A Study of the Role of the Science Teacher in Light of Michael Polanyi's Epistemology

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Abstract: Science education has been in a state of crisis for some time. To understand the science teacher's role, it is helpful to reconsider an aspect as fundamental as the nature of science. Since teaching cannot be separated from learning and knowledge, their very close dynamic processes need to prescribe the role of the teacher and student simultaneously. However, traditional views are limited because they tend to emphasize some particular selected aspect of learning and teaching. This paper investigates the epistemology of Michael Polanyi (1891 1976), which is often considered to transcend the confrontation between objectivity and subjectivity of knowledge. Polanyi reconceptualized science knowledge as 'personal knowledge' based on his own experience as a scientist and a thinker. In this study, I discuss 1) the nature of science in light of Polanyi's epistemology, 2) what this says about the meaning of science learning and teaching, 3) the potential of these ideas for the role of the science teacher.

Key words: Michael Polanyi, epistemology, the nature of science knowledge, personal knowledge, science teaching, the role of the science teacher

I. Introduction

Science education has entered a crisis. Science has been considered as a difficult and dull subject among students. Most of the students seem to be not interested in science; it is even very clear that they tend to avoid basic science subjects like physics. As a result, student recruitment is decreasing in post-compulsory science classrooms (Korean Institute for Curriculum and Evaluation, 2002). Therefore, international trends in science curriculum redevelopment are demanding new roles for science teachers in practical aspects. It is acknowledged that science education in our time has fallen short of meeting the needs of current students and society in perceived relevance even though education has to reflect and satisfy the needs of its time. However, this subject requires deeper exploration: it is a fundamental function of education to develop the human mind as the source of knowledge. From this point of view, there are two major values that lead human education: 'utility' and the 'reality'. Balancing these two needs requires a theoretical understanding of our education in whole. Theoretical understanding initiates practical methodologies. Nevertheless, current approaches to science education have lacked efforts to arrive at a theoretical understanding of education, compared with pragmatic recipes. In this paper, I ask if there might be more a fundamental role for the teacher.

In fact, the crisis of science education is as fundamental as the nature of science knowledge, and science education should be refocused, because it is not independent of incorrect understandings of the nature of science knowledge, learning, and teaching. An interest in 'good teaching' is emerging as a way to overcome this worldwide crisis among science educators. Seeking good teaching is also to ask for an understanding of the nature of knowledge. Epistemology is one of the fields of philosophy that reveals the essential nature and methodological condition of knowledge that equates with truth, and education considers acquiring knowledge and pursuing truth its most basic and important functions.

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Epistemology and education are inseparable because they both make 'knowledge' a common theme. Consequently epistemology has deeply affected science education since the modern age (Kim, 2003). In this study, therefore, I employ epistemological concerns as a theoretical background for science education.

Traditional science education, as well as other disciplines, has been grounded on objectivism based on partial understanding and analytic methodologies. In particular, inductivism has been the dominant philosophy among the various styles of objectivism and has grown even stronger under the influence of logical positivism. Modern science, which has achieved dazzling progress since the seventeenth century, has become a powerful academic paradigm, and has even developed into scientism among ordinary people. Yet, the darker side of this scientific and technological development, by causing a variety of ethical and social problems, has provided a reason to invite the rise of post-modernism in the twentieth century. A prominent aspect of postmodernism has been to provide a deconstructive critique of modern rationality, substituting relativism for claims to an absolute. This relativistic philosophy is already being reflected in science education (Yager, 1996). The new paradigm of science education that emerged in the late twentieth century has converged on constructivism, which could be interpreted in the context of relativism (Matthews, 1994). Present STS education is also influenced by a relativistic philosophy of science, which emphasizes the social context of science (Ziman, 1980). The competing perspectives on science education differ from each other concerning the nature of science teaching and the teacher's role. Constructivism emphasizes a student's spontaneous activity while traditional objectivism justifies the teacher-centered class. It is my contention that these views are limited by their emphasis on some selected aspect of teaching and learning.

