistemological beliefs

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Abstract

The study aims to determine pre-service science teachers' epistemological beliefs. For this purpose, five fourth grade pre-service science teachers enrolled at the education Faculty of a University in Kayseri participated in the research. Phenomenology design was used and a semi-structured interview including 13 items was conducted. The data were analysed through content analysis by developing codes and themes based on five epistemological belief categories. According to the findings, the participants' epistemological belief categories can be put in order from the most sophisticated to the most naive as follows: 'Omniscient authority', 'Certain knowledge and quick learning', 'Simple knowledge' and 'Innate ability'. The findings indicated that epistemological beliefs of the participants are at different development levels for each category. Since they reflect the individual differences, epistemological beliefs should not be ignored in developing a program and determining classroom activities.

Keywords: Epistemological beliefs, pre-service science teachers, qualitative study, phenomenology.

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1. Introduction

Epistemological beliefs (EBs) are the beliefs regarding the source and certainty of knowledge, and knowing and learning (Schommer-Aikins, 2004). If individuals believe that the ability to learn is genetically predetermined, knowledge is certain, simple and handed down by authority, and learning is not a gradual process, they can be considered to have naive EBs. On the other hand, if individuals believe that the ability to learn is acquired through experience, knowledge is not certain or simple, that it is reasoned out through objective and subjective means, and learning is a gradual process, then they can be considered to be individuals who have sophisticated EBs (Brownlee, Purdie & Boulton-Lewis, 2001; Pulmones, 2010; Schommer, 1990).

The students having sophisticated EBs are able to explain science and scientific knowledge; to think like scientists and use scientific methods; to use scientific knowledge in daily life; to express an opinion about the results of their studies and to make decisions about the quality of scientific knowledge (Bell & Lederman, 2003; Chan & Elliott, 2004a; Liu, Lin & Tsai, 2010; Pulmones, 2010; Sadler, Chambers & Zeidler, 2004; Schommer, 1990; Schommer-Aikins & Hutter, 2002). The students with sophisticated EBs have a deeper level of comprehension (Ryan, 1984; Schommer, 1990), better academic performance (Chen & Pajares, 2010; Schommer-Aikins, Duell & Hutter, 2005; Yang & Tsai, 2012) and a greater ability to solve ill-structured problems (Schraw, Dunkle & Bendixen, 1995), to integrate competing claims and to reach the right conclusions (Kardash & Scholes, 1996), and to consider evidence and to evaluate alternative points of view. These students are also more critical of inconsistencies and misconceptions (Nussbaum, Sinatra & Poliquin, 2008). Therefore, the studies about EBs in learning science are rapidly gaining importance in today's science education literature.

EBs and the goals of learners are obviously interrelated. Mohamed and El-Habbal (2013) supported that students' belief systems and the goals of learners play an important role in their learning in the classroom. Hence, having a naive EB may cause many handicaps in science learning. Studies have revealed that students with sophisticated EBs are usually more successful than students with naive EBs in science learning (Chan, 2004; 2011; Chen & Pajares, 2010; Hofer & Pintrich, 1997; Schommer, 1990; Tsai, Ho, Liang & Lin, 2011; Zeidler, Osborne, Erduran, Simon & Monk, 2003). For instance, in their study, Tsai et al. (2011) indicated that sophisticated EBs led to higher level conceptions of learning science, while naive EBs led to lower level conceptions of learning science.

EBs are also important in teaching as well as learning (Hashweh, 1996). Hashweh (1996) reported that teachers' EBs were consistent with their preferred ways of teaching. Also, studies indicated that naive EBs are associated with traditional pedagogical beliefs, while sophisticated EBs are more associated with constructivist views of teaching (Deng, Chai, Tsai & Lee, 2014; Ismail & Abdel-Majeed, 2006). For instance, Ismail and Abdel-Majeed (2006) stated that pre-service teachers with sophisticated EBs were more likely to adopt a student-centred teaching orientation compared to the pre-service teachers who hold naive EBs.

Students' EBs have been conceptualised by researchers. For instance, Perry (1968) stated that EBs have four dimensions: dualism, multiplism, relativism and commitment. Ryan (1984) classified students' EBs as dualistic and relativistic. Schommer (1990; 1994) suggested five EBs: omniscient authority, certain knowledge, simple knowledge, quick learning and innate ability.

