“COOLING-OFF”: THE PHENOMENON OF A PROBLEMATIC TRANSITION FROM SCHOOL TO UNIVERSITY.

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ABSTRACT

This paper will investigate the transition from School to University focussed specifically on mathematics. It will explain how students negotiate their response to the changes in the dynamics of the teaching and learning milieu. In particular, it will consider an important new viewpoint on the well-documented cognitive difficulties that first-year Mathematics Undergraduates encounter: their developing loss of interest in mathematics which we call the "cooling-off" phenomenon.

The paper is focussed on a study based on a close qualitative observation of 12 students who were followed from the last year of school through their first year at a prestigious mathematics department at a UK university. The data illustrate the development of the attitudinal profile of the students and the persistence of their beliefs about the nature of mathematics. We will consider how these persistent beliefs influence their 'didactical contact' (their view of their role and the teacher's role in the teaching/learning process). Comparing extracts of interviews from both school and university will highlight some of the subsequent difficulties in students' abilities to engage with learning and doing advanced mathematics. We will develop a theory which links the characteristics of the "cooling-off" phenomenon which, we hope, will simplify our understanding of some of the affective aspects of the transition to advanced mathematical thinking.

The paper will finally propose ways in which the mathematical community can diagnose the symptoms of "cooling-off" phenomenon and embark upon an adjustment of the mathematical courses in order to deal with it.

KEYWORDS: TERTIARY EDUCATION, ATTITUDES

Introduction

> "University mathematics is a lot like trying strong cheese-really difficult to swallow until you get used to it. Even then though it still tastes odd." (*First year undergraduate in mathematics*)

The above comment is representative of the views expressed by many first year undergraduates in mathematics we have come across (and there is no reason to believe that it does not represent views of many mathematics students more generally).

The issue of the transition from school to university in the case of mathematics has been of great concern in the field of mathematics education (Hoyles *et al*, 2001; LMS (1995); Robert & Schwarzenberger, 1991) by focusing mainly on the epistemological and cognitive difficulties first year undergraduates face upon their entrance to a Mathematics Department. As Tall (1991) argues "the formal presentation of material to students in university mathematics courses [...] involves obstacles that make the pathway very difficult for them to travel successfully". Bibby (1985) refers to that difficult pathway for students as a critical disorientation experienced by them due to the content of Analysis "in the sense that it regards as problematic what the student has taken for granted hitherto" (p. 48) and due to the rigour and formality in the style of teaching and learning.

However, as Sigel (1982) notes, cognition and affect are embedded in the same schemas and should be treated as equal components of the schema formed by one's experiences. The same could be argued in the case of the transition from school to university and as the research of Meyer & Eley (1999) reports, negative affective dispositions towards mathematics, could predispose students not to apply more elaborative learning processes.

Nevertheless the current studies concerning the transition from school to university mathematics provide only a general observation and description of the affective difficulties first year undergraduates face, without examining in depth the further consequences of students' difficulties with advanced mathematics setting and environment. Cooper's (1990) reinterpretation of Clark's (1960) theory of "cooling-out" reveals that students show a general tendency to lose their interest in mathematics after their transition to university, but his findings do not explore the nature of the development of this phenomenon.

The evidence from our research not only supports Cooper's theory but also elaborates on the characteristics and dimensions of what we are calling the "cooling-off" phenomenon: students' developing loss of interest in mathematics due to a combination of cognitive and affective factors with a focus on the persistence of their mathematical beliefs. In the case students' behaviour is characterised by more intense characteristics, the "cooling-**off**" phenomenon appears to have even more serious consequences in the students' academic performance and develops into what we are calling the "cooling-**out**" phenomenon.

The data presented in this paper will illustrate the developmental and affective nature of the "cooling-off" phenomenon by outlining the attitudinal profile of two students representative of the "problematic" student behaviours through the transition from school to university.

Methods of Data Collection

The paper is focussed on a study based on a close qualitative observation of 12 students who were followed from the last year of school through their first year at a prestigious mathematics department at a leading UK university.

Semi-structured interviews were conducted with the students while they were in their last year at school and another four series of interviews were conducted with them during their first year at the university. In addition the gathered data were triangulated though students' responses in attitudinal questionnaires and the attendance of their university supervision classes. The data that will be presented here are extracted from the first interview at school and the second one at the university in the middle of the first term, in order to include a fair range of the attitudinal development of students. At the end of the school interview, a mathematical task was given to the interviewees, adapted from Mason, Burton & Stacey (1982): "A four digit palindrome is always exactly divisible by 11. Is that true?". The mathematical task for the second interview at the university was: "How many natural numbers satisfy the inequality $3^n \leq n^3 + 1$?".

