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METAPHOR, STUDENTS' CONCEPTIONS OF LEARNING AND TEACHING, AND METACOGNITION

1. INTRODUCTION: METACOGNITION AND THE NEED TO CONSIDER STUDENTS' CONCEPTIONS

As a teacher I have always been interested in how students learn. My experiences in schools and now universities has seen me continually question how to teach students how to learn and, more recently, how to teach pre- and in-service teachers to teach their students how to learn. I see these tasks as central to education, especially given the pace of change in the world and the importance of learning and thinking efficiency in all spheres of human endeavour. Not surprisingly, while a teacher, this interest led me to investigate and use the thinking skills programmes, such as de Bono's CoRT program (de Bono, 1988), that were prominent in the 1980s and early 1990s. However, overriding the use of such practical programs was my interest in the substantive issue of metacognition which I define as an individual's knowledge, awareness, and control of his/her thinking and learning processes and strategies and also his/her knowledge of others' learning processes and strategies. My investigations into metacognition and how to develop and enhance students' metacognition led me to question many of the so-called 'thinking' activities and thinking programs in schools. I found it necessary to question a widely-held belief among many educators and colleagues that students would develop metacognition and learn how to learn well simply according to whether or not teachers employed certain classroom teaching and learning activities; even powerful strategies used in science education such as Predict-Observe-Explain (POE), Concept-Mapping and Venn Diagrams. My position was and still is that these activities are extremely valuable for helping students to learn science. This view is supported by abundant empirical studies in science education. Their value lies in their use as tools that enable students to transform their ideas and thoughts into tangible, often two-dimensional written or drawn artifacts that can then be

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reviewed, scrutinised, and possibly modified. However, I argue that using them by themselves is not sufficient to maximise the development and enhancement of students' metacognition. There is a need for students to have opportunities to consciously reflect on these strategies and assess their viability in relation to their own learning contexts. When and if students do so, they will use their conceptions of teaching and learning as referents in the reflective process. If teachers do not explicitly encourage such reflection, the opportunities for students to develop metacognition are greatly diminished.

It occurred to me that, just as there was a need for cognitive tools such as POEs and concept maps to enable students' science concepts to be made tangible and available for scrutiny, there was a need for a tool that could be used to make students' conceptions of learning 'visible,' subject to scrutiny and possibly to change. Further, such a tool might enable teachers and researchers to present what might be, for students, alternative conceptions of teaching and learning to them to consider. I saw this as essential because what has become increasingly evident over the years is that students are not passive players in the schooling process. Rather, they are key determinants of what occurs in classrooms and what learning takes place, even if the teacher supposedly wields considerable authority. Students bring to classrooms their own conceptions and beliefs about teaching and learning which influence their behaviours and cognitive processes and, therefore, the behaviours of teachers and the learning environments of the classroom. Their conceptions of learning are essential elements of students' metacognitive knowledge. However, such conceptions are most often tacit, difficult for students to elaborate, and therefore not the focus of discussion between teachers and students. In this way they are similar to students' alternative science conceptions that may be strongly held and that have been shown to influence students' learning of canonically acceptable science. Just as there is a need to acknowledge and understand students' conceptions in relation to science and to assist students to become aware of such conceptions and to modify them where necessary; so too is there a need to engage students who might possess inappropriate, possibly maladaptive conceptions of teaching and learning for their learning context in the processes of making these conceptions explicit, available for review and subject to processes akin to those of conceptual change. Therefore, the tool that I was searching for as a teacher needed to be flexible enough to facilitate two tasks:

1. to make students' conceptions of teaching and learning 'visible' and therefore available for scrutiny; and
2. to enable viable conceptions of teaching and learning to be communicated intelligibly to students so that they might assess their plausibility and consider their potential viability and value.