Schommer (1994) proposed that the source of knowledge ranges from knowledge is handed down by omniscient authority (naive) to knowledge is reasoned out through objective and subjective means (sophisticated). Certain knowledge was considered to range from knowledge is absolute (naive) to knowledge is constantly evolving (sophisticated). The organisation of knowledge was classified from knowledge is compartmentalised (naive) to knowledge is highly integrated and interwoven (sophisticated). Quick learning was categorised from learning is quick or not-at-all (naive) to learning is a gradual process (sophisticated). Innate ability was classified from ability to learn is genetically predetermined (naive) to ability to learn is acquired through experience (sophisticated). Like Schommer, Hofer and Pintrich (1997) also stated that EB is multidimensional and identified four dimensions: certainty of knowledge, simplicity of knowledge, source of knowing and justification for knowing.

In the above-mentioned studies, the majority of the participants were pre-service teachers. Starting from these studies, it is clearly seen that EBs are closely related with many research areas. Looking at the studies conducted about the EBs of pre-service teachers to date, it was seen that they are mostly quantitative studies (Angeli & Valanides, 2012; Conley, Pintrich, Vekiri & Harrison, 2004; Dunkle, Schraw, Bendixen & Grosskopf, 1994; Schommer, 1990). However, in order to understand the future teachers' EBs better, more qualitative studies are needed.

The objectives of science programs will be achieved if teachers are well-equipped, have sufficient knowledge in their fields, and share their knowledge with their students to allow them to become scientifically-literate individuals. Science teachers cannot achieve these objectives if they fail to comprehend the epistemology of scientific knowledge that takes part in the science program. Hence, the EBs of pre-service science teachers (PSTs) affect their performance and teaching strategy that they will use in their classrooms in future (Cheng, Chan, Tang & Cheng, 2009). Accordingly, the participants in this study were composed of PSTs. Therefore, the aim of this research is to investigate the EBs of fourth grade PSTs. Within this context, the research question was determined as follows: 'What are the views of PSTs regarding EBs'?

The sub-problems of the study are as follows:

1. What are the views of PSTs regarding 'simple knowledge'?
2. What are the views of PSTs regarding 'certain knowledge'?
3. What are the views of PSTs regarding 'omniscient authority'?
4. What are the views of PSTs regarding 'innate ability'?
5. (What are the views of PSTs regarding 'quick learning'?

2. Method

2.1. Research design

Phenomenology design was used in the study. In phenomenology studies, the researcher focuses on a phenomenon, collect data through in-depth interviews and interpret the participants' perceptions (Fraenkel & Wallen, 2009). The research was carried out with phenomenology design since it was aimed to describe participants' epistemological beliefs in detail through the interview.

2.2. Sample

Criterion-based (purposive) sampling was used to determine the participants. Purposive sampling is generally used in qualitative studies to focus on understanding rather than to make generalisations (Creswell, 2009). In this study, the participants consisted of five PSTs (one male and four females) from Elementary Science Education Department of a University in Kayseri. In third grade, PSTs took the course containing the nature of science and its dimensions, and epistemological beliefs. Therefore, fourth grade PSTs who completed this course were expected to be knowledgeable about EBs. Moreover, they are also expected to be qualified individuals with the necessary teaching abilities for their profession. For such reasons, fourth grade PSTs were selected as the sample. The study was conducted during the spring semester of 2014–2015. The participants were coded as Oya, Ela, Ece, Can and Arzu.

2.3. Instrument

A semi-structured interview was used to learn the participants' EBs in a detailed manner by looking at their mimics and movements (Patton, 2002). After the necessary literature and the reliable and valid instruments regarding EBs were reviewed (Perry, 1970; Schommer, 1990), a 13-open-ended-item interview form was prepared. Luft and Roehrig (2007) conducted a study with teacher participants. Hence, one of the interview questions was adapted to the pre-service teachers. Moreover, two interview questions were adapted from Chai's (2010) study. The other 10 questions were prepared by the researchers who were inspired by Schommer's (1990) Epistemological Belief Questionnaire.

