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Uncovering Preservice Mathematics Teachers' Views on Innovation with Invention Stories from the History of Science

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Abstract

The study is based on a qualitative research paradigm. Data comes from the invention stories from the history of science written by preservice mathematics teachers which was collected in the history of science course as part of their summative assessments. This data was analyzed using content analysis technique which resulted in seven categories, namely: existence of innovation, motivation for innovation, the development of the innovation, identity of the innovator, reason for innovation, areas of innovation time of innovation. Data was obtained through a mixture of inductive and deductive methods. The sample of this study consisted of 48 stories of invention. Results obtained from the invention stories reveal two main trends: First is the teacher candidates' image of the innovatory scientists as the status-quo breakers. Second is the perception of Turkish scientific figures as not being open to new experiences and as non-risk takers. As a result, findings suggest that innovation is generally perceived as a western-rooted and alien concept.

Keywords: mathematics education, teacher training, views about innovation, history of science, invention stories

1. Introduction

A considerable amount of studies about innovation and/or creativity in the area of education are about the innovative approaches on teaching (e.g.; Beckwith & Cunniff, 2009; Lehto & Penttila, 2013; Derin, Aydın, & Kırkıç, 2017) and teacher education (e.g. Lim, Cock, Lock, & Brook, 2009). As opposed to the international literature, in the national context, there are fewer studies in proportion to the general literature on innovation concerning the pre-service or in-service teachers' views about innovation. Many of such studies are of quantitatitive nature (e.g. Korucu & Olpak, 2015; Çorlu & Aydın, 2016; Aydın & Çorlu, 2016; Yenice & Yavaşoğlu, 2018) and that qualitative approaches are less common (e.g. Kocasaraç & Karataş, 2017). There is no study either in the national or in the international literature that aims to investigate views of preservice mathematics teachers (PMTs) views on innovation in the context of history of science.

1.1 The Aim of the Study

The dearth of qualitative studies would cause limitations in the obtainment of deep information about teachers' views about innovation. Moreover, the use of stories of invention as a source of qualitative data is, in itself, a methodological innovation.

Developing positive attitudes towards innovation and improving innovation literacy for the students of the next generation is the duty of the future teachers in the area of mathematics. Therefore, teacher training programs carry an important role in developing awareness towards the values related to innovatory and scientific thinking. A teacher candidate who prepares to teach mathematics at the secondary school level requires a background to achieve this purpose. As a result, it is important to have deeper information about how our mathematics teacher candidates think about the idea of innovation, how they relate the ideas of invention and innovation. Hence the present study uses invention stories to uncover PMTs' views about innovation. The aim of the present study is formulated as below:

> *What are preservice mathematics teachers' views about innovation emerged in their stories of inventions chosen from the history of science?*

1.2 Conceptual Framework

1.2.1 Innovation

In spite of popular beliefs innovation is not a new concept. It is possible to trace its roots back to the Industrial Revolution in England. The first known person who proposed a comprehensive theory of innovation is Joseph Schumpeter, who states that the major force for economic development is innovation which leads to radical or incremental changes, the former defining disruptive changes and the latter, a continuous process of change (cited in Croitoru, 2012). The incentive for innovation is to improve performance. There is a great deal of uncertainty in the decision concerning innovation (Rosenberg, 1994). Therefore, decision-makers tends generally to avoid it. Innovation has both product and process dimensions (OECD, 1997). A product can be technologically new or improved. There are many examples of both types of innovation the history of science and technology. A pencil can be an example of the former whereas when an eraser is added to a pencil we obtain an improved product. In the latter example existing technologies combine in a new use. OECD's Oslo manual innovation is defined as "the implementation of a new or significantly improved product or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations (Organisation for Economic Co-operation and Development [OECD], 2004). In Utterback's (1971) definition innovation is viewed as a process of delivering a discovery to the market as a new product. Hence, it is essential in an innovation, to achieve an economic value (Lundvall, 2007). In an innovational activity data obtained from the use of actual products can be used to improve the development of the next generation of products (McKinsey Global Institute [MGI], 2011). In the process of innovation, the value of a product is higher if it is the outcome of an inquiry.

