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UNDERSTANDING RESEARCH PARADIGMS: TRENDS IN SCIENCE EDUCATION RESEARCH

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Abstract

This essay offers several insights regarding the principles of qualitative and quantitative methods, defining how they shape the empirical process as well as knowledge acquisition in social science research. A comprehensive discussion includes comparing the assumptions and techniques of each paradigm, as well as a description of their respective strengths and weaknesses in research. These paradigms are examined in terms of past trends in science education research, indicating that over the last several decades a shift in approach from the quantitative to qualitative has occurred. The central thesis of the essay contends that methodological decisions should be based in pragmatism, rather than a pre-existent set of philosophies or beliefs irrespective of context. Implications for research are discussed in terms of the findings of several science education content analysis studies, conveying that research methods often coincide with the collective interest of the masses, policy, educational reform or program developments.
Key words: *paradigm decisions, qualitative research, quantitative research, science education, trends*.

Introduction

Rarely contested are notions that within the science education research community empiricism produces knowledge, ultimately resulting in recommendations for the improvement of policy or practice. One may argue that there is more than one way to acquire knowledge in such research, especially when many methodologies are available. Yet, fervent debate has existed over many years between the qualitative and quantitative paradigmatic camps in regards to this issue. This dispute has had implications for research in science education primarily because of world events, such as the launching of Sputnik in 1957, as well as changes in the teaching ethos in classrooms. The inherent problems associated with the methodological guidance of research often begin with concerns of quality, research focus or considerations of what constitutes empirical fidelity (Jenkins, 2000). Historically, Thomas Kuhn's (1962) seminal work, *The Structure of Scientific Revolutions* prompted the debate of what truly constituted epistemological inquiry and knowledge. The movement came to be known as the "paradigm wars" between parties believing that the two approaches possessed diametrically opposed values within each set of assumptions (Hill, LeGrange, & Newmark, 2003). Purportedly, an incompatibility existed that was impossible to resolve without betrayal of one philosophy for another (Howe, 1988). Around the time of Salomon's (1991) thesis, one in which it was claimed that compatibility was possible, did the paradigm dispute begin to take on further revisions of thought. This led to what some considered the emergence of a third paradigm (Burke-Johnson & Onwuegbuzie, 2004), or the belief that the researcher could be partisan in approach (Jenkins, 2000). Salomon reasoned that each approach was seriously limited when isolated, contending that both qualitative and quantitative methods must be used concurrently, thus resulting in more complete knowledge. Moreover, that one method could supplement the

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other method's weakness, thus bolstering the understanding of the phenomena under study. The following discussion supports the notion that research decisions should be based on situational conditions, not long-standing personal philosophies or beliefs.

Mixed methods research and design has set the stage for what some consider a dualistic method based on pragmatism. Pragmatism epitomizes John Dewey's idea of finding what works in building knowledge among those who seek to advance scientific truth (Creswell & Plano-Clark, 2007). Though there are numerous characteristics of pragmatism, the one advanced in this discussion is based on the principle of context, or that questions of research dictate qualitative, quantitative, or mixed methods (Malcolm, 1999). In this view, combining methods is deemed the preferential manner in which one can expect to arrive at knowledge of greater completeness. Pragmatism suggests that the methods in which one investigates a series of well-constructed research questions will result in a better understanding of human learning in the social sciences (Burke-Johnson & Onwuegbuzie, 2004), and in the case presented here – science education.

In a society that values evidence-based results, such as in the field of medicine, how does one rectify the differences between the paradigms in order to justify courses of action taken in science education research? Moreover, how have the assumptions and techniques of the qualitative and quantitative research paradigms coincided with past research in science education? The answers to these questions are not only found when one evaluates the types of research questions being asked, but with what one hopes to accomplish with the new found knowledge (Berliner, 2002; Feuer, Towne, & Shavelson, 2002).

Regardless of the reason, a more comprehensive discussion is warranted for those interested in applying or advancing the benefits of either method, alone or in concert, in science education research. Therefore, comparing assumptions and techniques of both qualitative and quantitative research paradigms should provide a clearer understanding for this purpose, urging those involved in research development to base decision-making on what will work for them in their particular context. Incorporating this type of approach to research can satisfy the needs and mandates of a wide variety of stakeholders, including educational researchers, project evaluators, practitioners and initiators of policy or reform.