2. ENTER METAPHOR

Around the time I was searching for my 'tool' the writing of Ken Tobin and his colleagues (Tobin, 1990, 1993; Tobin & Tippins, 1996) came to my attention. Tobin had been using metaphor as a tool for helping teachers to make explicit their tacit

conceptions of teaching and learning. In trying to shift these conceptions to be more constructivistly oriented, with the ultimate aim of changing teachers' behaviours, they had achieved some success. Tobin had used metaphor as a master switch to assist teachers to change these conceptions and, in so doing, their teaching behaviours. Such aims with teachers struck me as being parallel with my aims for my students. Therefore, I asked myself, "Could I too use metaphor with my students?" Metaphor appealed to me because it was a language device and was congruent with my constructivistly oriented view of how to improve science education and my own teaching. Language, according to von Glasersfeld (1996, p.7), "enables the teacher to orient the student's conceptual construction by precluding certain pathways and making others more likely". Further, as the primary form of figurative language, metaphor is central to the way language works (Bartel, 1983; Richards, 1936). I decided my question was worth seeking an answer to and so I set about trying to understand 'metaphor,' my potential tool.

3. DEVELOPING A PERSPECTIVE ON METAPHOR

The literature on metaphor is extensive, bridging linguistics, literature, psychology, and sociology. Therefore, I began by reviewing the literature that others in science education had referred to and this led me to the literature beyond science education. It quickly became apparent that metaphor was seen from a variety of perspectives. Theories and notions of metaphor are historically, socially, and linguistically determined and these variable determinants may explain the lack of a universally accepted theory of metaphor (Hawkes, 1972). Metaphor coexists with analogy as a variant of figurative language with metaphors and analogies being close relatives in that the terms metaphor and analogy are sometimes used interchangeably. Substantive similarities have been identified between metaphorical and analogical thinking to the extent that analogy might be considered a necessary condition for metaphor. Metaphors suggest some form of objective analogy, without stating explicitly in what the analogy exists.

I consider that two noteworthy perspectives of metaphor are evident. The first of these is what I term a structural, pragmatic perspective. It refers to understanding elements of metaphor and how each of these mechanically operates to create new meaning. From the literature, I adopted a blend of terminology from Richards (1936) and Indurkhya (1992) to conceptualise the elements of metaphor that were salient to my purposes. The word 'target' was adopted to represent the term or concept that is clarified or amplified in the metaphor. Providing a sense of directionality in a metaphor is an important facet of metaphor interpretation and construction and use of the term 'target' provides this directionality; some characteristic is 'aimed' at the target. The term 'source' was adopted to represent that which is known, the secondary subject that is used to characterise, clarify or amplify the target. Source is synonymous with origin and was chosen to reinforce the understanding that a characteristic that is transferred to the target in a metaphor has its origins in the source of that metaphor. The term 'ground' was adopted as it is suggestive of a

'common ground' relationship between the target and source. An individual constructs understanding of a metaphor when his/her understanding of the source is related to, and compared with, his/her understanding of the target. The shared elements of these two sets of understandings constitute the ground. This conceptualisation was consistent with that 'taken' across the literature; that an individual's comprehension of a metaphor is "guided by interpretive frames of reference that are grounded in their prior knowledge or experiences" (Weade & Earnst, 1990, p.134). As a teacher who held constructivist views, such an acknowledgement of the importance of prior knowledge in the interpretation, the development of metaphors was crucial for my appreciation of how they operate to create new meaning and how they might reflect what individuals already perceive to be evident. Further, the degree of dissimilarity between target and source in a metaphor results in the ground of the metaphor being initially hidden. The metaphor surprises its audience, provoking anomaly and producing emotional tension within its audience. I saw such tension as important as it seemed appropriate to use the tension invoked by metaphor to assist students to confront their beliefs, their tacit knowledge, and their understandings of what learning is.

The second perspective is what I refer to as a conceptual perspective. It reflects the writings of Lakoff and Johnson (1980) and Lakoff (1993, 1994). Metaphors are seen as metaphorical concepts, that is, those organising, structuring concepts that undergird our talk and give rise to sub-categorisations of the metaphorical concept that bear connection to the central 'them' of the metaphorical concept. Cooper (1986) argues that metaphorical concepts are overarching, commonly shared understandings that shape discourse and social cognition and that they are used in conversation to effect or to cultivate familiarity, custom, or intimacy between speakers. People's culturally acceptable interpretation of specific metaphors and their shared linguistic knowledge of established metaphorical practice develops this intimacy and enables them to interpret other related metaphors and expressions. If, as Lakoff and Johnson asserted, our language is metaphorically structured, then by examining students' metaphors for learning and their roles as learners we might be given a window into their culture in relation to teaching and learning. Further, because Lakoff and Johnson suggested that, as well as defining everyday realities, metaphors create the possibility of new social realities for us by getting us to try to understand how a metaphor, not previously considered, may be true or could be made to be true, I saw the potential of creating new social realities for my students about what constituted learning. This potential was similar in orientation to Tobin's for using metaphors to create new realities for teachers.

