

A Capsular Model for Developing Student Teachers' Pedagogical Content Knowledge for Nature of Science

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Abstract

This paper reports the findings from trying out a capsular model for developing student teachers' pedagogical content knowledge (PCK) for nature of science and nature of scientific inquiry. The study used a pre-test, intervention and post test design. The participants were a group of ten student teachers involved in a Post Graduate Certificate in Education (PGCE) Physical Science Methodology Course, for teaching Grades 10-12 of the South African Physical Science curriculum at a South African University. Participants' gains in PCK for nature of science, nature of scientific inquiry and how to teach these aspects were ascertained through: pre and post testing their subject matter knowledge and assessing the qualities of the teaching plans they produced before and after going through the programme. The results show that the capsular model is effective way for developing student teachers' pedagogical content knowledge for and abilities to craft pedagogical strategies for teaching.

1. Introduction

The development of teachers' pedagogical content knowledge for teaching nature of science (PCKNOS) has been receiving much research interest and focus from science education researchers during the last ten years [24]. The nature of science (NOS) refers to the ideas, beliefs, perceptions and values about scientific knowledge and the processes through which it is developed and validated [25]. There appears to be consensus that the development of teachers' understandings of the NOS and teachers' abilities to teach about the NOS and the nature of scientific inquiry (NOSI) can go a long way towards promoting scientific literacy as a goal of science education. While this is so, Hanuscin et al. [12] point out that a lot still needs to be known regarding the sources, nature, and development of teachers' pedagogical content knowledge (PCK) for teaching NOS. Drawing from the works of Bruner's [4] influential work on cognitive psychology, Ausubel's [2] Assimilation Theory of Cognitive Learning and Shulman's [20] work on pedagogical content knowledge (PCK), Bartos and Lederman [3]

examine what they call teacher knowledge structures for nature of science (NOS) and scientific inquiry (SI) and how these are communicated in teacher classroom practices. Subject knowledge structures are about the teacher's knowledge of discipline knowledge and abilities to restructure that knowledge and present it in a purposeful, creative, comprehensive, open and dynamic manner [6], so as to make it meaningful and comprehensible to learners. While there appears to be agreement that for teachers to teach learners effectively about the nature of science (NOS) and scientific inquiry (SI), they themselves must have a comprehensive understanding of these constructs; research to date has failed to address the issue of how effectively that knowledge might be developed in teachers in order to develop appropriate knowledge structures and abilities to teach. Furthermore, research has failed to clearly delineate what it that must constitute appropriate teacher subject matter knowledge (SMK) for teaching NOS and NOSI.

The knowledge structure of a teacher and that which is essential for effective classroom practice comprises of a matrix of components including subject matter knowledge, professional knowledge, cultural, historical, philosophical, psychological, sociological and practical knowledge [6, 19], from which appropriate disciplinary wisdom, knowledge and technical knowhow might be distilled and crafted for presentation to learners. Additionally, the teachers' own experiences in learning the subject to be delivered consciously or unconsciously bears upon the teacher's mastery and presentation of the subject matter to learners [24]. This is irrespective of the disciplinary knowledge required, whether it is about chemical equilibrium in Chemistry, waves in Physics, genetics in Biology or about the nature of science (NOS) and scientific inquiry (SI). It is widely accepted that the manner in which teachers are prepared greatly influence both their subject knowledge mastery and abilities to deliver in the classrooms [7, 8, 13].

Accordingly the purpose of this study was to determine how a pre-service teacher preparation model developed teacher pedagogical content knowledge regarding the nature of science (NOS) and nature of scientific inquiry (NOSI). Specifically

the study was guided by the following research questions:

- (i) To what extent was did the capsular model develop pre-service teacher subject matter knowledge understandings of the nature of science (NOS) and the nature of scientific inquiry (NOSI)?
- (ii) To what extent was the model effective in terms of teacher abilities to produce sound teaching plans for teaching learners about the NOS and the NOSI, as part of teaching Physical Science content at the Grade 11 level of the South African Physical Science curriculum?

2. Conceptual framework

Essentially, the capsular approach or model involves first teaching teachers about elements of the history of science, the philosophy of science, the sociology of science, aspects about scientific literacy and then introducing teachers to aspects of the nature of science and then introducing them to pedagogical aspects about how to teach learners about selected tenets of NOS and NOSI. Tenets of the NOS and NOSI are ideas about scientific knowledge and the processes of its development and validation which are generally held to be true by the science education community [23].

