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REGULATING MOTIVATION IN MATHEMATICS

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Abstract This paper explores some basic processes for self-regulation of motivation, which is conceived as students' choice of goals. As a theoretical basis the concepts of motivation and self-regulation will be elaborated. Three aspects of goal regulation will be specified and illustrated on an empirical base of a three-year ethnographic study of one mathematics class. Primarily, goals are derived from needs. In learning situations the psychological needs for autonomy, competence, and social belonging are the most significant determinants for goal choices. As a second aspect we accept the influence of students' beliefs about the accessibility of different goals. As a third aspect we look at how automatic emotional reactions influence goal regulation.
Keywords: self-regulation, motivation, learning situations

Introduction

To understand student behaviour we need to know their motives. Motivation in this paper is seen as the inclination to do certain things and avoid doing some others. In the literature (e.g. Ryan & Deci, 2000) one important approach to motivation has been to distinguish between intrinsic and extrinsic motivation. Another approach to motivation has been to distinguish (usually three) motivational orientations in educational settings: learning (or mastery) goals, performance (or self-enhancing) goals, and ego defensive (avoidance) goals (e.g. Lemos, 1999; Linnenbrink & Pintrich, 2000). Murphy and Alexander (2000) see interest (situational vs. individual) and self-schema (agency, attribution, self-competence, and self-efficacy) also as important conceptualisations of motivation. When further elaborated, motivation can be conceptualised through a structure of needs, goals and means (Shah & Kruglanski, 2000). In mathematics education motivation has been discussed under the terms motivational orientation (Yates, 1998; 2000), interest (Bikner-Ashbachs, 2001; 2003), and motivational beliefs (Kloosterman, 2002). Also Opt'Eynde, De Core and Verschaffel (e.g. 2002) have integrated the issues of motivation into their socio-constructivist perspective.

Hannula (2002b) conceptualised motivation as a structure of needs and goals and related it to the theory of self-regulated learning (SRL). The aim of this paper is to deepen that theoretical elaboration. As a foundation it will be necessary to clarify the concepts of motivation and self-regulation. Some findings from case studies analyses will be presented - mainly to give some 'flavour' of the application of the theory. Because of space constraints, the original data and analyses cannot be included. The interested reader should return to original papers.

Motivation

What is motivation?

There are two issues, not normally found in the mainstream of motivation research which are worth considering: acceptance of the importance of the unconscious in motivation and focusing on motivational states and processes rather than traits.

Murphy and Alexander (2000, p. 38) note that in contemporary motivation research "one assumption seemingly underlying a segment of this research is that individual's motives, needs, or goals are explicit knowledge that can be reflected upon and communicated to

others." However, the present view emphasises the importance of the unconscious in human mind. Motivational constructs, like much of our mind, are only partially accessible to introspection.

Dweck (2002) claims that two motivational systems (traits and processes) are characteristics of the individual that are formed at an early age. In contemporary research the focus has usually been on motivational traits. Such research may help us predict future learning orientation and success, but it will not help much in understanding why a particular student is putting a lot of effort into some activities and not into some others, or how to induce a desired motivational state in students. Furthermore, motivation is typically conceptualised as task-based: how strong and/or what kind of motivation does a person have for doing X. To understand motivation we need to focus on motivational structures more holistically (motivated to do X and Y but not Z).

Definitions

Nuttin (1984, pp. 81-83) was critical of the many psychologists who bypass the question of what motivates human beings for action. They may explain behavioural tendencies through anticipation and expectance of consequences, but avoid the question why behaviour is directed towards certain expected outcomes and away from some others. In his own definition, Nuttin formulated his view of motivation as giving direction for behaviour:

> The general and abstract term motivation refers to the dynamic and directional (i.e., selective and preferential) aspect of behavior. It is motivation that, in the final analyses, is responsible for the fact that a particular behavior moves toward one category rather than another. (p. 14)

A problem with this definition for motivation is that it is implicitly related to behaviour. Nuttin solved this problem by defining also cognitive processing of motivation as behaviour. Buck (1999) gave a more elegant solution for this problem. He has also stressed the directional aspect of motivation, but in his approach motivation is seen as analogous to energy in physics. Energy is a potential not seen, but manifested in heat, light, matter etc. Similarly he defines motivation:

