# THE SOCRATIC METHOD OF STRATEGIC QUESTIONING TO FACILITATE THE CONSTRUCTION OF THE TARGET-CONCEPT WITIDN THE STUDENTS ZONE OF PROXIMAL DEVELOPMENT

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*Many A-level examination boards have included a modelling approach in mechanics that demands a qualitative treatment of physical phenomena. The majority of students, however, have 'misconceptions' of force and motion that are resilient to change. It has become clear that if students are to develop a qualitative understanding of force and motion that is Newtonian, then a massive cognitive reorganisation is required. This paper will report on the Socratic method as a teaching strategy that challenges 'misconceptions' and facilitates the construction of the Newtonian system within the students zone of proximal development.*

## INTRODUCTION

Consider the following problem that illustrates how strategic questioning can be used to reach a target concept and the responses that are likely to be encountered as part of this process:

A bottle is at rest on a table. If the weight of the bottle is the *action,* then under the third law of motion: *for every action there is an equal but opposite reaction,* what would be the *reaction?*

If the answer is *The normal reaction of the table on the bottle,* then the student can be asked to consider the same problem but this time in the context of two questions that demand the same answer:

**1)** A bottle is at rest on a table. If the weight of the bottle is the action, then under the third law of motion, what is the reaction?

2) The same bottle is in free-fall. If the weight of the bottle is the action, then under the third law of motion what is the reaction?

If the answer to the first question is the normal reaction of the table on the bottle, then there will be most likely a contradiction between the answer to the first question and the answer to the second question. This contradiction between the two answers may not be enough for the student or class to realise the right answer, but it may well motivate the search for one ('internally'). The search will

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most likely end when, with guidance from the teacher via further questioning, the pupil or class has established the consistency between 1) and 2). For example:

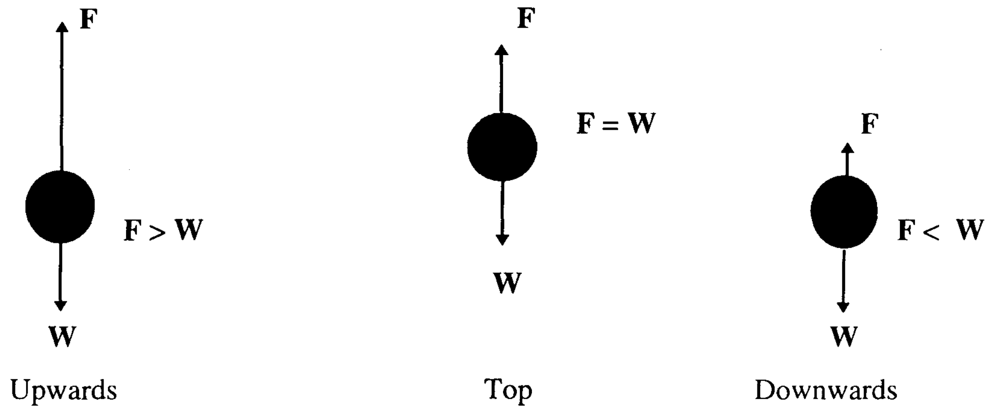
- The weight of the bottle can be defined as *the gravitational attraction of the earth on the bottle.* If the gravitational attraction of the earth on the bottle is the *action,* then under the third law of motion, what is the *reaction?*
- The arrow in the diagram represents the force of attraction of the earth on the moon. Draw a line on the diagram representing the gravitational attraction of the moon on the earth. How do the two lines compare?

**MODELLING IN MECHANICS - THE USE OF CONCEPT QUESTIONS IN THE SOCRA TIC METHOD OF STRATEGIC QUESTIONING**

The above juxtaposition of two situations that demand the same explanation or description is an attempt to illustrate the *Socratic method of strategic questioning* - the teacher asks a series of *concept-questions* [qualitative questions as opposed to quantitative questions - see Berry and Graham (1991)] in which the student reaches the 'target-concept' without it being given by the teacher. If a teacher/lecturer/mechanics text-book author holds a 'misconception,! concerning the third law of motion, and cannot be convinced by being told otherwise, then that must apply even more so to the intuitive ideas of the student.

The majority of students hold intuitive ideas, the most prevalent is the idea that force is the property of the body. For example, many students maintain that the force acting on a ball thrown upward is the force given by the thrower and is stored in the mass. Some students (e.g. three students from an engineering foundation course) have articulated the situation thus:

[1] *misconception* (or *preconception)* implies a well-defined concept that has been formed prior to a mechanics course. 'Misconceptions' are therefore best described as intuitive schemata'~,see Rowlands *et al* (in print).




The Socratic method of strategic questioning to overcome this particular 'misconception' might involve the following concept questions:

- Throw a ball up into the air. As soon as th~ ball leaves your hand, place your hands in your pockets. What forces are acting on the ball?

- A block is sliding on a rough horizontal table. What are the horizontal forces acting on the block, and in which direction are they acting?

- Imagine a world in which there is no gravity. If a ball is thrown up into the air, what would be the motion of the ball and what forces are acting on the ball?

- You are travelling on a train that is moving at a constant 60 mph on a straight track. Between your fingers is a ball. What is the speed of the ball relative to a stationary observer? What horizontal forces are acting on the ball?