The Student Types

The documented lack of a universal definition for attitudes (Kulm, 1980; Triandis, 1971) makes their measurement very difficult and therefore hinders the formation of a student's attitudinal profile. In our research, a student's "attitudinal profile" consists of their beliefs about the nature of mathematics, their beliefs about the teaching and learning of it and their previous experiences with it.

The analysis of our data suggests that there are two "problematic" student behaviours according how students deal with university mathematics, the degree to which the "cooling-off" phenomenon can be observed and the gravity of its consequences for students' further development on their mathematics course. The different student types are: the students who are expressing signs of the "cooling-off" phenomenon and the ones who are expressing signs of the "cooling-out" phenomenon. In the following paragraphs we will describe the characteristics of each one of these student types by presenting extracts from interviews with two representative of the above categories students: Kenneth and Katherine during two different interview times, once at school and once at the university.

"Cooling-off" type: The case of Kenneth

The main characteristic of the "cooling-off" types is that these students start with a quite positive attitude towards mathematics while they are at school as this is expressed through positive feelings about their interaction with school mathematics and through positive, although rather restricted beliefs, about the nature of it.

The preferences of these students concerning mathematical topics are also very "systematic" because they favour exercises and topics where "working towards a definite answer" is the key goal, as Kenneth said in the attitudinal questionnaire distributed to students at school. The "cooling-off" types also have an inclination towards mathematical problems where they can count on the "security" of a known topic or method or even in the teacher's guidance.

I: Why do you think that Further Maths is more difficult?

K: Uhm, it’s just like different topics, like Complex Numbers and things like that which…well take a bit more time. ‘Cause things like, with the Statistics it’s really straight, it follows on from Normal Maths that is pretty easy, but uhm, the Pure Maths it’s just like…a bit different. It doesn’t really follow up from what we’ve done before.

The way Kenneth initially attacked the mathematical problem was through the testing of numerical examples in order to find a pattern that worked. His initial approach did not include any formalisation and it was until further on during the solving of the exercise that he realised the need for a mathematical proof but could not proceed with it. Only after being prompted for the general representation of a four-digit palindrome he managed to produce an algebraic formula for it (yxxy = ya +xd, where a = 1001 and d = 110) and justify his answer. His reflections after the end of the mathematical task were very indicative of his dependence on known methods:

K: Uhm…probably difficult to know where to start because basically I didn’t know where to start at all! And ‘cause we haven’t done anything like that at A-level, uhm…

When the “cooling-off” students enter university they are confronted with a teaching, learning and working environment that is not only different from the one experienced so far but also from the one they know how to function in successfully. The experienced mismatch between their beliefs about the nature of mathematics and its rigorous university character soon makes them lose their interest in mathematics and develop a negative attitude towards it.

I: Uhm, so uhm, could you tell me how do you find Maths at the moment? In what stage you are…

K: Uhm, I'm finding it quite difficult, uhm mainly because it’s really quite a lot different to A-Level Maths, and it’s not like where you, ‘cause at A-Level Maths you just like got told a method of doing something and then you just had to apply that to different questions whereas here it's more like sort of, I don't know proofs and stuff like that. […]There are quite a lot of things, especially in Analysis they were like, you had to prove these things, but quite a lot of them, I mean you could just look at, and say that looks true, whereas…so you weren't proving anything.

The first signs of the “cooling-off” phenomenon make their appearance from the first week of the course with their most intense expression around Week 4 of a UK university, meaning slightly before the middle of the term when the students can no longer cope with both the advanced content of mathematics and their loss of interest in it. But what differentiates the “cooling-off” types from the other student types found in this research is that they gradually manage to adapt to the new environment after the “peak” point of their “cooling-off” route, their attitudes towards the course and university mathematics start to “warm-on” and they put more effort in adjusting their beliefs to the new status. The following passage from Kenneth’s interview could show this:

I: Right. You said it got better after some time, could you, sort of,..two questions, could you define more or less when, could you tell me from what point and on it became better, and better in what sense?

K: Uhm, I think sort of from the start of last week, start of week 5. I'm still not finding it sort of easy, but, especially with the Analysis booklet, I sort of understood it more and, now I'm getting used to like how you structure the proofs and how you write them. Getting more used to doing things like that, so that's got a bit better now.