Both perspectives of metaphor seemed useful to me. Firstly, students might be able to express the essence of their understanding of learning and their roles as learners in science classrooms through metaphor. To do this they would need to consider their possibly tacit conceptions of learning and teaching and seek to identify or to develop a metaphor or metaphors in which the target concepts of teaching and learning were informed by their choice of the source concept. Secondly, I might be able to use a metaphor that reflected a constructivist conception of learning to inform students of what for some might be new possibilities in relation to how they conceived of learning. This might consequently

lead to students modifying their knowledge, control and awareness of learning and their learning processes, that is, their metacognition. Thirdly, I might be able to, as Tobin had done with teachers, use changes in students' metaphors to monitor changes in their conceptions of learning and seek correspondence between any such changes in their metaphors with congruent changes in their learning processes. In what follows I draw on my research into each of these potential uses of metaphor and draw conclusions related to the efficacy of metaphor for each potential use.

4. AN INITIAL INVESTIGATION OF STUDENTS' USE OF METAPHOR: GROWING IN CONFIDENCE

My preliminary investigation into students' use of metaphor took place in 1995 with secondary school science students (14-17 years old). I was immediately impressed with how students could use metaphor to communicate what they considered key elements of their conceptions of their roles as learners and the roles of teachers. A review of some examples of different students' metaphors from a preliminary study (Thomas & McRobbie, 1995) points to some interesting elements of the metaphors. Students' metaphors entailed varying levels of active processing and passive acceptance of information. Further, different views of the roles of teachers are evident in some metaphors.

The view of the student as an information recipient and storer of information is evident in metaphors (b) and (c) in Table 1 as well as in the illustrated metaphor shown in Figure 1. Such a view of the role of the student is widespread in educational and social thought and reflects the cultural press about what is meant by learning science (McRobbie & Tobin, 1997). However, it is widely criticised (e.g., Scheffler, 1991) because it places the student in a position where passive acceptance of information from the teacher is the norm and the student has no independent motive or expression of choice.

Following this study I was more confident that students understood and might be able to use metaphor to communicate their conceptions of teaching and learning and the roles of students and teachers. The initial study was followed by a larger interpretive case study (Thomas, 1999; Thomas & McRobbie, 2001) in which I, as a participant observer, sought to explore in more depth the aforementioned potential uses of metaphor with my class of Year 11 chemistry students in a non-streamed Australian school. In this study I triangulated data from multiple sources that included student journals, semi-structured and stimulated recall interviews, the Learning Processes Questionnaire (Biggs, 1987), and video analyses to build metacognitive profiles of individual students and to propose credible and trustworthy conclusions regarding the efficacy of metaphor for use with students in relation to the three aforementioned potential uses of metaphor.

Table 1. A selection of students' metaphors for communicating conceptions of teaching and learning and the roles of teachers and students

Metaphor	*Entailments of the metaphor and interpretation*
(a) I am an ant. I like to find my own food. However, sometimes I pick up too much food (information) at once and I have to break it down. When I get too much food I don't know what to do. Sometimes I leave it and find something else to eat…other times I make the effort to divide my food.	Learning is an active process. Knowledge is like food to be consumed. The student likes to be in control of his/her own learning. Sometimes there is too much information selected that requires that the student feels a need to analyse it. However, sometimes the student will ignore the situation of too much information and prefer to find new information.
(b) I am like a container with some leaks because I take in information but some leak out after a while. I do not refill with the same information. I would like to be a container with no leaks because I take in the information and it stays there and does not need to be filled with the same information.	Learning is about storing information. Some information is forgotten and needs to be taken in again and re-stored. When information is forgotten new information takes its place. The student has a preference to improve his/her information storage capacity and make learning more efficient.
(c) A teacher is like a caterer who serves up information rather than food. The students don't always enjoy what they are being fed, so the caterer tries to make it more interesting. It is still the responsibility of the student (not the caterer) to eat.	Teaching is about transmission of information. It is the responsibility of the teacher to make the diet interesting for the consumer but it is still the consumer's responsibility to take in the information.
(d) Being a chemistry student is like being on a merry-go-round and the teacher is the operator. His job is to make sure everyone stays on course and does not fall off, but has fun doing it.	The teacher sets the directions about what students' are to learn. The teacher's responsibility is to ensure that all students make progress and do not fail, and to ensure that the learning is a fun process.
(e) I am a mountain climber. Before I take the next step up the cliff of the mountain my last step must be secure. I don't take the next step until I'm satisfied with the present one. As a learner I will not attempt the difficult questions/ideas/issues if I don't know the basics. The basics are my foundations. If I climb too quickly the mountain will shake.	Learning is sequential, a step-by-step process that requires that the student understands the basics and does not try to learn new material unless the previous material has been understood. If the student tries to learn new material or attempt new problems before the past material is understood this can be problematic.