Qualitative Research

According to Glesne (2006), qualitative methods strive to understand some type of social phenomena through the perspectives of the individuals involved. Two major assumptions include a predisposition that reality is socially constructed and that the variables in a situation are highly complex, interwoven and difficult to measure. The purpose of such research is to contextualize, understand and interpret a situation. Typically, qualitative research begins with some type of inductive inquiry, resulting in a hypothesis or participant generated theory. The researcher is considered the main instrument in a setting that is as naturalistic as possible. The methods involved require a high level of descriptive writing and attention to detail. Moreover, a significant amount of time to collect and process the data is required. The researcher is directly involved with the research in a personal way.

The various methodologies of qualitative inquiry allow a researcher to choose a strategy that is best suited for his or her purpose. Examples of qualitative research include ethnographies, grounded theory, case studies, phenomenologies and narratives (Bogdan & Biklen, 2003; Creswell, 2003; McCaslin &Wilson-Scott, 2003; Patton, 2002). Each methodology relies on specific protocols such as interviews, observations, content analysis, fieldwork, video and audio-taped transmissions, surveys or open-ended questionnaires. Denzin and Lincoln (2000) suggest that data resulting from qualitative research should be "thick" in description, meaning that it go beyond surface explanation, expressing in-depth understanding not possible with quantitative methods. The methods of qualitative research are concerned with process, or how

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something occurs within the confines of the inquiry (Patton, 2002). The researcher constructs, analyzes and interprets data in a non-linear, non-chronological fashion.

Rossman and Rallis (1998) suggest that the methods of qualitative research are a highly interactive open-ended process. These interactive methods are subjectively interpretive, reflecting the experiences, values and biases of the researcher. Qualitative research significance or trustworthiness is determined by how compelling the researcher's narrative is pieced together to explain the process as well as the results found. The components of this trustworthiness as explained by Guba (1981) cited in Krefting (1991) consist of truth value or credibility, applicability within the context or setting, consistency or whether similar results would be found with participants in a related context, and neutrality or freedom of researcher bias.

The validity of qualitative research is dependent on how a study regulates and cross-checks its data (Krefting, 1991). Mathison (1988) and Denzin (1978) describe one such method as triangulation, or an approach to improve the validity of one's findings. Specifically, triangulation seeks to provide a holistic portrayal of a phenomenon, social or otherwise, in which multiple data sources are aligned in a way to allow for the confirmation of a finding or implication. Triangulation also can assist the researcher in determining the point at which to cease the study's inquiry. Moreover, when data being collected begin to repeat from various sources to a point of redundancy, it is said to be saturated. It is at this point that the researcher could take the position that all data intended to be discovered has occurred.

Fundamental qualitative researchers justify their preference for the method because of their deep-seeded beliefs that knowledge is constructed as a result of personal experience. This type of research is said to be in the realm of social constructivism. In this paradigm, proponents argue that knowledge is subjective and is interpreted through the perspective of the viewer. Thus, truth is based on multiple constructions of reality which cannot be formulated free of bias. Truth is said to have an inability of being subject to any type of broad-based generalization because of its situational "context" (Creswell, 2003; Creswell & Plano-Clark, 2007; Lincoln & Guba, 1985, 2000; Schwandt, 2000).

Qualitative inquiry can provide insights to multifaceted, complex social situations or problems. As a result, an individual's personal experience with a phenomenon is revealed, placing that experience into a more meaningful context. The nature of this type of inquiry requires the researcher to investigate a limited number of cases very closely. As a result, an individual's personal experience with a phenomenon is revealed, placing that experience into a more meaningful context. Because the integrity of the social *context* is upheld, the research can have a more responsive effect on immediate situations of the participant. The focus of study in qualitative research can shift at any moment during the process. This flexibility is indicative of how phenomenon that would have otherwise been overlooked, missed or not considered is less likely to occur. How and why questions can be answered when a researcher uses qualitatively designed research. This aids in the exploration of phenomena related to the experiences of the participants. The causes of particular events can be examined in this regard (Burke-Johnson & Onwuegbuzie, 2004). However, some argue that situational causation cannot be determined in qualitative research because single, or limited, cases cannot merit such inferences (National Research Council [NRC], 2002). Qualitative research can be used as a tool for the evaluation of various programs and program materials. This provides the participants and stakeholders with immediate feedback upon the completion of the evaluation (Patton, 2002).