First, the questions were prepared in a manner that is clearly understood by the participants and in accordance with their experience. Second, to avoid short and implicit answers like 'yes' or 'no', open-ended questions were asked to take detailed explanations. Last, in addition to each interview question, probe questions were added to deepen each participant's thoughts.

The interview questions were formed based on the Schommer's five EBs sub-dimensions. The interview form includes three questions regarding 'simple knowledge', three questions regarding 'certain knowledge', two questions regarding 'omniscient authority', two questions regarding 'innate ability' and three questions regarding 'quick learning'. The prepared interview form was checked by three science education experts and the final version was obtained. Some of the interview questions are given below:

- In your opinion, how do you obtain scientific knowledge? (simple knowledge)
- What do you think about the certainty of knowledge in your information sources? (certain knowledge)
- Do you believe everything that you have learned directly? (omniscient authority)
- In your opinion, how does learning occur? (innate ability)
- Is learning genetically predetermined? Why do you think so?
- Is learning acquired through experience? Why do you think so?
- How would you describe your speed of learning? Can you give examples, please? (quick learning)

2.4. Data collection procedure

The interviews were performed by one of the researchers by adhering to the interview form. During the interview process, a voice recorder was used with the approval of the participants. The interviews were performed in a suitable and quiet environment at the Education Faculty of the University. The interviews lasted for approximately 35 minutes. After the data were transcribed, transcripts were given to the participants to verify the records.

2.5. Data analysis

Content analysis, which is used to formulate themes and categories in order to organise and make sense out of large amounts of descriptive information (Fraenkel & Wallen, 2009), was used in the study. Therefore, first the obtained data were examined. Second, the codes and themes were determined and mutually negotiated with another researcher and the necessary regulations were decided on. The findings were presented in the light of five categories (Table 1).

Table 1. Categories and developed themes

Categories	Themes
Simple knowledge	The ways to obtain scientific knowledge
Certain knowledge	The certainty of knowledge in the information sources
Omniscient authority	Authority versus reasoning out
Innate ability	Innate ability versus experience
Quick learning	Quick *versus* gradual process and concentrated effort

In order to classify PSTs' EBs, the classification system (naive, between naive and sophisticated and sophisticated) was used based on the related literature (Pulmones, 2010; Schommer, 1990). In simple knowledge category, a participant was seen as 'naive', if she/he believes that knowledge is compartmentalised. However, if she/he believes that knowledge is highly integrated and interwoven, this participant was seen as 'sophisticated'. In the same way, in certain knowledge category, a participant was perceived as 'naive', if she/he believes that knowledge is absolute, but if she/he believes that knowledge is constantly evolving, then she/he was considered as 'sophisticated'. In the category of omniscient authority, a participant who thinks that knowledge is handed down by authority was considered as 'naive', while a participant who thinks that knowledge is reasoned out through objective and subjective means was considered as 'sophisticated'. In innate ability category, a participant who considers that the ability to learn is genetically predetermined was viewed as 'naive', while a PST who considers that the ability to learn is acquired through experience was classed as 'sophisticated'. Finally, in quick learning category, if she/he considers that the learning is quick or not-at-all, this participant was considered as 'naive'. However, if a PST considers that learning is a gradual process, she/he was classed as 'sophisticated'. Moreover, for all categories, if she/he had a view between naive and sophisticated, then this participant was classed as 'between naive and sophisticated'.

2.6. Validity and reliability

First, a long-term interaction with the PSTs was provided during the interviews to enhance internal validity. Second, researchers confirmed the participants' responses during and after the interview process. Third, the findings were presented as direct quotations without interpretation.

In order to ensure external validity, sample was selected appropriately for the purpose of study. Moreover, to enhance external validity, the research design, study group, data collection tool, data collection, analysis and findings were explained in detail.

In order to enhance internal reliability of the study, the findings were presented without any interpretation. Moreover, the themes and codes were finalised after consultation with another expert.

Last, in order to ensure external validity of the study, in other words confirmability, the findings were controlled by an expert in science education.

3. Results

In the following sections, the themes and codes that were generated by the researchers are presented in the tables. The participants' responses to the interview questions are presented without any interpretation. The findings obtained by data analysis are presented based on the five categories. Also, the PSTs' EBs are presented considering the classification.

3.1. Simple knowledge

The codes regarding Theme-1 are given in Table 2.