Teaching cannot be separated from learning and knowledge and their very close dynamic processes prescribe the role of the teacher and the student simultaneously. Insight into this relationship can be gained through attention to the work of Michael Polanyi (1891-1976), who opened a new chapter of epistemology that transcended the confrontation between objectivity and subjectivity. In his 'Personal Knowledge' (1958) based on his experience as a prominent scientist and a thinker, Polanyi defined science knowledge as a structure of personal participation. In this paper, I firstly examine the nature of science knowledge in the light of Polanyi's epistemology. Secondly, I consider what this examination tells us about the meaning of science learning and teaching. Finally, I discuss the potential these ideas have to reconceptualize the role of the science teacher. This present discussion, which debates the fundamental role of the science teacher, will help grasp the crisis in science education which we face and legitimize possible ways to resolve this crisis.

II. A Description of Polanyi's Epistemology

Michael Polanyi (1891-1976) was broadly educated and early in his career studied medical science, but later received a doctoral degree in chemistry. He worked at Berlin University for ten years, where he gained a brilliant reputation in the fields of X-rays, crystals and rates of reaction. After the advent of the Nazi regime, he moved to Manchester University in England. He left substantial scientific achievements not only through his own work but also through that of his students. However, Polanyi confessed to experiencing severe difficulties because of the lack of acceptance of his achievements under the influence of contemporary hard-line positivism. In his fifties, after having experienced all of these events, Polanyi transformed his career in order to dedicate himself to the study of the new field of epistemology. This dedication led to him writing many significant philosophical publications, including 'Science, Faith & Society (1946, 1964), 'Personal Knowledge: Towards a Post-Critical Philosophy' (1958), 'The Study of Man' (1959), 'The Tacit Dimension' (1967), and 'Meaning' (1975).

Personal Knowledge

Polanyi began by criticizing as fiction the notion that objective knowledge is separable from human beings. His key insight was an attempt to define science knowledge as personal knowledge, while avoiding its characterization as subjective knowledge. For Polanyi, science remains objective, not in the detachment of the knower from the known, but in the power of science to establish contact with a hidden reality based upon the personal commitment of the knower. It is not that he saw knowledge as simply either subjective or objective, but that he understood it as the product of personal participation, a key feature of which is the notion of tacit reality. In 'Personal Knowledge', Polanyi prefaced his position: "Hence the wide scope of this book and hence also the coining of the new term I have used for my title: Personal Knowledge. The two words may seem to contradict each other: for true knowledge is deemed impersonal, universally established, and objective. However, this seeming contradiction is resolved by modifying the conception of knowing" (Polanyi, 1958, p.vii).

'Personal knowledge' can be objective knowledge since it ultimately reflects 'reality'. Polanyi's epistemology is based on the conception that reality can be known by tacitly regarding the idea of reality itself. This concept is different from understanding the hidden reality through the process of knowing, which is logically inquired; rather, this concept requires a form of intuition, which is considered as an important factor in tacit knowledge. Polanyi presented the paradox of this idea as "anything that can't be understood can be understood" (Polanyi, 1964, p.10). This paradox justifies the capability of intuition, thus providing a way to tacit knowing, such as the judgments or comprehension of scientists. In other words, any discovery that has the possibility attracts the very spirit that reveals it, and brings up the desire of creativity and hands proper implication. We cannot state this process with words, and it is a difficult field for us to guess without experience. However, Polanyi testified that the desire of scientists comes from a strong stimulation to try to achieve contact with reality. This is a desire that Polanyi understood well himself because he was a scientist who had faithfully experienced all of that process.

I think that the notion of personal knowledge has a tendency to move toward solipsistic subjectivism, despite the significance of the tacit dimension of knowledge as a reality. Polanyi did not examine this point; rather, he showed the broad processes through which scientists communicate with their community such as shared premises, methodology, and language (1958; 1964). This community has the means to secure universal validity through the function of handing down knowledge. Since the scientific community has a tradition based on tacit reality, personal knowledge has the possibility of being objective (Kim, 2003).