1.2.2 Invention vs. Innovation

A dynamic view of science assumes that history of science is a history of finding solutions to problems that humankind faced (Popper, 2001). Every invention is a result of a problem solving process. An invention is a reciprocal relationship between two pieces of knowledge and that most of inventions are based on the improvements on the available conditions, tools, technologies and processes to find a solution to an existing problem. Shlesinger (1987) states that five stages of the invention process are (1) the identification of the problem (based on a need or grievances), (2) history of the problem, (3) obtaining information based on qualitative and/or quantitative analysis, (4) design & synthesis and (5) re-designing (Shlesinger, 1987). Since all of these stages overtly or covertly exist in every invention in the history of science, the area of history of science can be viewed as history of inventions (Herlea & Herlea, 2014). This, it is believed, is an indication of a link between invention and an innovation.

1.2.3 Views about Innovation

In this section we will explain why we prefer to focus, in our study, on 'views' instead of 'literacy' on innovation. Scientific literacy requires the competencies of explaining phenomena scientifically, evaluating and designing a scientific inquiry interpreting data and evidence scientifically (OECD, 2015). The definition of innovation literacy involves the skills of understanding and using written materials to make judgments and scientific inferences in achieving the construction of a product (Erdogan, Corlu, & Capraro, 2013). Literacy is a cognitive skill pertaining to Bloom' higher mental processes (i.e. explaining, evaluating, designing, interpreting understand & use are the verbs corresponding to higher mental processes) (Krathwohl, 2002). Views about innovation, on the other hand belongs to the affective domain (McLeod, 1989). Views about innovation can provide information about level of awareness of the idea of innovation

2. Methodology

The present study is based on a qualitative paradigm in a survey design because to answer the research questions there is a need to obtain deeper information about PMTs' views about innovation The data which came from the invention stories written by the teacher candidates was collected as part of summative assessments of the course in the history of science. The author of the present study believes that history science presents a very fruitful opportunity to reveal PMTs' hidden attitudes and beliefs about science and the relationship between the ideas of invention and innovation. The sample of this study consisted of 48 stories of invention written by 81 PMT who are trained in a mathematics education teacher training program at the secondary and post-secondary levels in a state university.

2.1 Data Collection Tool

In this study, data was collected through the invention stories written by the teacher candidates throughout the last 4 weeks of the course in the history of science. In order to answer the research question, the major themes emerged from the stories that PMTs wrote were analyzed. PMTs were required to write 'invention stories' as part of their

summative assessments. In doing so, they were encouraged to work in groups of two (individual works were also accepted). The PMTs were required to write a story of an invention. This needed to be an innovation-focused research on a specific period or theme. It was expected that a story includes the process of emergence of an invention, the explanation of its design and its functioning. The PMTs could also choose to focus on a specific example, and describe its design. Each story had to include these four dimensions:

- The importance of the invention, the challenges faced during the invention, the need for the invention should be addressed in its in historical context.
- Benefits of the invention: the solution and innovative dimension
- Influence of the invention to the broader community
- Detailed information about the inventor(s)' personality trait(s), communication(s) with the family and occupational environment and worldview(s).

PMTs were given information about how this work would be accomplished until the end of the deadline for the decision of the topic. PMTs, then were required to give a proposal for their work. Their proposals were assessed for appropriateness to the instruction stated above and were given feedback immediately. During their writing process they were encouraged to ask for feedback from the lecturer either via emails or through pre-arranged face to face appointments. The nature of these feedbacks tends to be non-directive and only limited to the explanations of the rules.

2.2 Data Analysis

Content Analysis method was utilized to analyze the qualitative data. The coding schema of the study were deduced and shown in Table 1, along with a brief description of each category. These categories were decided using both the inductive and the deductive methods. In the deductive method categories from the two sources were adapted (Mamlok-Naaman, Ben-Zvi, Hofstein, Menis, & Erduran, 2005; Erdemir & Kandil-İngeç, 2016). Inductive method yielded codes from within the story data. The author of the study used help from another researcher during the coding process. The same data was coded twice. Miles and Huberman (1994) formula was used to estimate the reliability of the coding scheme which yielded in an agreement rate of 0.81 between the two codings, which is deemed highly acceptable.