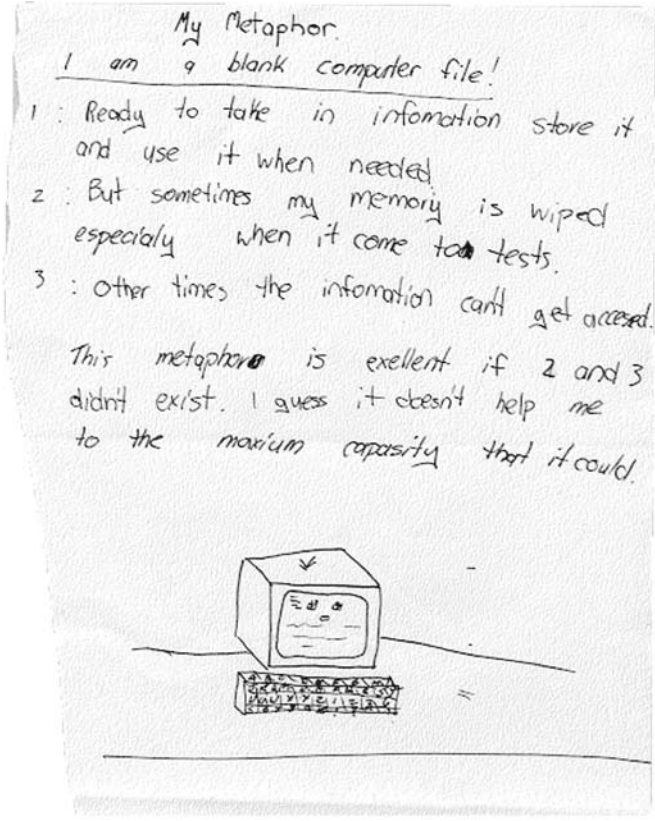

Figure 1. A Year 9 student's metaphor highlighting passive learning tendencies. (Thomas & McRobbie, 1995, p. 11)

5. METAPHOR AS A MEANS OF PROBING STUDENTS' CONCEPTIONS OF TEACHING AND LEARNING

One question that came immediately to mind in the larger study, and that built on the 1995 study, was whether there was congruence between students' metaphors and their learning processes and their classroom environment perceptions and preferences. This was a prominent question because I saw a need to evaluate the credibility of students' metaphors in a more robust manner if they were to be used as evidence in relation to, and as representations of, students' conceptions and learning processes and any changes to those conceptions and processes. If there was evidence

to support congruence then I might be able to propose that students' metaphors could be used as historical markers for their conceptions of teaching and learning and of their learning processes at any given time and, therefore, able to be used in pre-and post- fashion to monitor changes in such conceptions and processes. In answering that question McRobbie and I (Thomas & McRobbie, 1999) reported that, (a) students were able to use metaphor to describe themselves as learners in their chemistry classroom, (b) students' metaphors were congruent with their conceptions of their roles as learners, their learning processes and their classroom environment preferences, and (c) students' metaphors were sensitive to and highlighted different personally prominent aspects of their conceptions that each individual student perceived was significant at the time of the research. One student, Beverly, outlined her metaphor as follows:

> My learning is a person eating an apple. Slowly but surely I nibble my way through my chemistry, absorbing all the nutrients and letting the unimportant stuff pass out the other end. Just as I enjoy eating apples and they are good for me – my chemistry is also good and I enjoy learning (eating) it. The core of the apple is the test at the end of the unit and every new unit is a new apple. The core gets chucked away but all the nutrients from the previous apple are in my body still and this helps my brain to comprehend new topics (i.e., I refer to stuff I learnt in my previous topics to help me understand new stuff.)