The tacit nature of personal knowledge

"We can know more than we can tell" (Polanyi, 1958, p.88), is a core proposition within Polanyi's epistemology. Human study expresses itself as an articulate system, namely language; however, this expression is the extension of an inarticulate intellectual factor. We can see this expression well in the calculating procedures of mathematics, where we set an equation and find an answer by using signs. The tacit nature of intelligence mediates this process; thus, such knowledge that cannot be articulated. Polyani defined this type of knowledge is defined as 'tacit knowledge'. Polanyi explained that the process of knowing is tacit: "Such is the functional relation between the two terms of tacit knowing: we know the first term only by relying on our awareness of it for attending to the second." Polanyi called the first type of knowing, which describes a knowledge that we may not be able to explain, "proximal" and labeled the second type as 'distal' (1967, p.10).

Polanyi also described 'knowing that can be said' as 'focal awareness' and 'knowing that can't be said' as 'subsidiary awareness'. When subsidiary awareness is defined as 'knowing without being able to express in words', it signifies a logical 'unspecifiability' but not a methodological unspecifiability. Subsidiary awareness and focal awareness are mutually exclusive, because we can attend to only one focus at a time. (Polanyi, 1958, pp.55-65) For example, a doctor who reads x-rays understands the significance of focal awareness relying on subsidiary awareness developed through years of experience (Ibid, p.101). He knows the situation of the lungs not the bones in the dark picture of a patient's chest on the fluorescent plate through the functional relation between focal awareness and subsidiary awareness. Similarly, there are no cases when we understand the meaning of the object only through focal awareness. Understanding itself relies on subsidiary awareness, and its result remains inarticulate. The supportive function of subsidiary awareness and focal awareness is applied to all knowledge from a simple physical skill to an intellectual study. This application is also the same for scientists during the processes of both theoretical and experimental work. The significance of focal awareness can be understood based upon its relationship to subsidiary awareness.

A mystery of knowing

Scientists usually start their work of discovery with clues that they feel subsidiarily but cannot express focally: such a beginning must seem like an unavoidable process of groping for something in the darkness. During this process, scientists' intellectual passion can motivate them to transcend the logical gap between the problem and the solution that they are trying find. This passion that thirsts for discovery is called 'heuristic passion'; however, discoverers soon shift toward 'persuasive passion', because they long for the new knowledge to be accepted by the public. These intellectual passions are not psychological by-products; rather, they have a central promotional role and a logical function in making the discovery and acceptance possible (Polanyi, 1958, pp.143-150). The function of passion, understood this way, dictates that science knowledge cannot be a 'mechanical knowledge' separated from the scientist's mind. On the contrary, passion makes personal commitment an essential ingredient in the nature of knowledge. During the process of discovery, personal factors, such as the scientist's evaluative ability, range of techniques and connoisseurship in each situation become involved: these factors usually belong to tacit knowledge that is hard to specify. This kind of very personal knowledge bridges the gap between separated subjectivity and objectivity.

Plato's Meno Paradox had already shown the mystery of knowing as a perpetual task of education (Petrie, 1981). Polanyi introduced it weightily: "Yet Plato has pointed out this contradiction in the Meno. He says that to search for the solution of a problem is an absurdity; for either you know what you are looking for, and then there is no problem; or you do not know what you are looking for, and then you cannot expect to find anything" (Polanyi, 1967, p.22). In other words, low-level learners cannot understand high-level learning because there is a logical gap between two levels. If this is correct, learning and teaching is logically impossible. However, if we consider the dynamic function of focal awareness and subsidiary awareness in the process of tacit knowing, learning cannot come out of one of the two states where we know or we do not know, but rather out of a state in which 'we don't know but actually we know', which is one of subsidiary awareness. In this context, although new knowledge has not yet been found, the existence of hidden reality can be foreboded and discovered. Actually, the Meno Paradox can be solved when knowledge is not limited to propositional knowledge arrived at through focal awareness. At this point, like Polanyi, we need to change the concept of knowledge into tacit knowledge.

Ⅲ. The Meaning of Science Teaching

Polanyi believed that science knowledge was personal, and that the process of knowing was a mutual function of subsidiary awareness and focal awareness. In particular, Polanyi saw that personal intellectual power and passion, which is related to the mind, was the true meaning of objectivity, by passing over the tiny criterion of objectivity. If science knowledge really is like this, science learning and teaching has to be transformed because it is taught according to the nature of science knowledge. Regarding this point, I reflect that modern objectivism intentionally does not admit the tacit dimension of knowledge like the human mind because of the obsession with trying to pursue clear and certain knowledge such as the results of modern scientific discovery. Post-modern relativistic epistemology eventually moved to the point of no longer holding the concept of objective knowledge; however, it is similarly inappropriate to exclude the tacit dimension out of knowledge because it does not acknowledge reality as the source of knowledge (Rorty, 1982). Among Polanyi's several innovative ideas, I think his conception of 'subsidiary awareness' is very helpful when discussing the meaning of science teaching.