Table 2. The ways to obtain the scientific knowledge (Theme-1)

Codes	Participants				
	Oya	Ela	Ece	Can	Arzu
Following a strict plan	+	+	+	−	+
Memorisation	−	+	−	−	−
Making integration	+	−	−	+	−
Classification	N-S	N	N-S	S	N-S

N: Naive epistemological belief.
N-S: Between naive and sophisticated epistemological belief.
S: Sophisticated epistemological belief.

At the beginning of the interview, participants were asked about the ways in which scientific knowledge is acquired. According to the participants, the most common way to obtain scientific knowledge is to follow a strict plan (Table 2).

With the exception of Can, four participants thought that they can acquire scientific knowledge step by step, by following a strict plan. Ece expressed her thoughts as *Without any doubt, a plan should be followed... I don't think that we can acquire knowledge randomly.* In contrast, Can stated that *There is no single best way to acquire scientific knowledge. The way that you use to acquire knowledge is the best way for you.*

Ela argued that memorisation is also an important way to obtain scientific knowledge: *Memorisation is learning. During the memorisation process, you learn the things.*

Regarding 'making integration' code, only two participants implied that they integrate scientific knowledge into their lives. Oya stated that *If I can solve the questions about that topic… If I use and transfer this new knowledge to my daily life, it means that I have learned it.*

3.2. Certain knowledge

The codes regarding Theme-2 are given in Table 3.

Table 3. The certainty of knowledge in the information sources (Theme-2)

Codes	Participants				
	Oya	Ela	Ece	Can	Arzu
Uncertainty	+	+	+	+	+
Exemplification	−	+	−	+	−
Classification	N-S	S	N-S	S	N-S

All of the participants thought that the scientific knowledge is a developing process rather than being certain. Arzu stated that *Scientific knowledge can be changed or improved.* However, only two participants gave examples for the uncertainty of knowledge (Table 3). Being one, Can stated that … *we know that the ideal gas equation is P.V = n.R.T. Until a new formula is proposed and proven, and accepted by the IUPAC, it does not change. If a new one cannot be formed, we use it although it is not certain....*

3.3. Omniscient authority

In this category, three codes regarding Theme-3 are given in Table 4.

Table 4. 'Authority' *versus* 'reasoning out' (Theme-3)

Codes	Participants				
	Oya	Ela	Ece	Can	Arzu
Depending on authority	−	+	+	−	−
Criticising the authority	+	−	+	+	+
Learning to learn	+	+	+	+	+
Classification	S	N-S	N-S	S	S

Three participants implied that they do not depend on the authority. Arzu stated that she does not obtain scientific knowledge by using specific information source(s); but instead, she said *I search… Not only through books… For example, if I am doing a research on genes, I do an experiment… Also, it is more effective to consult different people who have different views about the topic'.* However, other two participants implicitly stated that they depend on authority. Ela expressed her thoughts as *I obtain knowledge via books, the internet, newspapers and magazines. A student's learning process depends on the environment, instructor and his/her characteristics.*

As seen in Table 4, while four participants criticise the authority, only Ela does not: *I try to implement what they said… I do not question some laws about which I have inadequate knowledge.* Being a critical participant, Oya stated that: *I do not believe everything that I have learned directly.*

Because it may be someone else's opinion, it may not match my own. I question it in my own way… I have to believe it before using that information… If I find it logical, I accept it after I search and question its illogical parts.

The last code regarding Theme-3 is learning to learn. All of the participants stated that they learn by using their own methods, which means they learn how to learn. Ece stated *that To obtain scientific knowledge, I appeal to books, dissertations… I appeal to my instructor or teachers when I cannot obtain answers from these sources… I learn by using my own method… I don't think that I learn via exams.*

3.4. Innate ability

The codes regarding Theme-4 were given in Table 5.

Table 5. 'Innate ability' *versus* 'experience' (Theme-4)

Codes	Participants				
	Oya	Ela	Ece	Can	Arzu
Ability to learn is innate	−	+	−	−	−
Both innate and experience	+	−	+	+	+
Learning ability is acquired through experience	−	−	−	−	−
Classification	N-S	N	N-S	N-S	N-S

Ela is the only participant who indicated that the ability to learn is innate (Table 5): *We are not born with an empty mind. We come into the world by knowing certain things, but when we do not improve our knowledge of these things, we decline. Actually, there are many things we have that are innate.*

Other four participants claimed that both learning ability is innate and it is improved through the experience. Arzu expressed her thoughts as *Learning is something that is both innate and acquired. They complement each other. None of the participants thought that learning is acquired only through experience.*

3.5. Quick learning

The four codes regarding Theme-5 are given in Table 6.