> Motivation is defined as the potential for behavior that is built into a system of behavior control, and emotion is defined as the readout of motivation potential when activated by a challenging stimulus […] motivation is conceptualized as a potential that is not seen in itself, but rather is manifested in emotion. (Buck 1999, 303)

To understand this definition correctly, one needs to know that Buck does not restrict emotions to 'hot', intense states of arousal, but perceives humans to be always in some emotional state. This is the view adopted in this paper as well.

Buck's (1999) view of motivation as a potential that is built into a control system can be refined in some aspects. When motivation is seen as relating to the directional aspect of behaviour, it is not a potential for behaviour, but a potential to *direct* behaviour. To distinguish motivation from reflexes and instincts it needs to be restricted to mechanisms that control *emotion*. Using the views of Nuttin (1984), the manifestation of a motivation can take place also in cognition or behaviour, not only emotion. For example, the motivation to be socially included might be manifested in sadness if excluded, but also in efforts to please others (behaviour), or in beliefs about appropriate behaviour (cognition). Combining these views will lead to the following definition for motivation:

Motivation is a potential to direct behaviour that is built into the system that controls emotion. This potential may be manifested in cognition, emotion and/or behaviour.

Although elegant, this definition is not very useful unless we somehow specify how this potential is realised. For this we shall use the concepts of needs and goals.

Needs – the roots of motivation

Nuttin (1984) defines needs through optimal functioning; "Behavioral needs can be conceptualized as categories of [individual-environment] relationships that are *required* for optimal biological and/or psychological functioning" (p. 62). The 'requiredness' of certain relationships can be inferred, for example from deterioration of functioning when a relationship cannot be established or from the behaviour and emotional reactions of an individual (p. 62). Needs are specified instances of the general 'potential to direct behaviour'.

Nuttin (1984) refuses to give any lists of needs. He does, however, elaborate some needs for self, cognitive functioning, and social functioning. Psychological self-preservation and self-development require identity, autonomy, and consistency. Cognitive functioning requires exchange of information with environment and, furthermore, there is a need to comprehend self, others, and the world one lives in. As requirements for optimal social functioning he mentions interaction (need for contacts), need to have positive responses from others, and a need to benefit others.

In the existing literature psychological needs that are often emphasised in educational settings are autonomy, competency, and social belonging (e.g. Boekaerts, 1999, p. 452; Covington & Dray, 2002, p. 47). While teacher-centred and teacher-controlled teaching modes are often in conflict with students' needs for social contacts and autonomy, collaborative project works give more space for students to satisfy their need for autonomy and their social needs.

Needs into goals

Nuttin describes the difference between needs and goals in their different levels of specificity: "Whereas a need is directed toward a relatively large category of objects, a [goal[1]] is directed toward a specific object" (Nuttin, 1984, p. 139). For example, in the context of mathematics education, a student might realize a need for competency as a goal to solve tasks faster than other students or, alternatively, as a goal to understand the topic taught. A social need might be realised as a goal to contribute significantly to a collaborative project work and a need for autonomy as a goal to challenge the teacher's authority.

The definition suggested for motivation in this paper was a potential to direct behaviour. This potential is structured through needs and goals. We can further continue the elaboration of this structure. For example, we may elaborate the different connections between goals: they are hierarchically arranged in the structure and one goal may be, inhibitory, necessary, or sufficient to reach another goal (Nuttin, 1984, Power & Dalgleish, 1997, Shah & Kruglanski, 2000). The hierarchical structure can be extended to means (Shah & Kruglanski, 2000), plans, and actions (Nuttin, 1984). Boekaerts (1999, p. 452) discusses how some students may pursue multiple goals simultaneously, navigating elegantly between them, while others approach their goals serially. Overall, the complexity of human needs-goals structures makes it a problematic research topic: "the multiplicity of goals sought by man represents a chaotic puzzle that is inconsistent with the simplicity sought by science" (Nuttin, 1984, p. 83).