Beverly was a highly motivated achiever in chemistry. She was diligent in class and studied chemistry regularly at home at nights and weekends. Chemistry learning for Beverly was characterised by her systematically understanding material through an active process of deconstructing and recoding chunks of information into more manageable pieces. Her learning processes also involved identifying the relationship between new information and her prior knowledge and discarding what she thought was irrelevant detail. Data from multiple sources consistently suggested that, consistent with her high levels of academic achievement, Beverly used significantly more deep and achieving approaches to learning than most other class members. However, the selectivity of Beverly's metaphor is apparent in that, even though in interviews she reported value in collaborating with other members of her class to assist her learning, "if somebody else has a different understanding or they've read different things, or they've drawn from different sources, then you can combine your ideas and come up with a much broader knowledge of the whole thing," the role of such social interaction for her learning is absent from her metaphor. McRobbie and I concluded that, due to the selective nature of what may or may not be communicated by students through their metaphors, metaphor would be most appropriately used as one element of a raft of methods for investigating students' conceptions of teaching and learning and their learning processes.

Interestingly, such a use of metaphor was seen as a highly reflective and metacognitive experience by students. For example, in reporting on her development of her metaphor Beverly suggested, "It (developing the metaphor) made me sit down and actually think about things I hadn't previously thought about, about how I actually learn. I've never had to describe how I learn to anybody before." Such intimations were not uncommon amongst students and their prevalence suggests that, at least in the class of students involved in this study, students' knowledge in relation to their learning processes is indeed often tacit, requiring an opportunity and

a means to make it explicit, and not often the object of investigation or reflection in science classrooms.

6. USING METAPHOR TO PRESENT A CONSTRUCTIVIST CONCEPTION OF LEARNING

Having established that students could use metaphor as a means for making their tacit conceptions of teaching, learning and their learning processes explicit, I sought to use the metaphor 'learning is constructing' to communicate with students about a view of learning and complementary learning processes consistent with constructivism. Because constructivism was the epistemological referent for my research and my teaching I saw this metaphor as appropriate. Further, such a view of learning is widespread in the literature (e.g., Fosnot, 1996; Marshall, 1996; Spivey, 1997) with Spivey suggesting that constructivism itself is a "cultural metaphor that belongs to a large group of people interested in communication" (p. xiii). The use of metaphor with students consisted of three elements. Firstly, I presented the metaphor to the students for their interpretation and asked them to identify key factors of the source of the metaphor, 'constructing'. I then asked them to relate these to their existing conceptions of learning. In doing so I recognised that each individual might identify a different ground of the metaphor and that it was therefore important to allow students to identify entailments of the metaphor that were salient for them. Once students had selected personally salient entailments of the metaphor they were given the opportunity to trial processes and activities that were consistent with their interpretations. These interpretations included that learning (a) requires developing a sound base of ideas, (b) requires that ideas be linked together in a firm but malleable structure, and (c) involves monitoring the constructive process. These interpretations suggest that using the metaphor served as a means of communicating valuable propositions about learning that students themselves could identify without difficulty. The ground of the metaphor was very apparent to them and their linguistic knowledge of metaphor facilitated a plethora of entailments. Finally, to reinforce these valuable interpretations of related learning processes, and students engagement with these, I modified my classroom discourse with the aim of illustrating, emphasising, and reinforcing to students the value of the metaphor as a referent for learning and learning processes. Comments from me such as "What ideas can be linked to this new information, and how can they be linked?" exemplified such change in what was said by me in class. Students noted the value of my use of language entailed by the metaphor for maintaining a focus on their conceptions of learning and their learning processes. For example, one student (Debbie) suggested, "You remind us [about learning and learning processes]…at the front [of the classroom] by mentioning constructing and then I think, 'Oh, learning is constructing.' If you weren't doing that then it probably wouldn't happen." Obviously there is a need for teachers to maintain a focus on using a language of learning in classrooms and the short term use of a metaphor for promoting

consideration of a particular conception of learning; and the development of valuable learning processes may not be sufficient for some students.