Once again Kenneth approached the mathematical task given to him at the end of the interview by trying out some numerical examples. He was quite willing to proceed with the solution of the exercise and he recognised himself the need for a mathematical proof after his informal justification of the result, although he finally gave only a verbal proof. When Kenneth was asked to reflect upon the mathematical problem after solving it he said:

K: I don't think it was too difficult because just by putting numbers in that's like a way you could start it, so it's not like you looked at it and you didn't have any idea about how to go about it, so just by playing around with it you can get some ideas.

We believe that Kenneth's mathematical reaction during the solving of the exercise was indicative of his regained interest in engaging himself with mathematics in particular and of his "warming-on" behaviour in general.

"Cooling-out" type: The case of Katherine

The characteristics of the "cooling-out" types are very similar to the "cooling-off" ones at least when the students are still at the school environment. The starting attitude is also very positive and these types of students also enjoy doing mathematics. The difference at this point is at the focus of attention of the students. Although their preferences concerning mathematical topics include topics where the exercises have "an exact answer to be found at the end", as Katherine responded in the school attitudinal questionnaire, it is the "convenience" of mathematics that attracts them the most by emphasising on correct answers obtained in a short time-span, as the extract below indicates:

KP: I'd always liked maths. I think I just, uhm during the lower school and GCSEs I just got sick of writing essays! And I preferred the scientific approach, just an answer and sort of short explanation answer rather than 3 pages essay!

The students who belong to this category usually seek for the teacher's guidance in the solving of exercises instead of counting on independent work and like working towards definite answers through applying an already acquired technique.

The way Katherine initially approached the mathematical task was by specialisation through the use of numerical examples. However she was not feeling confident at all about her chosen technique and when she reached an (incorrect) result could not prove it "mathematically" as she said. Reflecting back upon the mathematical problem Katherine justified her mathematical behaviour during solving it:

I: How did you find this exercise?

KP: Uhm, it's quite interesting. I didn't have a clue where to start.

The university environment of instruction and learning has very critical consequences for "cooling-out" students. The "cooling-out" students find themselves in a situation where their beliefs about the nature of mathematics and the setting of exercises are no longer appropriate for their adjustment to university mathematics. That has as a result the students' diversion of attitudes towards negative scales and the subsequent appearance of "cooling-off" signs. What then differentiates these students' behaviour from the previous' category one is the intensity of these signs and their persistence, which make their performance in the university setting almost unbearable. The following extract from the interview with Katherine is representative of the "cooling-out" behaviour:

> I: Uhm, I've only got one big question to ask you which is how do you find Maths until now?

> KP: Incredibly difficult! Uhm, yeah, uhm, I'm finding it so hard! Uhm, all of the courses. With the exception of Statistics. Stats Lab 1 I can do because basically we haven't done anything yet, that I didn't cover in my A-Level. And, I'm finding that really easy, which is good because I know that there is one lecture which I can go to where you can go "yeah I know what that is", but all the others are a nightmare!

The first signs of "cooling-off" are revealed from the very beginning of the first academic term but they also continue to be present even after the middle of the term with their intensity remaining at high levels. The "cooling-off" behaviour blocks students from adapting to university mathematics and also creates a feeling of personal disappointment, which in its turn prevents them even more from making an effort to adapt to it. As Katherine says:

> I: Right, so overall how do you find maths, apart from difficult, as you said before?

> KP: (*hesitates*) Well I don't really know what else to say, it's just very difficult! I just feel so lost, with all of it at the moment.

The same attitude could be manifested during Katherine's attempt to solve the mathematical task given to her. Her initial reaction to it was: "Oh my Goodness! I don't know where to start." Katherine not only was lacking significantly in confidence but also was not willing to proceed with her starting strategy for the task: "the only thing I can think of is logs, but I don't really know how you would use them." Her lack of interest to work with the mathematical problem was evident throughout the whole time dedicated for its solution and her reflections upon it illustrate it very successfully:

> I: How do you find this one? What do you think of this exercise?

> KP: It's horrible; I just don't know where to start. I really don't know where to start.

Katherine's mathematical behaviour was very representative of the "cooling-out" types regarding her lack of motivation and even denial to engage herself with the task.