What to teach

Human subsidiary awareness is a part of human existence and attached to the core of the mind, which is essential to understanding focal awareness. If only focal awareness is emphasized in teaching, it is usually separated from learner's mind; thus, focal awareness cannot by itself achieve conceptual change or contribute in forming the mind. It should be remembered that Polanyi was not the first to consider that tacit knowledge is an important aspect of human study; therefore, the concept is not that new to us either. A narrative of the ancient Chinese philosopher, Chuangtzu (莊子), is an exemplar:

A king of Fan Kung (桓公) was reading a book in the hall. An old man of Biān (扁) was cutting the wheel of a cart. Biān dropped his hammer and chisel and came to Fan Kung and asked, 'Your majesty, what are you reading now?'. Fan Kung answered, 'What the sages said'. Biān asked again, 'Are those sages alive now?'. Fan Kung said, 'No, they have already passed away.' Biān said, 'Then, what you are reading now is a residue of them.' Fan Kung was angry. 'Hey, you! You are nothing but a man who is cutting the wheel of the cart. How dare could you say that what the sages said is residue? What on earth do you know? If you can't explain what you are talking about to me reasonably, I bet you will get killed!' So Biān explained, 'I am nothing but a man who is cutting the wheel of the cart. I will explain by using a metaphor based on what I do. When I cut the holes of the wheel, it's not tight enough if I hit with the hammer too slowly, but it's too tight to fit if I hit too hard. This technique, which can cut it properly, not too slowly or without measuring, can't be expressed by words because only my hands know and my mind responds. There are exquisite techniques, but I can't hand them down to my son and he can't learn it from me. So I have been doing this until I am now 70 years old. Old sages might be like me. Their real knowledge has gone to the tomb with them. And they might leave what they couldn't carry to the tomb, and so is your book. Then what do you think the book is about?' (Chuangtzu, 2001, translated by researcher)

This sharp insight helped us be aware of the nature of knowledge 2400 years ago. In this story, the knowledge that cannot be conveyed by words must be Polanyi's subsidiary awareness and the residue knowledge that can be expressed by words is focal awareness. Polanyi also suggested vivid examples related to this phenomenon including hammering, riding bicycles, distinguishing raincoats, reading x-rays, the knowledge of surgeons, all kinds of scientific judgments like connoisseurship, playing the piano, reading letters, and the use of a cane by the blind. (1958). However, if we read Chuangtzu's narrative superficially, it seems to say that we do not have to teach by using language or written materials as is the case in current classrooms. However, if the narrative were to be interpreted as such, I think its substance would truly be lost. Rather, Chuangtzu means we have to find the hidden meaning of such an articulate system and try to teach just this hidden meaning. In other words, what we need to teach is essentially subsidiary awareness that cannot be expressed through words: the question then becomes how to achieve this goal.

Ⅳ. Science Learning

Learning is 'internalization' from knowledge to learners (Polanyi, 1959). This observation means that the content to be learned completely becomes part of the learners; some function is completely absorbed into their body. Thus, it is the opposite idea of what we call mechanical learning. Mechanical learning is the concept that objective knowledge existing outside of the learners is entered into their bodies, like entering data into a computer. Compared to this idea, internalization is not just to replay the knowledge that was conveyed by teachers but to create a new technique by making it a part of the body, or it is the state in which the learners open their eyes to a new world that they did not know until this internalization (Lee, 2000). According to Polanyi, internalization is connected to the concept of personal knowledge. Personal knowledge cannot be separated from the subject of perception and mind, but its base was assumed to be a hidden reality, not a personal subject. In this point of view, tacit knowledge is unified to the subject: it is considered to illuminate an ideal reality, which the subject tries to reach; furthermore, it can be an alternative for overcoming the limitations of traditional epistemology which assumes that knowledge simply exists inside and outside of the subject. When we consider the concept of tacit knowledge in this manner, internalization is a process for reaching the hidden reality whose source is the subject; moreover, internalization is considered as an increase or growth in the level of knowledge. This knowledge does not necessarily come from outside: we may realize knowledge that we already possess, but which is now passing from one dimension of understanding to another dimension of understanding.