Table 6. 'Quick' *versus* 'gradual process and concentrated effort' (Theme-5)

Codes	Participants				
	Oya	Ela	Ece	Can	Arzu
Learning is quick	−	−	−	+	−
Between quick and gradual process	+	+	−	−	−
Learning is a gradual process	−	−	+	−	+
Learning is a concentrated effort	+	+	+	+	+
Classification	N-S	N-S	S	N-S	S

Can indicated that the learning occurs quickly as: *For example, you might read a text quickly and get an idea about it, whereas I read it slowly but do not understand it. Then, you learn a lot more things than me and start to learn another thing while I am still trying to learn it. You make progress, but I go one step forward and two steps back. How can I make progress then?*

Two participants thought that the learning is 'between quick and gradual processes'. Oya expressed her thoughts as: *If I am interested in something, I learn more quickly. However, if it is a course that I do not like, it takes more time.*

Ece and Arzu claimed that the learning is a gradual process. Ece stated that: *Learning takes place gradually, throughout life… For instance, somebody reads a text very fast but if s/he does not understand it, I do not think meaningful learning took place. I learn when I spend time on something.*

All the participants indicated that the learning is a concentrated effort. Arzu said that: *To learn a difficult subject, you have to spend more effort and do more research.*

3.6. Pre-service science teachers' epistemological beliefs

The sub-problems were evaluated in the light of the themes and codes to seek an answer to the research problem. Accordingly, the classification of PSTs' EBs is given in Table 7. Regarding simple knowledge category, Ela had naive and Can had sophisticated EB, while other three participants had a view between naive and sophisticated EB. Regarding certain knowledge, three participants had a view between naive and sophisticated EB, whereas the views of two were considered as sophisticated EB. With respect to omniscient authority category, three participants had sophisticated EB, while the other two participants were thought to have a view between naive and sophisticated EB. With regard to innate ability category, only Ela had naive EB, while the other four PSTs had a view between naive and sophisticated EB. Last, regarding quick learning, two participants had sophisticated EB and three participants had a view between naive and sophisticated EB.

Table 7. Pre-service science teachers' epistemological beliefs

Participants	**Categories**				
	Simple knowledge	**Certain knowledge**	**Omniscient authority**	**Innate ability**	**Quick learning**
Oya	N-S	N-S	S	N-S	N-S
Ela	N	S	N-S	N	N-S
Ece	N-S	N-S	N-S	N-S	S
Can	S	S	S	N-S	N-S
Arzu	N-S	N-S	S	N-S	S

4. Discussion

Based on the content analysis results, PSTs' EB categories can be put in order from the most sophisticated to the most naive as follows: 'Omniscient authority', 'Certain knowledge and quick learning', 'Simple knowledge' and 'Innate ability' (Table 7). Likewise, Chan and Elliott (2000) also found that PSTs had more sophisticated EBs on quick learning than on innate ability. In addition, Saylan, Bektas and Oner Armagan (2015) investigated Turkish PSTs' EBs in their study and stated that simple knowledge and certain knowledge are more sophisticated than innate ability. Thus, it is important that the development levels of EBs should be sophisticated in all categories and for this aim, all educators must make an effort in this regard.

Understanding and teaching EBs is one of the main goals of science education. However, since it is a long and time-consuming process, studies have revealed that such concepts cannot be taught in a short period of time (Schommer-Aikins, 2002). Hence, PSTs should acquire the necessary information and concepts about EBs during their undergraduate education to learn how to teach these issues to their students in the near future. By doing this, they will help their students to develop more sophisticated EBs. EBs also affect teachers' pedagogical content knowledge. If teachers have adequate EBs, they will use effective teaching methods, assessment and evaluation techniques, and teaching materials, know how to manage the classroom and what the students should focus on during the learning process and be aware of the misconceptions of their students. Therefore, the present study investigated the EBs of PSTs in order to enhance their awareness regarding both EBs and the teaching profession.