The capsular model Deriving from the work of Duschl [9], Duschl and Grandy [10, 11], and Van Dijk, [22], my capsular model is based on the premises that in order for teachers to teach NOS and NOSI effectively they also require substantive knowledge base of the history, philosophy, psychology and sociology of science; aspects of scientific literacy as well as the practice of science as a form of inquiry. When following this model, teachers do a module during which they are taught about aspects of the philosophies of Thomas Kuhn, Karl Popper, Imre Lakatos and Paul Feyerabend. Additionally various philosophies of science ranging from objectivist to constructivist are explored. They have lectures on the history of science- with major focus on development of atomic theory. As a part of the module they are required to do readings on the philosophers and the history of science including the development of atomic theory. An assignment is given requiring them to reflect on philosophical and historical aspects of science. Additionally, they are given lectures on what scientific literacy is and why it is an important goal for science education, required to read readings on the history of science education and papers on scientific literacy including by Laughksck [14] and given an assignment based on these aspects. Lastly they are taught about NOS and NOSI tenets and given an assignment which includes preparing a lesson for teaching learners about a selected aspect of the NOS and the NOSI, at the Grade 11 level of the South African Physical science curriculum. As part of this they were asked to

describe, explain, illustrate and justify how their teaching plan would explicitly bring about learners' understanding of selected aspects as well as assess learners' understandings.

The module is based on the premises that encasing SMKNOS within a layered capsule, with the history, philosophy, psychology and sociology of science forming the periphery, moving deeper into inner layers of subject matter knowledge for scientific , can bring about better teacher understandings. Gains in both substantive and syntactic SMKNOS are anticipated. Figure 1 below shows a summary of the model.

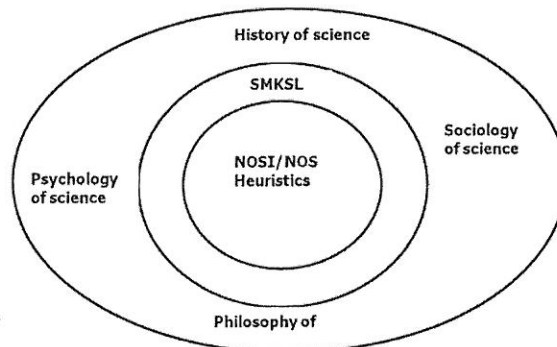


Figure 1. Capsular model for developing teachers' subject matter knowledge for nature of science

At the same time, the model proposes making sense of SMKNOS through a hierarchical curriculum and pedagogical approach as shown in Table 1. This approach can also aboard the spiral disciplinary structures taking elements from Bruner [4] and Ausbel [2]. My argument is that if understanding of the NOS cannot be separated from practicing and experiencing inquiry, then a pedagogical model as shown in Table 1 would be logical. The suggestion is that it is possible to map and develop SMKNOS content along the lines shown in Table1.

Table 1. Matching teaching of NOS teaching to levels of inquiry

Group	Characteristics	Nature of knowledge focus
NOS/NOSI Heuristics uncoupled	List of tenets teaching independent of science subject matter no involvement in inquiry	substantive
NOS/NOSI heuristics content coupled	teaching of tenets coupled with specific concepts/topics in science with low levels	substantive

	of inquiry	
NOS/NOSI heuristics content coupling and practices of science	teaching of NOS/NOSI heuristics tenets coupled with specific concepts/topics in science together with medium practices of inquiry	substantive
NOS/NOSI heuristics content coupling and practices of science	teaching of NOS/NOSI heuristics tenets coupled with specific concepts/topics in science together with high level practices of inquiry	Substantive and syntactic
NOS/NOSI / scientific literacy /heuristics content coupling and practices of science	teaching of NOS/NOSI/ scientific literacy heuristics tenets coupled with specific concepts/topics in science together with high level practices of inquiry	Substantive and syntactic
THE CAPSULE NOS/NOSI/ Scientific literacy History, sociology, psychology, philosophy of science elements	teaching of NOS/NOSI/ scientific literacy heuristics tenets coupled with specific concepts/topics in science together with high level practices of inquiry introduction to history, sociology, psychology, philosophy of science elements	Substantive and syntactic