Self-regulation

Zimmerman and Campillo (2003) have characterised self-regulation as "self-generated thoughts, feelings, and actions that are planned and cyclically adapted for the attainment of

[1] Nuttin writes in the original text about motives instead of goals. However, he uses the term 'motive' with similar meaning as most other writers use the term 'goal'.

personal goals, such as solving a problem" (p. 238). They divided self-regulation into three phases that all have several sub processes (p. 239):

1) Forethought phase (task analyses, self-motivation beliefs)
2) Performance phase (self-control, self-observation)
3) Self-reflection phase (self-judgment, self-reaction).

The process of self-regulation proceeds through phases one and two to phase three, and then back to phase one.

Boekaerts (1999) has outlined the three roots of research of self-regulation: "Our understanding of self-regulated learning has been informed by three schools of thought: (1) research on learning styles, (2) research on metacognition and regulation styles, and (3) theories of the self, including goal-directed behavior" (p. 451). Based on these schools of thought, she presented a three-layer model for self-regulation:

- The innermost layer pertains to regulation of the processing modes through choice of cognitive strategies.
- The middle layer represents regulation of the learning process through use of metacognitive knowledge and skills.
- The outermost layer concerns regulation of the self through choice of goals and resources.

These layers can be illustrated as a simplified flowchart of three nested processes, where one regulative process is a sub procedure of another (figure 1). The regulative processes on all three levels include automatic, unconscious processes, such as bias of memory and attention. It is possible to combine Zimmerman and Campillo's (2003) three-phase idea to this model, when regulation of the learning process (together with regulation of the processing modes) is seen as the performance phase of regulation of self. It is also possible to focus on more detailed processes and perceive regulation of the learning process as a forethought phase and regulation of processing modes as the performance phase.

Although the human mind is never motionless, and hence we cannot say that the process of self regulation ever 'begins', we may see more or less coherent episodes from an adoption of a goal to its accomplishment. For example, when preparing for a test on multiplication tables, a student may adopt a goal to get full points in the test (choice of a goal). The student is aware of already knowing the tables of 1, 2, 3, 5, and 10 by heart (use of metacognitive knowledge) and decides to focus first on table of fours (regulation of learning process). The student reads the table and chants the list in his mind: "four, eight, twelve, …" (choice of cognitive strategy). After a while, the student puts the table away and checks whether the list has been learnt, and continues to the six times table (regulation of the learning process). After having thus proceeded through the whole table, the student asks a sibling to test this new knowledge (choice of resources). During this testing the student becomes aware of not mastering seven and eight, and decides to study those further (regulation of learning process). There may be further cycles of self-regulation until the test is over, but after that the original goal is no longer valid. Any further learning of multiplication tables will require adoption of a new goal.

Most research has focused on the two middle layers and little effort has been made to integrate motivation control, action control or emotion control into theories of self-regulation (Boekaerts, 1999, p. 445). Boekaerts and Niemivirta (2000) have proposed a broader view for self-regulation that would accept a variety of different control systems, not only metacognition:

> [Self-regulation] has been presented as a generic term used for a number of phenomena, each of which is captured by a different control system. In our judgment, self-regulation is a system concept that refers to the overall management of one's behavior through interactive processes between these different control systems (attention, metacognition, motivation, emotion, action, and volition control). … In the past decade, researchers involved in educational research have concentrated mainly on activity in one control system – the metacognitive control system – thus ignoring the interplay between the metacognitive control system and other control systems. (p. 445)

Although the scope of the present paper (or the expertise of its author) does not allow elaboration of all the abovementioned control systems, the present view sees self-regulation to be much more than mere metacognition. Most notably, the important role of emotion is acknowledged.