4.1. Simple knowledge

By looking at the findings regarding first three codes of simple knowledge, it is seen that only Ela has naive EB. The reason for this may be the longstanding imposition of memorisation in Turkish educational system. In parallel, Yilmaz Tuzun and Topcu (2008) stated that Turkish educational system is still based on memorisation of the concepts. Students often try to memorise concepts without reasoning to pass the national exams. Chan and Elliott (2000) also stated that students who have sophisticated EBs have deeper approaches regarding learning while students who have naive EBs prefer memorisation. As an example of this, Schommer (1994) stated that an individual who believes that knowledge is simple would probably try to memorise events and dates. However, a person who believes that knowledge is complex would probably try to understand events by associating them with each other.

The participants' EBs on simple knowledge are mostly between naive and sophisticated. The reason for this may be that PSTs have begun to change their EBs, especially on simple knowledge, due to the effect of the constructivist approach.

4.2. Certain knowledge

Three participants had a view between naive and sophisticated EBs, whereas two participants had sophisticated EBs on certain knowledge. This is an encouraging finding since earlier studies conducted in Turkey found that the pre-service teachers mostly thought that knowledge is certain (Topcu, 2011). Since constructivism was introduced in schools in Turkey about 10 years ago, the students' EBs on this category may have developed. Concordantly, within the scope of their study, Otting, Zwall, Tempelaar and Gijselaers (2010) found a positive relationship between certainty of knowledge and the traditional conception of teaching and learning. Another reason for this finding may be the positive effects of 'Nature of Science' course.

4.3. Omniscient authority

The participants had the best developed EBs in omniscient authority category. Three participants had sophisticated EB and two participants had a view between naive and sophisticated EB on this category. Before the introduction of constructivism, the learning process was teacher-centred in Turkey. The role of instructors was the most dominant during lessons, and they were the only authority since they transmitted knowledge directly to the students. However, with the recent reforms based on constructivism, nowadays teachers have a role to encourage students to ask questions and to make them more active during the learning process.

EBs of participants concerning 'omniscient authority' dimension were identified as naive in countries like China, Japan and Taiwan where eastern culture is dominant (Loyens, Rikers & Schmidt, 2007; Wang, Zhang, Zhang & Hou, 2013). In addition, Yilmaz Tuzun and Topcu (2008) found that Turkish PSTs' EBs regarding omniscient authority were naive and concluded that the participants' previous learning experiences might have led them to comprehend that science is a body of knowledge discovered by scientists, and teachers deliver this knowledge. However, over the years, the effects of constructivism on PSTs have been observed more concretely. Hence, PSTs in the present study had more sophisticated EBs on omniscient authority than in previous studies.

4.4. Innate ability

The participants had the least developed EBs regarding innate ability. In this category, there were no sophisticated participants since the participants of the present study had a conservative/religious view of life. Therefore, since they believe that intelligence is a gift from God, they think that learning ability is predetermined.

4.5. Quick learning

Two participants had sophisticated, while three participants had between naive and sophisticated EBs regarding quick learning. Likewise, Saunders (1998) and Saylan (2014) investigated university students' EBs and realised that the majority of participants had a view between naive and sophisticated in this category. In the course 'Nature of Science', they learned that scientific knowledge is not certain and the development of scientific knowledge is a gradual process. Therefore, they might think that learning is a gradual process rather than a quick one.

5. Recommendations

According to the findings, the following recommendations can be offered to educators and researchers. First, long-term qualitative and quantitative data collection investigations should be planned in order to determine the factors affecting the development of EBs. Second, in the present study, only five PSTs' EBs were investigated. By including more participants and adding new questions to the interview form, more in-depth studies can be conducted. Third, data triangulation was not performed in this study. A semi-structured interview was used as the only data collection tool. Therefore, other qualitative data collection tools (observation and documents) should be used in future studies.

The findings of this study indicated that EBs of PSTs may be at different development levels for each category. Hence, researchers and educators should not have the expectation that all students have the same developmental level in terms of EBs during the course of their training. From this viewpoint, because they reflect the individual differences, EBs should not be ignored in constructing and developing a program, and in determining classroom activities.

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