Polanyi assumed that the basic power that made internalization of subsidiary things possible was already in the learners' minds. According to him, 'knowing that can't be said' is in our minds. Gaining knowledge can be accomplished by applying this 'knowing that can't be said' to the object of 'the knowledge that can be said' by extending knowing that cannot be said to the outside. To the same degree that the 'knowing that cannot be said' is one's own, the 'knowing that can be said' which may be applied through this underlying knowledge is one's own also. Moreover, the passion and dedication that make this 'personal participation' possible emerge because of the existence of a point of view that is specifically one's own. Therefore, we have to accept discovery as a process of learning that internalizes knowledge through the dedication and passion for it; however, scientific discovery is a process that reaches focal awareness by starting from subsidiary awareness because it is a process of revealing clear knowledge from reality that is not as yet known. In contrast to scientific discovery, the learning process tries to reach subsidiary awareness by making focal awareness a priority.

Science teaching

When learning is prescribed as above, teaching can be considered to provide focal awareness; however, the question then becomes how to teach subsidiary awareness. The fact that subsidiary things are not prepared beforehand is problematic. If focal awareness is taught only by itself without subsidiary awareness, it becomes 'mechanical teaching'. This problem is exactly the point of dispute concerning this prescription for learning as a teaching method. In fact, given that any potential method reveals its features through content, potential teaching content and methods cannot be clearly distinguished because the methods cannot exist separately from the content. If we say scientists are the experts of content knowledge, the experts of teaching methods have to be the science teachers. Actually, the teacher is a live teaching method. In contrast, textbooks are considered as a teaching method of another dimension forming the foremost line where teachers and students meet. The pedagogical function of books, including textbooks, is not new. In addition to providing information, books also have greater potential to change learners than a direct meeting with teachers; thus, as with teachers, we have to consider textbooks as a kind of teaching method.

Oakeshott (1965) categorized teaching into two dimensions: 'instructing' and 'imparting'. This scheme is made possible by dividing knowledge into two dimensions: 'information' and 'judgment'. Oakeshott prescribed that instructing is just meant to convey linguistic information whereas imparting involves judgment, which is included in the knowledge that cannot be said. A teacher's superficial role is to transfer information to students through a plan. Most teachers conduct teaching activities that structure and convey seemingly infinite types of information; however, it is not impossible for students to obtain such information by themselves. In contrast to information, judgment is not a form of knowledge that students can obtain by themselves; in fact, even teachers cannot structure and convey it through a plan. This form of knowledge is conveyed indirectly through the process of the teacher conveying information with pedagogical passion. In other words, a teacher's passion creates wise teaching methods such as narratives that endow information with significance and value. At this time, judgment, which composes the other side of the teachers' teaching activity, can be shared with students even without being noticed.

Judgment is interpreted as a form of tacit knowledge based on Polanyi's concept of subsidiary awareness. Polanyi argued that the process of discovery requires various personal judgments: each situation requires a scientist's ability to evaluate and apply a variety of techniques. These types of personal judgements constitute a form of connoisseurship that is hard to specify; however, it is exactly these kinds of very personal knowledge that usually belong to tacit knowledge and bridge the gap between the separated subjectivity and objectivity. Polanyi saw that the personal intellectual power and passion of scientists, which are related to the mind, make discovery possible by passing over the tiny criterion of objectivity. To convey judgment is when teachers' intellectuality is shared with the students and enjoyed by them. Because judgment cannot be returned to information, the factor of partial knowledge, to hand down judgment is possible only by setting an example of the existence that internalized it. Students can learn judgment only through the moment it is used by the people who have judgment or through the result of its use. This form of learning is a necessity of the apprenticeship system that Polanyi advocated and a fundamental reason for the existence of the education community (1958). If it is clear that subsidiary awareness involves teaching content and that it is more important than focal awareness, one's teaching cannot be convincing if subsidiary awareness is intentionally excluded.