Table 1. Categories used for the analysis of data in the invention stories

Category	Description
Existence of innovation	Does the story of the invention have an innovation dimension as defined in the OECD document?
Motivation for innovation	How the authors(s) perceive the meaning of invention explained overtly or covertly?
The development of the innovation	How does the invention/innovation works, how does it function in the targeted domain(s)?
	Is the work individually accomplished?
	Was there teamwork involved in the process?
	What is the nature of the teamwork?
Identity of the innovator	What are the personal characteristics of the person(s)
	Who are involved in the inventory/innovatory attempt (e.g. occupation, national identity)
Reason for innovation	What is the main rationale for the attempt?
	What is the intention of person(s) working,
Areas of innovation	In which area(s) invention/innovation was made (e.g. military, transportation)
Time of innovation	What is the time of the invention/innovation?

3. Findings

In this section, the findings related to each category presented in Table 1 will be explained. In order to analyze the stories written by the PMTs, frequencies of occurrence of the codes within each of the category were calculated. There are a total of 48 stories, 33 of which were written by groups of two and 15 of the stories were individual works. Stories were written in Turkish except one story which was written in English by an international student. The length of the stories was within the 3-7 pages range due to the limitations set by the lecturer at the outset.

The findings of the content analysis will be presented below under the headings of the seven categories obtained by the inductive and the deductive methods (Table 1).

3.1 Existence of Innovation

In order to understand whether a story reflects an innovational dimension, we looked for clues in the story. These included the explicit use of the word "innovation", or less obvious clues that evoked from the flow of the story. Finally, we reached the conclusion that 24 of the 48 stories (50%) can be said to have an innovation dimension. Stories that have an innovation dimension can be grouped under three themes: inventions that are made in the 19th or 20th century that have strong influences on our daily lives (e.g. photography & Braille Alphabet) (7/24); the life stories of the inventors of such inventions (e.g. Nicola Tesla & Louise Pasteur) (6/24); the national high budget government projects (e.g. the Istanbul underwater rail system & the construction of the third Istanbul airport) (11/24). Stories that that do not have an innovation dimension include the evolution of some mathematical concepts (8/24), life stories of historical figures of the 'golden years' of Islamic Civilization (7/24).

3.2 Motivation for Innovation

Under this category we analyzed how the PMTs perceive the meaning of the concept of innovation in relation to the definition given in the OECD document. Two motivating factor surfaced in the stories: Need and personal characteristics of the innovator. Most pertinent factor for innovation emerged as need (mentioned 29 times), followed by the personal characteristics (mentioned 11 times). All of the motivating factors under these two main themes are given in Table 2. There are four (not necessarily distinct) themes under the need factor: (1) economical argument (mentioned 11 times), (2) Humanitarian argument (mentioned 5 times) (3) Social argument (mentioned 8 times) and (4) The utilitarian or practical argument (mentioned 4 times).

Table 2. The motivating factors for innovation

	Need				Personal characteristics	Total
	Economical.	Humanistic	Social	Utilitarian or practical		
Insufficiency of the existing system/conditions	*4*	*1*	*1*	*1*		*7*
National security/development	4		1			5
Finding a cure for an illness		3	2			5
Solution of an existing problem	2	1	2	3		8
Existence of complaints		1	2			3
Geographical conditions	1					1
Perseverance					5	5
Purely scientific curiosity					2	2
Genius					3	3
Mental leap caused by the accumulated knowledge.					1	1
TOTAL	11	6	8	4	11	40

3.3 The Development of the Innovation

We analyzed whether or not "how the innovation works" is explained in the stories. Our analysis indicated that provision of an explanation is infrequent (5/24). The story of Braille Alphabet, the Meglev speed train story, the history and evolution of photography, life story of Nikola Tesla contain certain amount of information about the functioning of the system. The attempts, however, lack depth mostly due to the complexity of the system. We also looked at the organization of the work accomplished which yielded that the stories about individual attempts are approximately equal to the stories of teamwork (13/24 & 11/24 respectively).

3.4 The Areas of Innovation

The analysis of the texts indicated that there are six mutually inclusive areas in this category. Transportation has the highest frequency (mentioned 7 times), followed by health (mentioned 6 times), construction (mentioned 5 times), communication (mentioned 3 times), military (mentioned 3 times), and education (mentioned once) (see Table 3).