The intervention was influential in acting as a master switch for some students who altered their conceptions of learning and their learning processes. One such student was Tim. Prior to the intervention Tim had little procedural metacognitive knowledge and lacked a language to describe in any detail the learning processes he employed. He found it difficult to come up with a pre-intervention metaphor because, as he put it, "It's hard to decide on what I do." Tim's default metaphor for himself as a chemistry learner was, "I am a calculator… I work for a while and then I switch off... that's just like my brain. If I don't use my brain it'll just switch off and I won't think anymore. All this chemical information goes in… [usually it just goes in one ear] and out the other side." One key concern in relation to Tim's learning processes was his lack of understanding of the value and use of his existing science knowledge for learning new information. As he suggested, "Once I learn [something] I usually think, 'Oh, this mustn't be relevant for anything else'." This lack of associating new information with existing knowledge was a major impediment to his learning chemistry with understanding. During the intervention Tim proposed the following entailments that he thought could be associated with learning: "…labour, you must put in the effort; design, to design something you first need a plan or idea; and joining, joining the knowledge from the past with the present to be able to learn". Tim enacted some of the entailments of the metaphor, altered his learning processes and was aware of doing so, and became increasingly in control of his new cognitive processes. He suggested:

> The metaphor's the principle of the way I learn. I just go on with what the metaphor's taught me. I just think about what we've done in the past, which is what the metaphor's really saying…when I see something new I find out where it fits in with what I've learnt in the past. Way back ago we had a test and we were talking about buckyballs, and I was reading about a week ago that they've now got 120 carbon atoms or something like that; like the next step up from buckyballs. Before we'd done the metaphor I would never have considered those sorts of connections. In the past I just read though [the text] and hope to learn it off by heart. I still read the text… but now when I read, I think "Where does '*this*' fit in with what I've already done?" and "How does it fit?" and I can tell myself "*This* has to do with *that*".

7. METAPHORS AS MARKERS OF STUDENT CHANGE

For Tim and others in the class the metaphor acted as a guide for altering their conceptions of learning and their learning processes and for articulating their newly developed conceptions and processes. These changes were further evidenced in the changes in students' metaphors for themselves as learners. For example, Debbie prior to the intervention described herself as a "person in maze" in relation to her learning. The journey through the maze represented "a struggle but not impossibilities". The maze itself represented "different paths to learning, different ways of learning through different techniques, different ways of dealing with things". Debbie admitted, "I haven't explored many of these pathways". Debbie, like Tim, provided evidence of substantial revisions of her conceptions of learning

and her learning processes and these changes were consistent with her post-intervention metaphor for herself as a learner.

> Learning is creating a collage and I am a collage creator. The collage is the overall result, the overall picture that the learner has created…a representation of the learner's mind, the product of learning. Many different materials are used and each material enhances the other and the overall production. Separated from the collage, each different material is of little significance, use and meaning. It's not until it's placed amongst the other materials in certain places that they become useful, accessible and meaningful. By putting them together in a certain pattern they mean something. Concepts/information are placed in/on our mind and are linked by understanding. [I] link different information/concepts with different links. Use the wrong glue on a material and it will fall out of place and wreck the collage. Use a wrong link and the information/concept will be misunderstood and useless.

It is clear from Debbie's metaphor change that, following the intervention, she developed a different, more cognitively oriented and proactive conception of learning and of herself as a learner when compared with her maze metaphor. Her changed conception is also metaphorically structured and carefully considered. The change in her metaphor was also very consistent with changes to her learning processes as reported in Thomas and McRobbie (2001). This was the case for many students. Such intimations from students made it apparent that it was possible that metaphors could be used as one form of evidence of change/s in students' conceptions of learning, of themselves as learners, and of their learning processes even if, as was the case with Beverly's metaphor, the new metaphor only communicated some aspects of the students' total conception. The efficacy of metaphor for use with students seemed clear.

8. CONCLUSION

My strongly held view is that, as well as teaching students science well, there is a need to teach students explicitly about learning, what it means to learn, and how to learn. For students such metacognitive knowledge is invaluable irrespective of their future learning and career paths. However, students possess often tacit conceptions of such matters that are difficult to access and therefore difficult to scrutinise, evaluate, and challenge. To make such conceptions explicit and to teach students about such matters with a view of altering, as necessary, possibly maladaptive conceptions a language tool is necessary. In this chapter I have proposed the following points that demonstrate the value of metaphor as a means of engaging students in metacognitive reflection, development, and enhancement.