Qualitative results cannot be robustly generalized to other groups or populations of interest. This reflects how a low number of participants involved during an investigation are exclusive to only that situation. The credibility of qualitative findings are loosely supported as strong scientific evidence in a number of different venues in the social sciences, including with administrators and commissioners of programs (Berliner, 2002), in past legislation (No Child

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Left Behind [NCLB], 2001), by the government and in certain reform efforts (Feuer, Towne, & Shavelson, 2002; National Research Council [NRC], 2002).

Quantitative Research

The use of quantitative methods in the social sciences can be described as a way of acquiring knowledge based on broad generalizations across greater populations. The proponents of this paradigm are concerned with generalizing outcomes or predictions as a means of explaining specific events. Major assumptions include the belief that social facts have an objective reality outside the subjective perspective of the individual researcher. Because of this, the researcher plays a detached role as an investigator of a phenomenon and should in no way interfere with the study findings. Specific variables are narrowly identified, focused and categorized so that the relationships between them become apparent through some type of experimentation or correlational analysis. The experimental nature of the quantitative paradigm is deductive, meaning that inquiries progress from the general to the specific. Data that is collected is subsequently condensed through numbers, indices and statistics related to the research design (Glesne, 2006; Libarkin & Kurdziel, 2002). Advocates of this paradigm generally imply causation between a carefully crafted set of variables in a rigid or quasi-experimental design. The research approach typically begins with the testing of a hypothesis or theory through the use of formalized instruments. These instruments must be shown to be both reliable and valid in measuring the phenomena of interest prior to use. Some examples of the strategies used in the quantitative paradigm include studies of correlation, causation-comparison, true and quasi-experiments, and survey research. Each study has its own design and set of statistical approaches as applied to the measurement of the variables specified in the research questions (Isaac & Michael, 1995).

Quantitative research can be generalized to other populations of interest, assuming certain statistical assumptions are met. Generalizations of research results typically occur when findings hold strong dependencies on the random choice within and across similar populations being investigated. Lending credibility to causation, quantitative research can explain cause-and-effect between closely monitored independent and control variables. One of the most notable strengths of quantitative research is that it can be construed as more credible to administrators, policy makers, and individual organizations that fund programs or related research projects (Feuer, Towne, & Shavelson, 2002). On the hand, the researcher's agenda or hypothesis testing may not reflect the needs of those immediately involved. Because of strict constraints placed on variables, the researcher may pass up opportunities to build new theory around observed phenomena. The direct application of the findings may also be inhibited due to high levels of abstraction in the results (Burke-Johnson & Onwuegbuzie, 2004).

Paradigmatic Comparisons

Creswell and Plano-Clark (2007) summarize the comparison between qualitative and quantitative research in respect to process:

1. Qualitative research seeks to understand meaning individuals give to a phenomenon inductively; quantitative research tests a theory deductively to either support or refute it.
2. Qualitative research typically asks open-ended questions, seeking to understand the complexity of a single idea or phenomenon. Yet, can include close-ended questions in certain circumstances; quantitative research asks close-ended questions that test specific hypotheses or questions. These questions may be open-ended depending on the

use of statistical procedures designed to explore a given phenomenon quantitatively.

3. Qualitative research identifies the personal stance of the researcher; the quantitative researcher remains in the background and takes precautions to remove bias.
4. Qualitative research validates data using validity procedures that rely on the participants, the researcher or the reader; Quantitative research validates data using validity procedures based on external standards, such as judges, past research or statistics.
5. Qualitative research uses literature scantly in justifying the problem; quantitative research uses the literature in a major way to justify the problem under investigation and to identify specific questions and hypotheses.
6. Qualitative research collects data in the form of words and images, from few participants at a few research sites, and studies the problem at their location; quantitative research analyzes data using numbers from many participants in many research sites, where the instruments are either sent or administered to the participants (p. 29).
7. The basis for qualitative research is phenomenology, or the organized and postulated report from the first-person perspective; quantitative research embraces the positivism tradition, or the notion that conditions for inferring outcomes are rooted in contingencies surrounding cause and effect and logical progression.