Self-Regulation of motivation – some observations

Empirical background

The empirical background of this paper is a longitudinal (three years) qualitative study. The researcher has interacted a lot with the students as their teacher, and collected a large and varied data (classroom observations, individual and group interviews, interviewing parents and teachers) on a small number of students (gradually decreasing to 10 focus students). The main bulk of the data consists of 68 interviews. In the analyses of data two basic approaches have been used. One has focused on an individual student. In such approach the researcher has explored the available data on a particular student and tried to interpret and reconstruct the student's personal developing ways to perceive oneself and one's experiences in the world. Sometimes the results have been reported through the use of a model (e.g. Hannula, 1998b), and at other times through a narrative (e.g. Hannula, 2003a, 2003b). The other approach has been to focus on a certain phenomenon, and to look how it manifests itself in the data (e.g. Hannula, 2002b; submitted b). Such approach has included use of a software tool (Nud*Ist) for coding the original data and then reorganising the data to be read 'phenomenon-wise'. I will draw from these studies to illustrate how regulation of motivation is unfolding in actual students' lives. The two main topics in the interviews that have contributed to the analyses of students' motivation were their views about the usefulness of mathematics in their future studies, work, and life, and their mathematics-related emotions.

Deriving goals from needs

The importance of needs is obvious when we think of physiological needs: hungry or tired students cannot concentrate well on studying mathematics. Similarly, students may decide not to pursue learning goals when they feel that one or more of their psychological needs are thwarted (Boekaerts, 1999). Some case studies suggest that different dominating needs lead to adoption of different primary goals and to different kind of behaviour in mathematical situations. In the comparative case study of Eva and Anna (Hannula, 1998b, 2003a, submitted a), social needs were dominating Eva's goal choices, while competence was a more important need for Anna. In the specific social situation, these led Anna to give priority to learning goals while Eva's behaviour was determined by interpersonal relationship goals.

Of course, needs-goals relationships are mediated by personal beliefs. One may perceive a single goal to satisfy multiple needs and a need to be satisfied through multiple goals. Goals may also be seen as contradictory in a sense that reaching one goal might prevent achieving another goal. For example, mastery and performance are usually seen as competing motivational orientations (e.g. Linnenbring & Pintrich, 2000; Lemos, 1999). However, in my analyses of Maria and Laura (Hannula, 2002b), mastery and performance were goals that

supported each other. Maria was driven by her need for competence, and mastery of mathematics was her primary goal. However, performance in mathematics tests was an important subgoal for her evaluation of reaching that goal. Laura, on the other hand, was primarily driven by her desire to gain a high status in the class 'hierarchy'. Performance (outsmarting other students) was her main goal, while mastery of mathematics was an important subgoal. Furthermore, while Laura tried to hide possible deficiencies in her understanding, it was hard for her to participate in collaborative activities. Rather, she tried to learn mathematics through he own individual effort or with help from her father. Dweck (2002, p. 73) has also noted that performance and mastery should not be seen as mutually exclusive goals.

Perceived accessibility of goals

Students' beliefs about accessibility of different goals is another aspect of regulation of motivation. This is usually discussed under the term 'self-efficacy beliefs' (e.g. Philippou & Christou, 2002). It seems that for a change in motivation to take place two conditions must be met. Firstly, there must be a desired goal and, secondly, one's beliefs must support the change. The author has previously reported on the case study of Rita, where a radical change in beliefs and behaviour included these two aspects (Hannula, 1998a, 2002a). Using the terminology of goals, we may say that Rita had self-defensive goals dominating her behaviour in the beginning ("You don't need math in life"). However, this was later replaced by performance goals ("I will raise my math mark"). Behind this change, there was a new awareness of the importance of school success in general (change in values) together with more positive self-efficacy beliefs (success is possible). In the case of Anna and Eva (Hannula, 1998b, 2003a, submitted a), we can also see these conditions for successful goal regulation. Although both students see mastery of mathematics as a desirable goal that is not accessible by simply listening to the teacher, only Anna manages to act according to this goal. One important difference between Anna and Eva was that Anna had higher self-confidence in mathematics and thus believed that she can learn mathematics through independent study.