V. The Role of the Science Teacher

Teaching and learning activities, as described above, require work to understand the role of the science teacher. Both focal awareness and subsidiary awareness are teaching content; however, by using words, teaching cannot help starting from the point of focal awareness. Teachers mainly teach through language, which constitutes both the foundation and the limitation in teaching method. Therefore, I would suggest that the core of teaching method is not the teachers' language itself, but rather the teachers' intellectual power or passion that are being conveyed through their language. This energy influences students to trust teachers, and is then transferred into learning passion. Polanyi aptly referred to this process as being "faith in search of understanding (Fides quaerens intellectum)" (1964, p.45). Intellectual power and passion can form an emotionally bonded class community, which is a prerequisite for giving any teaching method life. If such is not the case, one is left with what is actually just a mechanical classroom, mainly consisting of dry language and fragmentized individuals. Therefore, teaching is not reversible engineering or uniform technology but almost an art; it is even an art of the heart. The reason for this comparison is that art activities absolutely obey the artistic judgment of the artist; similarly, students' minds are alive and active: "If rich and various teaching materials are to be pedagogically meaningful, there must be someone who can understand it first and remind us that it was someone's vivid and specific experience once. ... Teachers are not those who order or deliver ready-made learning materials, but are rather an incarnation of the teaching content; in other words, those who relive the learning process as living knowledge" (Lim, 2000, p.316, translated by researcher).

If we accept this view that knowledge is the incarnation the human beings' minds, then teachers, students and knowledge are all alive; furthermore, teaching itself becomes a process of the mutual functioning of the three factors that is also personal and alive. Thus, the teacher is not a technician who mechanically conveys knowledge, but is instead an artist who handles students' minds: "The reason why we can understand what others say and think and how they act is that they express themselves in the same way to mental reality as we do" (Lee, 2000, p.262, translated by researcher). When viewed in this way, the teacher as a technician thinks his role is to archive useful exterior results by considering the relation between the means and the purpose of the technique; in contrast, the teacher as an artist tries to change students' minds/views. However, the current atmosphere of science education (which has actually existed since the Modern Ages) has brought the role of science teachers down to the level of the technician rather than the level of the artist: this reduction can be seen in the uniform application of science teaching skills or instruction models.

Ideal science teachers already have to internalize science knowledge as a part of their minds not only through the focal awareness that is written clearly in the textbooks, but also through subsidiary awareness that cannot be expressed via language. However, in the case of the teacher who does not possess this kind of knowledge, true teaching is logically impossible. Therefore, as there is no conclusive end to education as a general rule, science teachers have no choice but to possess only an imperfect form of science knowledge. Even so, they have to be better prepared than other types of teachers, because students expect science to be the purist possible subject. After all, science teachers are the living embodiments of science: their minds are science and science is their mind.

VI. Conclusions and Recommendations

Polanyi prescribed the process of knowing as the mutual function of subsidiary awareness and focal awareness, and revealed the true meaning of the tacit dimension of science knowledge. Therefore, science teaching has to be transformed because we have to teach science according to the nature of science knowledge. If it is clear that subsidiary awareness is a teaching prerequisite, and it is more important than focal awareness, good teaching depends on how well subsidiary awareness is handled. In this point of view, teaching is nothing but another paradox that has to express the tacit knowledge that cannot be expressed by words. The teacher should not be a mechanical technician, but rather an artist who tries to change students' minds or views. This role includes overcoming the Meno Paradox of Knowing. Therefore, science teaching should entail teachers grasping subsidiary awareness of their subject matter based on their intellectual power and passion, which needs to be included in professional teacher education. Science teaching undoubtedly differs according to how the science teacher thinks about science knowledge - and this conception influences how they access their classes. Of course, just as we can be a lover without knowing the meaning of love, so too can we teach science without ever identifying the epistemological basis of science teaching. However, understanding more about the nature of science knowledge helps us to realize what science teaching could be: I believe this understanding is the essential factor that defines the quality of the science teacher, and could serve as a powerful way forward from the present crisis in school science education.

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