Table 3. The areas of innovation mentioned in the stories

Area	Military	Construction	Health	Education	Transportation	Communication
Frequency	3	5	6	1	7	3
Example	Design of a vehicle for carrying the personnel in land mined areas	The story of the water canal project combining two regions of the country	The story of Besim Ömer Paşa, the founder of the first maternity hospital in the country	The story of the Braille Alphabet for the education of the visually impaired.	The story of the Eurasia Tunnel Bridge Project	The story of the invention and the development of the cell phone technology

3.5 Time of Innovation

None of the 24 stories that carry an innovational perspective covers the period earlier than the beginning of the 19th century. There are 11 stories that cover the years after 2000, followed by 7 stories of the years 1950-1999, 4 stories of the years 1900-1950 and 2 stories of the years 1800-1899 (Table 4).

Table 4. The areas of innovation mentioned in the stories

Time interval	1800-1899	1900-1950	1950-1999	2000 & later
Frequency	2	4	7	11
Example	Nikola Tesla story	The story of Besim Ömer Pasha, the founder of the first maternity hospital in the country	The Sergei Korolev story: Sputnik Satellite	The story of Aziz Sancar, the first Turkish scientist who win the Nobel Prize.

4. Discussion of the Findings

It is important to develop an innovation culture in young minds. Formal education is an important tool for enhancing innovational thinking, being one of the most important 21st century skill (Bialik & Fadel, 2015). Researchers in the area of education develop new concepts about innovation (e.g. innovational literacy and innovational awareness) in their search to find ways to enhance this culture. This, in itself, requires an innovational outlook in education. Opportunities are sought after within the educational system, from kindergarten to the university to raise innovation related attitudes and skills. Robotics programs, for example, are used in raising innovational literacy among high school students (Erdogan, Corlu, & Capraro, 2013). The burden, in this regard, is on teacher training programs. Teacher researchers in different areas of teaching are trying to find ways to improve innovational skills through innovational approaches. Science and mathematics teacher education carry more important roles.

Two main trends emerged from the analysis of the invention stories. First, almost all of the stories written by PMT reflect the attitude of the scientists towards the status-quo. Breaking the status-quo is emphasized frequently in history of science textbooks and that many historical figures shines through their 'revolutionary' characters in the books about history of science which the teacher candidates might have encountered during their story writings. Ashall (1994), for example had chosen the title for his book 'Remarkable Discoveries' (which was translated to Turkish) to describe the scientific discoveries of the 19th and 20th century. On the contrary, risk taking is lesser emphasized as a feature scientific discoveries in science in the textbooks of history of science (Ronan, 1983). Second main theme relates to the conservative nature of the Turkish society (Yayla, 2008). Taking risks and openness to new experiences are not very favorable attitudes in the Turkish culture.

Innovation is generally perceived as a western-rooted and a novel concept. Inventions made in the past centuries were not generally perceived as innovations unless their influence is directly visible in our current environment (Ronan, 1983). For example, the participants seem to think that electricity and photography are innovations but discovery of complex numbers is not. Moreover, none of the stories that carry an innovational perspective covers the period earlier than the beginning of the 19th century.

The acts of innovation are more likely identified with non-Turkish and non-Islamic figures. There are a few exceptions to this which have innovational outlook but these mostly are about big-budget government projects as in the case of the story of the construction of the underwater tunnel and not about scientist or an inventor. The contribution of the Turkish and/or Islamic scientists is generally written in a classical storytelling manner far from carrying an innovation perspective. National feelings rather than scientific explanations often surface in these

narrations. In the stories of Turkish scientist of the 21st century, an epic style is observable, as in the case of the Aziz Sancar who won the Nobel Prize in Chemistry in 2015. Hence, we can conclude that a comprehensive conceptualization of innovation does not seem to exist in the minds of the participants. It is possible that the cultural factors are responsible for the smallness of the influence of the course.

At the brink of the fourth scientific revolution, enhancement of teacher candidates' awareness and understanding of innovation is a very important challenge for the educators. We believe that possibilities do exist and need to be sought after by the teachers and teacher trainers.

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