3. Teacher abilities to produce sound teaching plans and aspects of NOS and NOSI

Teacher abilities to produce sound teaching plans and aspects of NOS and NOSI

In addition to determining student teacher abilities to produce sound teaching plans for NOS and NOSI the model specifically aimed to develop teacher knowledge of the following tenets as described by Bartos and Lederman [3]:

Aspects of nature of science (NOS) (1) scientific knowledge is empirically based; (2) observations and inferences are qualitatively distinct, in that the former are directly accessible to the senses while the latter is only identified through its manifestation or effects; (3) scientific theories and scientific laws are

different types of knowledge; (4) the generation of scientific knowledge requires, and is a partly a product of, human imagination and creativity, from generating questions to inventing explanations; (5) scientific knowledge is theory-laden (i.e., influenced by scientists' prior knowledge, beliefs, training, expectations, etc.); (6) scientific knowledge both affects and is affected by the society and culture in which it is embedded; and (7) scientific knowledge, while reliable and durable, changes. Aspects of scientific inquiry (SI)

(1) scientific investigations always begin with a question; (2) there is no single set or sequence of steps in a scientific investigation; (3) the procedures followed in an investigation are invariably guided by the question(s) asked; (4) scientists following the same procedures will not necessarily arrive at the same results; (5) the procedures undertaken in an investigation influence the subsequent results; (6) conclusions drawn must be consistent with collected data; (7) data are not the same as evidence; and (8) scientific explanations are developed through a combination of evidence and what is already known.

4. Methodology

4.1. Data collection

This study used a one group, pre-test-posttest design [5]. The group completed two pre tests (questionnaires), namely, one measuring their understandings or beliefs about the nature of scientific knowledge and nature of scientific inquiry [1] and The Views About Scientific Inquiry (VASI) [14] at the beginning of a seven week programme. The two questionnaires were also completed by both groups at the end of the programmes. At the end of the programme the qualities of lesson plans developed to teach the selected aspect (s) on teaching NOS and on teaching NOSI were evaluated, using a rubric.

4.2. The participants

The group (n =10) who participated in the capsular based programme, were students studying for a Post Graduate Certificate in Education specializing in Physical Sciences Methodology. Six of the participants were female and 4 were male. All but two of the student teachers had no experience teaching Physical Science at the Grades 10-12 level of the South African Physical science curriculum. All the participants had never done anything on NOS and NOSI before and held B.Sc. degree. They had all taken Physical Science as their content major for this degree.

4.3. Data analysis

Quantitative data analysis on NOS and NOSI

For understandings or beliefs about the nature of scientific knowledge and nature of scientific inquiry questionnaire (BASSQ), student teachers' responses were scored (with reverse scoring where appropriate) on the five-point Likert-type frequency response scale following the procedure used by [1]. Thus items were allocated 1, 2, 3, 4, or 5 points for the respective categories: Almost Never, Seldom, Sometimes, Often and Almost Always. In our case a higher score (>70% of the total score on the ten items on each subscale category) represents constructivist view or understanding of NOS or NOSI and a lower score a positivist or objectivist understanding. Results are only shown here for those who were constructivist, in the pre and post test computed as a percentage of student teachers. For example 3/10 translates to 33.3% of group scoring greater than 70 % on the ten items, i.e. classified as constructivists for the total score on the ten items added together, with reverse scoring. For the VASI, responses were analyzed to give an indication on whether the student teachers gave an informed, mixed or naïve understanding of the eight aspects of inquiry on each of the eight items listed above similar to what was done by Gaigher, Lederman and Lederman. For this paper only percentage shift for student teachers who had informed understandings from the pre to the post-test is shown as the interest was in determining the effectiveness of the model.

Qualitative and interpretive analysis of teaching plans the student teachers' plans were assessed using a rubric designed according to selected aspects from Duschl and Grandy [11] and constructivist reflection oriented teaching approaches. The following criteria were included: (A) Was the teaching plan based on explicit rather than implicit approaches?; (B) Did the plan couple NOS and/or NOSI teaching with Physical Science content; (C) Was there planning for explicit assessment of learners NOS and/or NOSI understandings; (D) immersion of learners in cognitive, epistemic and social enactments and practices of science; (E) promotion of core discourses of science -e.g., talk/argument, models/representations; critique and communication; (F) asking learners to reflect on their NOS and NOSI understandings; (G) inclusion of philosophical views from different science disciplines; and (H) used history of science cases in a holistic way.