Automated regulation

There are two fundamentally different ways in how emotional state may be changed (Power & Dalgleish, 1997). One way is the (possibly unconscious) cognitive analysis of the situation with respect to one's goals. Another route to change emotional state is through association to one element of the situation. Emotional associations are learned via classical conditioning and they form the core of attitude as an emotional disposition (Hannula, 2002a). Although they allow shorter reaction times to possible threats, they lack flexibility and are an inertia force of behavioural changes. Once formed, these associations are difficult to change. During school years, students usually develop some emotional disposition to different mathematical actions and goals. Therefore, emotional associations may function as an inertia force against change, even when change should be 'rational'. Malmivuori (2001) and Boekaerts and Niemivirta (2000) have also distinguished between this automatic and a more reflective self-regulation. In the case of Anna and Eva, one possible obstacle for Eva was her automatic emotional reaction, shame, when she needed to ask for help.

Paradoxically, the automatic 'inefficient regulation' can be highly efficient when used in concert with more reflective self-regulation. Involvement is an example of such automatic but productive self-regulation, and students may even consciously use different strategies to become involved (Reed, Schallert & Deithloff, 2002). Involvement clearly relates to the notions of flow (Csikszentmihalyi, 1990, see also Williams, 2002) and mathematical intimacy (DeBellis, 1998), and thus also to the concept of shared cognitive intimacy (Hannula,

submitted b). These all overlap, and they all share the phenomenon of psychological engrossment, where attention is focused on the task. At this point the person is totally immersed, and has little self-consciousness. This experience is generally reported afterwards as a positive, satisfying experience.

Discussion

In the theory of self-regulated learning, Boekaerts (1999) expressed the need to increase our understanding of the regulation of motivation. She argued that this least developed area of SRL is essential in understanding student behaviour in classrooms:

> information about ... the goals [students] set for themselves ... provides an indication of why students are prepared to do what they do and why they are not inclined to do what is expected of them. (Boekaerts, 1999, p. 451)

In the present paper, the concept of motivation is elaborated and a new definition is suggested. Motivation is conceptualised as a potential to direct behaviour through the mechanisms that control emotion. This potential is structured through needs and goals. Based on this view of motivation, some observations are made on regulation of motivation. Three aspects of motivation regulation were observed in empirical data: deriving goals from needs, the influence of goal accessibility beliefs, and automated regulation of motivation. However, systematic qualitative research may point to further important factors as well as disregard some of the conclusions made on the bases of this small number of case studies.

The field of affect in mathematics education is usually divided into emotions, attitudes and beliefs (e.g. McLeod 1992), and possibly including a fourth element, values (DeBellis & Goldin, 1997; Goldin, 2002). I do not see motivation as another element of human affect. Rather, motivation is a different view to affect. It is a potential to direct behaviour that is built into the emotion control mechanisms. As a potential, motivation cannot be directly observed. It is observable only as it manifests itself in affect and cognition. How different elements of affect (emotions, attitudes, values, and beliefs) and motivation relate to each other and interact with each other is an issue that needs further research.

Another important field for future research is teaching practice. All mathematics educators want their students to be motivated. What should we do to increase motivation? Despite the emphasis on theory and the small scale of my empirical study, I attempted to draw some plausible implications for teaching. We often think (at least I did), that if students just knew how useful mathematics is, they would be motivated to study it. But we must understand that students in a mathematics classroom are motivated to do many things, not only the ones we expect them to do, or indeed hope they will do. Instead of just trying to control students' needs, we should learn to use their needs. Carefully designed collaborative activities provide opportunities for all kinds of social needs to be met. Students may feel that their need of autonomy is fulfilled when they are working on investigations or open problems. Tedious routines can be practiced with help of entertaining games. When students feel that their needs are met in mathematics class, they are willing to participate whole-heartedly. Another important issue for teachers to remember is the students' self-confidence. If students don't believe that they can learn, they will not put effort into it. Also the less able students must feel that they are competent in mathematics – they can do some mathematics and they can learn more – even if they have not mastered all topics. How about the 'traumatized' students, the ones who are anxious when facing mathematical tasks? They need a safe environment and enough support for their emotion-control. Encouraging or soothing words at right times may sometimes be enough. And finally, if we manage to get our students interested and are able to

provide them with optimally challenging tasks, they may experience 'flow', intimacy with the task, or even shared cognitive intimacy while solving it. Such an experience would most likely be the best motivator.

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