Generalisation

The close observation of all twelve students during the realisation of this study confirms the similarity in the behavioural route of the ones who belong to the same category as Kenneth through a gradual "cooling-off" and then a "warming-on" period. There were 6 students out of the 12 who showed signs of "cooling-off" behaviour and 4 students who had developed a "cooling-out" behaviour similar to Katherine's, which was present even during the last interview with them at the third term of the university. Finally only the remaining 2 students appeared to be the ones who managed to make a smooth transition to university, without any signs of "cooling-off", not only because their starting beliefs about mathematics were more in line with the university setting but also because they managed to quickly modify the ones that weren't working during the very first week of the term.

From "Cooling-Off" to "Cooling-Out"

The above illustrations of the two student types throughout their passage from school to the middle of first term at the university demonstrate the development of their attitudinal profile from positive scales to relatively negative ones and the consequences this development has in their further mathematical performance and way of approaching mathematics in general.

In the case of Kenneth, a "cooling-off" type, his positive attitude towards mathematics while he was still at school was a product of his confidence and successful performance in working with it and his matching beliefs with the actual school setting. However, the carriage of his system of beliefs to the university created substantial difficulties in his engagement with the advanced mathematics setting. His beliefs about the didactical contact, the learning process, the setting of the mathematical exercises and the nature of the mathematical concepts could no longer be in accordance with the university teaching and learning style, and the working and assessment requirements. Kenneth's reaction to this mismatch of his beliefs caused him to increasingly develop a negative attitude towards university mathematics and gradually lose his interest in it, which was the indication of his "cooling-off" behaviour. Nevertheless, Kenneth soon found ways to "recover" from his "cooling-off" disposition and showed signs of "warming-on" by readjusting some of his beliefs and modifying his negative attitude. His mathematical behaviour, which was intimately linked to his attitudes towards mathematics, was also altered during the "warming-on" period, including a more willing approach of the mathematical problem given and an adaptation to university techniques and levels of formality.

In the case of Katherine, the gap between her beliefs about mathematics while she was still at school and the experienced situation in the university caused her to firstly express signs of "cooling-off" behaviour from the very first days at the university. Her expectations of university mathematics not only didn't match the reality but also were causing her a cognitive and attitudinal block for her adjustment to university. However, Katherine's attitude towards mathematics underwent a serious break and turned towards a very negative preoccupation towards university mathematics causing her a complete loss of interest in it. It was at this point that Katherine passed from the "cooling-off" behaviour to the "cooling-out" one, a gradual switch that was accompanied by her denial to alter her beliefs and her subsequent attitude towards university mathematics and mathematics in general. Her mathematical behaviour was also indicative of her "cooling-out" disposition, since Katherine had expressed no sign of any interest in the mathematical problems given to her, almost refusing to attempt a solution from her fear of failure and her lack of confidence in her mathematical abilities.

However, the trends found in the twelve students who participated in this research illustrate a phenomenon rather that quantify categories. Students' documented transition from school to university is a problematic one and the phenomenon of "cooling-off" is one of its affective consequences. Before students come to university, their attitudes towards mathematics are very positive, especially in the case of students applying for a mathematics degree, and these attitudes are shaped by their beliefs about the nature of mathematics and its school teaching and learning approaches. When these students enter university some of these beliefs might no longer be appropriate for the advanced mathematics environment causing the students cognitive and affective difficulties during their adjustment to the university setting. The students who experience a mismatching of their beliefs with the actual university situations encountered are very likely to demonstrate a negative attitude towards university mathematics in particular and mathematics in general, which can result in its turn in a malfunctioning in the university environment. The students then undergo a gradual loss of interest in mathematics, which is manifested as the "cooling-off" behaviour. It is then up to the students themselves to either recover from that phase or give up and lose not only their interest in mathematics but even their interest in the course and develop a "cooling-out" behaviour, which is very intense in its signs, very difficult to change and might even result in a drop-out from the course.

The questions that immediately come into mind are: how can we detect the symptoms of the "cooling-out" phenomenon and how can we prevent it from reaching the "cooling-out" stage? Since this research has taken place in one of the leading UK universities for mathematics with very supportive tutorials and supervision classes, we could assert that it is representative of a phenomenon present in most universities. The prevention of the appearance of these phenomena should start in school, perhaps by integrating a mathematical problem solving module or topic from an advanced point of view. At the university level, a revision of the first term's courses in order to include a systematic introduction to the university style of working should be considered. The carefully planned run of support tutorials could also be very beneficial not only for the students themselves but for the trained tutors who could trace the possible signs of a "cooling-off" behaviour and prevent it from being an obstacle for the students' academic performance and attitudes.

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