These concept questions are 'parallel' to the original concept question, and the asking of each *parallel question* (Graham and Berry, 1994) would depend on the response to the previous question. The aim of strategic questioning is to remove misconceptions so that the target concept may be reached. Much research into student misconceptions suggests that students cannot model the real world unless their intuitive ideas are challenged![2] This point is even more salient today given that

[2] For many educators, the very idea of 'challenging' the intuitive ideas of students is a controversial one. We would contend, however, that this controversy has been generated by the relativist emphasis of constructivism. For a full discussion of this controversy see Rowlands *et al* (in print).

most A-level examination boards have recently included a modelling approach in mechanics that demands a qualitative treatment of physical phenomena.

The Socratic method of strategic questioning should involve discussions that are structured by the teacher according to the target-concept to be reached and the initial knowledge state of the class. The Socratic method should enable the teacher to facilitate the construction of the target-concept by first considering the initial knowledge state and then contradicting that state if it proves necessary. In mechanics the *concept question* asked may elicit an intuitive response that may be challenged by a series of *parallel questions* in which the same principles of mechanics apply. Consistent with the Vygotskian perspective (see Rowlands, forthcoming), parallel questions may be seen as exemplifying anomalies that serve a contradictory role of becoming 'hurdles' to overcome in order to develop cognitive growth, yet which also serve as props or hints to facilitate the process. An anomaly is both a diagnostic tool and at the same time a tool of remediation. A teacher frames a question that challenges students to think according to the constraints of the question (e.g., *A box is at rest on a frictionless table. How would you make the box move across the table in uniform motion?).* The student response (e.g., *Give the box a continual push* - revealing, in this example, an 'Aristotelian' response) is then challenged through an anomaly (e.g., *What happens to the motion of* ǫ *rocket in deep space when its engines exert a continual push?).* By the asking of such questions, the teacher is asking the class: *Given such and such a situation, what happens and why?* Students have to think according to the parameters set by the conditions imposed, a condition that we have described as *idealised abstraction* (Rowlands *et al*, in print). ldealised abstraction is similar to Nersessian's (1992) understanding of *thought experiment:*

*What we do is construct a simulation of a prototypical situation and 'run' it. It is the simulative aspect of the experiment that gives it its empirical force. Although it is not well understood yet just how the simulation process takes place in thought, it does seem that it is the construction and developmental aspects of a thought experiment that gives it applicability to the real world.*

An example of a 'prototypical situation' is 'running' (in thought) the scenario of the ball on the train above, or the 'running' of a box on a frictionless surface. By the asking of such questions, a demand is being made on the use of scientific concepts. That use is structured according to idealised abstraction, but may reveal the spontaneous concept (the intuitive counterpart of the scientific one) as the student attempts to answer the question. This is consistent with Vygotsky's emphasis on the need to teach decontextualised concepts because such concepts initially lie outside th~ 'experience of the individual and consequently the learning of such concepts develop the ability to reason. To have to think according to the parameters set by the conditions imposed requires a move from thinking in the concrete to thinking in the abstract.

## CONCLUSION - THE SOCRATIC METHOD AND THE ZONE OF PROXIMAL DEVELOPMENT

Idealised abstraction, structured by concept questions referring to the Newtonian system, together with the initial knowledge state of the student, as revealed by the response to the concept question, comprises the student's *zone of proximal development.* In the context of strategic questioning in the teaching of mechanics, the student's ZPD may be defined as the difference between the Newtonian explanation of a concept question presented by the teacher (the 'target concept') and the intuitive response to the question. Parallel questions serve as props and hints to facilitate the construction of the Newtonian system in its abstract form (e.g. the first law of motion as applied to ice pucks moving on frictionless surfaces - a situation that could never exist in the real world!) a form that requires thinking in the abstract.

'Misconceptions' of force and motion tend to be resilient to change. For misconceptions to change, the student has to construct the defining features of the Newtonian concept and this will not happen unless the student sees the need to do so. If a student realises that his or her intuitive ideas are inadequate in accounting for a phenomenon, then change is possible. If a teacher presents an anomaly to student reasoning in mechanics, then the anomaly may contain the possibility of rendering 'misconceptions' impotent in their account of the anomaly and thus allow for the facilitation of the construction of the Newtonian system: *Learning a new conceptual structure involves more than creating dissatisfaction with existing representations. It includes this and active construction of new representations* (Nersessian, 1992; author's emphasis). This dual aspect of anomalies - as a challenge to misconceptions and as cues, props or hints in the facilitation of learning the Newtonian system, is what Hestenes (1992) refers to as the *modelling game.*

The student's response to a concept question is often determined by the perceived *dominant features* (see Rowlands *et ai,* in print) of the example presented (e.g. for a ball to overcome gravity, then there must be a upward force to overcome the force of gravity). The parallel question is an anomaly to the student response. It is not the drowning of preconceptions in a sea of anomalies, but rather:

1) the raising of a qualitative example that the student has to consider within the context of idealised abstraction,

2) challenging the student's spontaneous and intuitive response with a parallel question - a question that is specific to the student's response yet has the same explanation as the original concept question within the Newtonian system.

A series of concept and parallel questions facilitates the construction of the Newtonian system within the student's zone of proximal development because each question demands consistent reasoning: that demand challenges the student's cognitive state as revealed by his or her previous response. The target concept (as expressed by a concept question) stands at one end of the ZPD, and spontaneous (and intuitive) concepts stand at the other. Parallel questions stand in between. Concept and parallel questions must not be seen as using and working with spontaneous concepts. They should, instead, be seen as a challenge to spontaneous concepts, and this would be consistent with Vygotsky's point that scientific concepts start their life in the student's mind at the level that his or her spontaneous concepts reach only later.

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