Results from the beliefs about the nature of scientific knowledge and nature of scientific inquiry questionnaire.

Figure 1 shows a comparison of pre and post test of student teacher subject matter knowledge understandings of the nature of science (NOS) at the beginning and end of the programme. As can be seen the student teachers as a group shifted from towards

showing more informed ideas of NOS. Figure 2 shows a comparison of the pre and post test performance of student teacher understandings of the nature of scientific inquiry (NOSI) at the beginning and end of each programme. Overall, the results show that the capsular model was effective in shifting the student teachers ideas from being naïve to being informed.

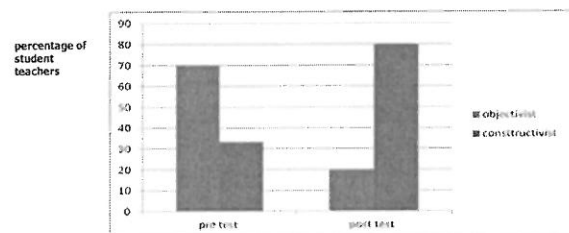


Figure 1. Shift in student teachers' NOS ideas from objectivist to constructivist in pre to post test based on BASSQ

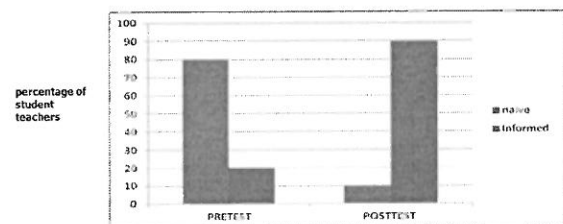


Figure 2. VASI questionnaire shifts in student teachers' NOSI ideas from naïve to informed in pre and post test

4. Results from qualitative and interpretive analysis of teaching plans

Overall, our findings were that the qualities of teaching plans produced by student teachers in the post test were much higher than those produced by teachers in the pretest. For example all the teachers during the post test asked learners to reflect on their NOS and NOSI understandings.

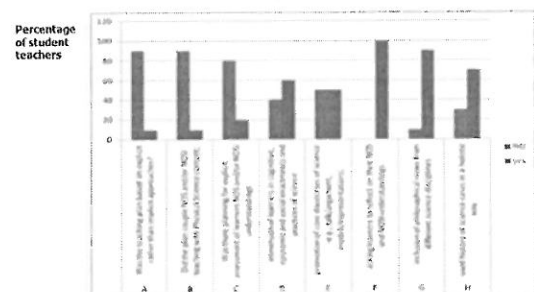


Figure 3. Results from qualitative and interpretive analysis of teaching plans

However surprisingly no shifts were observed in terms of promotion of core discourses of science -

e.g., talk/argument, models/representations; critique and communication.

5. Conclusions and recommendations

Overall the results suggest that the capsular model is effective way for developing student teachers' PCKNOS –their SMK understandings of both the NOS and NOSI and abilities to craft pedagogical strategies for teaching. This supports suggestions by of Duschl [9], Duschl & Grandy [11] and Van Dijk, [22], who argue that in order for teachers to teach about NOS and NOSI effectively, they require substantive knowledge base of the history, philosophy, psychology and sociology of science; aspects of scientific literacy as well as the practice of science as a form of inquiry. It is possible that teachers who are exposed to these aspects develop much deeper knowledge and more organized knowledge structures for nature of science (NOS) and scientific inquiry (SI) [3] and are thus more capable to craft better and sound pedagogical strategies for teaching.

Thus, for purposes of preparing teachers to teach about NOS and NOSI, it is necessary that science teacher trainers in universities and teachers colleges when preparing teachers for achievement of the goals of science education for scientific literacy to approach content preparation following a layered capsule, with the history, philosophy, psychology and sociology of science forming the periphery, moving deeper into inner layers of subject matter knowledge for scientific literacy (SMKSL) and NOSI/NOS heuristics. This approach followed by introduction to pedagogical strategies for teaching these aspects could be more effective compared to simply teaching the NOS and NOSI aspects as heuristics to be passed on to the learners. The teacher training experience from the current study point towards teacher, gains in both substantive and syntactic SMKNOS and SMKNOSI following the disciplinary approach of the capsular model.

6. References

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