- Students can understand metaphor and characterise their conceptions of teaching and learning and their roles as learners using metaphor.
- When students use metaphor to conceptualise their conceptions of learning, their roles as learners, and/or their learning processes it is a highly metacognitive experience.

- A conception of teaching and learning consistent with constructivism can be communicated to students using metaphor.
- Changes to students' conceptions of learning, their roles as learners, and/or their learning processes can be monitored to some extent using metaphor.

The metaphors that we and our students use, both consciously and unconsciously, as referents to guide our thinking and action should be the focus of continued interest and research in science education. Through their explication and consideration we have the potential to improve students' metacognition, their learning of science, and our own teaching, and in so doing meet important goals of science education.

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8.1 References

Bartel, R. (1983). *Metaphors and symbols*. Illinois: National Council of Teachers of English.

Biggs, J. (1987). *Learning processes questionnaire*. Melbourne: Australian Council for Educational Research.

Cooper, D. E. (1986). *Metaphor.* Oxford: Basil Blackwell.

de Bono, E. (1988). *CoRT thinking: Teachers' notes (Vols. 1, 2, 5).* Sydney: Pergamon Press.

Fosnot, C. T. (1996). Constructivism: A psychological theory of learning. In C. T. Fosnot (Ed.), *Constructivism: Theory, perspectives and practice* (pp. 8-33). New York: Teachers College Press.

Hawkes, T. (1972). *Metaphor.* London: Metheun.

Indurkhya, B. (1992). *Metaphor and cognition: An interactionist approach*. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Lakoff, G. (1993). The contemporary theory of metaphor. In A. Ortony (Ed.), *Metaphor and thought* (2nd ed.), (pp. 202-251). New York: Cambridge University Press.

Lakoff, G. (1994). What is metaphor? In J. A. Barnden & K. J. Holyoak (Eds.), *Advances in connectionist and neural computation theory* (Vol. 3, pp. 203-258). Norwood, NJ: Albex Publishing.

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by.* Chicago, IL: University of Chicago Press.

Marshall, H. H. (1996). Implications of differentiating and understanding constructivist approaches. *Educational Psychologist, 31*, 235-240.

McRobbie, C., & Tobin, K. (1997). A social constructivist perspective on learning environments. *International Journal of Science Education*, *19*(2), 193-208.

Richards, I. A. (1936). *The philosophy of rhetoric.* Oxford: Oxford University Press.

Scheffler, I. (1991). *In praise of the cognitive emotions.* New York: Routledge, Chapman and Hall.

Spivey, N. N. (1997). *The constructivist metaphor: Reading writing, and the making of meaning.* San Diego: Academic Press.

Thomas, G., & McRobbie, C. J. (1995, June). *The use of metaphors in developing students' thinking and learning.* Paper presented at the Learning and Educational Research Network Conference, Townsville, Australia.

Thomas, G. P. (1999). Developing metacognition and cognitive strategies through the use of metaphor in a year 11 chemistry classroom. Unpublished PhD Thesis, Brisbane: Queensland University of Technology.

Thomas, G. P., & McRobbie, C. J. (1999). Using metaphors to probe students' conceptions of learning. *International Journal of Science Education, 21(6)* 667-685.

Thomas, G. P., & McRobbie, C. J. (2001). Using a metaphor for learning to improve students' metacognition in the chemistry classroom. *Journal of Research in Science Teaching, 38*(2), 222-259.

Tobin, K. (1990). Changing metaphors and beliefs: A master switch for teaching. *Theory into Practice*, *29*(2), 122-127.

Tobin, K. (1993). Referents for making sense of science teaching. *International Journal of Science Education*, *15*(3), 241-254.

Tobin, K., & Tippins, D. (1996). Metaphors as seeds of conceptual change and the improvement of science teaching. *Science Education, 80*(6), 711-730.

von Glasersfeld, E. (1996). Aspects of constructivism. In C. T. Fosnot (Ed.), *Constructivism: Theory, perspectives and practice* (pp. 3-7). New York: Teachers College Press.

Weade, R., & Ernst, G. (1990). Pictures of life in classrooms, and the search for metaphors to frame them. *Theory into Practice*, *29*(2), 133-140.