Each approach, either alone or in collaboration, can lend itself to a different set of outcomes as a result of an investigation. These comparisons delineate potential strengths or weakness for each respective paradigm. In knowing this, one can improve the likelihood of answering research questions more expansively when certain aspects of either method are implemented during research.

Qualitative and Quantitative Trends in Science Education Research

Over the course of the last several decades, science education has employed both quantitative and qualitative research paradigms to study questions and topics under various conditions. Such research has been drawn from multiple paradigms, including but not limited to perspectives from philosophy, psychology, sociology and economics (Cunningham & Helms, 1998; Jenkins, 2000; Treagust, 2004). It is no surprise that science education research has employed both paradigms in appraising the merit of academic decisions and educational policies (Bassey, 1995). Understanding paradigmatic trends can be useful in understanding past research practice(s) in order to aid the development of new approaches with collective "mixed method" design. Nonetheless, a series of recent content analysis studies indicate that there has been a significant shift in paradigms from the quantitative to the qualitative (De Jong, 2007; Tsai & Wen, 2005; White, 1997).

White's (1997) work exemplifies the existence of such a shift. Content analysis of *Research in Science Education* sampled between the years 1966 and 1995 indicated that fewer hits for the words "constructivism" and "discovery" were found within article titles in the early years. On the other hand, many hits for words like "laboratory" surfaced instead, indicating widespread use of quantitative methods. The number of hits for the word "laboratory" remained strong, up until a slight decrease in the early 1990's. Hits for the words "constructivism" or "constructivist" were virtually non-existent at the beginning of the search years, but gradually increased over time, indicating that more studies became qualitative in nature. White also found that the style of research corresponded to the type of research question asked. For example, questions such as the following were asked during analysis: "Was there a contrived intervention, or merely the gathering of information? Did the study involve measuring correlation between variables, or was there comparison of one naturally-occurring group with another? (p. 217)." The most notable finding was that experimental and curriculum evaluation studies were being

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replaced with descriptive inquiries or studies of personal accounts of classroom practices. These practices were documented with interview techniques and qualitative-based data gathering. White describes this shift as a movement away from the psychological (experimental or quantitative) and toward a more historical or journalistic (qualitative) one. Other analysis also showed that the number of interviews and observations increased drastically from 1975 to 1995, along with a corresponding decrease in the use of inferential statistics. For the chosen sample years and with this particular content analysis, more qualitative designs were being implemented in science education research.

A similar content analysis study carried out by Tsai and Wen (2005) found that between 1998 and 2002 research reported in the *International Journal of Science Education*, *Science Education* and *Journal of Research in Science Teaching* was both rigorous and empirical in nature. However, they left undefined the categorizations of this research according to the paradigms. Despite this, findings appeared to signal that the qualitative paradigm had gained ground in recent years. For example, topics related to student learning contexts, conceptual change, social, cultural and gender issues increased in popularity. These areas are often examined most effectively through the qualitative means, considering they deal with complex social issues and related challenges (Glesne, 2006). Ultimately, Tsai and Wen suggested that the variability of research trends in science education was found to be in state of flux, primarily due to the diversity of research goals or objectives found among researchers in various international contexts.

More recently, De Jong's (2007) content analysis yielded similar findings with those of both White (1997) and Tsai and Wen (2005). Analysis of the *Journal of Research in Science Teaching*, the *International Journal of Science Education*, and *Science Education* over the previous 50 years showed only slight differences in the categorization of trends. Yet, De Jong contended that science education had responded to different "waves of reform" and influential psychological theories by adjusting the methodologies accordingly. Analysis examined specific topics of study, which research methods were most widespread and what developments were most influential to the field of science teacher education. In the earliest sampling of years (1960's), quantitative methods were dominant, and in more recent times (2000's), qualitative methods commanded a greater presence. The quantitative methods were described as matching large-scale educational psychology investigations of the 1960's, some of which included enacting learning tasks outside of school settings. However, the qualitative research methods during this time were reportedly smaller in scale and more classrooms oriented. Increases in "design research" or project evaluation type studies explained the shift to the use of more qualitative orientated methods. Developed science education programs had increased during this time, requiring evaluation methods that could carefully examine the outcomes related to program objectives, aims or underlying frameworks. Other indicators of this paradigmatic shift included trends in the types of instruments used to gather data. In the earlier years, data was collected with quantitative instruments, taking the form of surveys or questionnaires. In the later years, there were more qualitative instruments, such as interviews and observations.

Most recently, research trends reported by Cavas, Cavas, Ozdem, Rannikmae, and Ertepinar (2012) indicate, albeit indirectly, some similarity in findings as those reported by Tsai and Wen (2005). Although research by Cavas et al. did not explicitly categorize qualitative or quantitative trends in their analysis, they offered some useful indicators of the trends as demonstrated by researched topics. Their study examined 166 articles published in the *Journal of Baltic Science Education* from 2002 to 2011. A comparable procedure as employed by Tsai and Wen was selected to review applicable articles. In that regard, qualitative trends continued to be evidenced, as there have been increases in research related to learning-conception, teaching and learning-context. Again, these areas are often examined more effectively through the qualitative means, considering they deal with complex learning situations and settings (Glesne, 2006). On

the other hand, research related to goals, policy and curriculum were also evidenced, indicating that quantitative approaches may have recaptured some interest. The presence of large-scale reforms mandated for improvement of science education is the likely agent of this trend. Such research areas are best supported through quantitative means because they satisfy the needs of administrators, policy makers, and individual organizations that fund various programs or related research projects (Feuer, Towne, & Shavelson, 2002; Guven, 2008). Cavas et al. also found that the attention being paid to cultural, social and gender issues has waned. Evidence of those types of qualitative trends *as inferred by researched topics* was in contradiction to those reported by Tsai and Wen.

Conclusion

Relevant content analysis studies (Cavas et al., 2012; De Jong, 2007; Tsai & Wen, 2005; White, 1997) have revealed that within the most recent decades, science education research has been under the auspices of the qualitative paradigm. Undeniably, the justifications for this originate with methodological pragmatism. Topics of interest in science education have changed dramatically since the early 1960's and 1970's, foreshadowing the need to understand phenomena in its immediacy, rather than risk generalization of an outcome to a population without similar, if not identical characteristics. During the early years, researchers were more interested in theory verification or testing to provide evidence as dictated by various reforms or outside entities. Many were studying the effects of different types of science curricula or methods of instruction on student achievement. As such, perspectives regarding student learning, conceptual understanding and other variables have influenced this change. Many interests evolved into the study of classroom experiences and related science education programs. Each experience is often set in its own particular context, thus requiring a research method to reflect a deeper understanding of the situation. Jenkins (2000) argues that the qualitative paradigm has augmented the stronghold of the quantitative tradition because of its ability to define otherwise undetectable subtleties within educational teaching and learning. This could have considerable implications for those interested in explaining any number of factors related to student achievement or other high-stake areas. Given the multitude of highly contextualized settings that exist in science education today, understanding multiple paradigmatic viewpoints within research can offer to further explain such areas without threatening the integrity of empiricism.

The inference that quantitative methods have lost favor with researchers in science education would be erroneous. Rather, interpretations of the trends reported here should be regarded as methodological functions subject to change in response to the current educational milieu. As such, and in consideration of the most current examinations of research trends, it appears that some quantitative approaches have begun to reemerge on an international scale because of the ever-present need for governmental entities to usher in mandates that seek to improve the status of science education – especially in countries such as Turkey (Cavas et al., 2012). This may certainly be the case in other areas of the globe. Yet, the non-existence of any reference to mixed methods categorization in the discussed trends might indicate that suggestions for a *third* paradigm might not be taking hold as a separate, universally accepted branch of empirical research. Instead, such a method might exist as an integrated addendum to data collection, meant to strengthen the implications of research outcomes. Nevertheless, those intending to more fully embrace the paradigmatic camps either simultaneously (Creswell & Plano-Clark, 2007) or apart from each other (Creswell, 2003) for science education research are encouraged to consider not only the discussion outlined here, but also the how current research trends are depicted in accordance to the collective interest of the masses, policy, educational reform or program developments.

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