CHAPTER SEVEN

Instructional Experiences and Flow

There can be little doubt that instructional experiences affect motivation. Unfortunately, the usual result is that students lose interest and feel less competent in mathematics, as well as other subjects, despite the good intentions of schooling (Eccles & Midgley, 1989; National Education Goals Report, 1993; Wigfield & Eccles, 1994). This perverse effect starts with students between the fifth and sixth grades and continues into adolescence, affecting gifted students as well (Middleton, et al., 1991).

Changes in Flow

While it was shown in the previous two chapters that flow at the beginning of the year predicts flow at the end, flow generally occurred less frequently and became less pronounced. In some instances the reverse happened and students reported more flow at the end of the year than they did at the beginning. In the majority of cases, those who entered the program with strong intrinsic interest finished the year with much of their interest intact. Nonetheless most of these began to doubt their abilities, a tell-tale sign of eroding self-motivation. The complexities of classroom tasks related to these changes in flow were the focus of Study III and the topic of this chapter, informed by seven talent search classes which met during the 1993-94 school year.

The year under consideration was not unique in that when students arrived for the first night of instruction they were excited and a bit apprehensive about the new experience awaiting them. To capture this moment, students completed a background questionnaire about their math experiences. In their responses, students reflected the enthusiasm one might expect of young persons who qualified to attend math classes at a college, an opportunity reserved for only 1 out of every 100 young persons their age. Table 7.1 shows that in all but the first year, flow perceptions were at their highest before the start of instruction.

For the year during which classroom data was gathered, flow was at its peak at the beginning of the year, its lowest at the mid-point. The drop during the first half of the

Table 7.1 Changes in Flow over the School Year

Year	Flow A	Flow B	Flow C	Change	
	Week 1	Week 15	Week 30	(Week 1 to 15)	(Week 15 to 30)
92-93	.322	.286	.324	$t = 0.26$	$t = -0.80$
93-94	.480	.362	.397	$t = 3.95$***	$t = -0.84$
94-95	.420	.296	.271	$t = 3.92$***	$t = 0.93$
95-96	.421	.363	.323	$t = 2.32$**	$t = 2.15$*

* $p < .05$ ** $p < .025$ *** $p < .001$

year was statistically significant and the most pronounced of the four years ($t = 3.951$, $p < .001$). A similar phenomenon may be noted for two of the other years as well: a loss of intrinsic interest possibly due to the effect of challenging mathematics or at least a challenging pace. For most new students who complained that math instruction back at their regular schools was not challenging enough, the talent search experience seemed to serve as an abrupt awakening. Students unaccustomed to studying for tests, who rarely had to be concerned with math homework, soon discovered that their lack of study habits now earned them C's and lower. Rather than boredom in math--which prompted parents to consider the expense and inconvenience of an alternative math program in the first place-- students now began to experience frustration. The frustration at the mid-point of the 93-94 instructional year was significantly higher than at the beginning ($t = 4.882$, $p < .001$), whereas boredom decreased.

Of course, other explanations for the decrease besides challenge-based frustration are also plausible: perhaps students did not find the material interesting, perhaps they did not like the teacher or the way the class was run. As each of these may have affected their motivation, they were also examined.

Between the middle and the end of 1993-1994, flow responses rebounded but did not return to the ebullient high where they started. Despite the recovery, the difference between Flow A and C was still significant: $t = 2.993$, $p < .005$. While many students experienced less flow, this was not universal. Students' flow experiences differed depending on which class they were in. Table 7.2 compares the seven classes by teacher, subject matter and flow measured at the beginning, middle and end of the year. There were some notable differences in initial flow. One class in particular, taught by Teacher B, was lower than all the others to start with and remained the lowest the entire time. Students in the Math class taught by Teacher C experienced a significant loss in flow over

Table 7.2 Changes in Flow by Classes

Teacher	N	Type	Flow A week 1	Flow B week 15	Flow C week 30	Change week1 to 30
C	15	Math A	.475	.385	.297	-0.178
A_1	15	Math A	.521	.314	.444	-0.077
A_2	10	Math B	.544	.420	.472	-0.072
Q	14	Math B	.423	.318	.460	0.037
B	10	Math B	.313	.159	.197	-0.116
R	11	Geometry	.514	.496	.504	-0.010
J	12	Geometry	.569	.509	.462	-0.107

the 30 weeks ($t = 3.133$, $p < .01$). The only other significant change occurred in the other Math A class, taught by Teacher A ($t = 2.934$, $p < .025$). These were the two classes which covered two years of high school mathematics in one, double the pace of math B and geometry.

Every class experienced a loss of flow between weeks 1 and 15, which may suggest that the math or the pace of instruction was more challenging than the students anticipated. However, the most interesting differences occurred between the middle and the end of the year. Teacher Q's algebra students finished with more flow than they reported to begin with. All the Math B classes had a higher average flow at the end than at the middle. After a slight loss, Teacher R's geometry students recovered most of what they had lost. The second geometry class experienced less flow as the year progressed. One of the two groups of Math A students continued to falter while the other one partially recovered intrinsic interest. This suggests a strong teacher effect and invites closer scrutiny of what went on in classrooms that may explain these differences.

To reduce the multiplicity of comparisons, students in classes that reported more than a 5% decrement in flow by the end of the year were grouped together, constituting a flow loss group (n = 65). These were all the students taught by Teachers A, B, C and J. On the average, students in classes taught by Teachers Q and R retained their initial levels of flow or gained; for the purpose of comparison, these individuals comprise the flow gain group (n = 25). The mean flow change in these two groups was 0.014 and -0.22, respectively ($t = 5.876$, $p < 0.001$).

Classroom Complexity

What did students experience in their classes that may explain why they retained or lost flow as a group? What made the experience inherently enjoyable or not? To understand these questions better, the two flow change groups were compared using the model of classroom complexity described in chapter 3. Briefly to review the model, it was hypothesized that complex classrooms would provide more opportunities for students to interact and make choices, satisfying their need for competent control. Therefore, one would expect to find more group work, projects, student presentations and discussion. On the other hand, more time may be devoted to teacher presentation, recitation, seatwork and housekeeping chores (grading papers, etc.) in simple classrooms. In addition, complex classrooms are thought to provide clear goals and feedback that is both informative and immediate rather than controlling and delayed.[1] Regarding the variety of formats, no effect is expected, since individuals who engage in flow often do so for long periods of time without altering the activity. Novelty is expected in the types of problems studied, however. Complex classes are hypothesized to attend to fewer known solution problems, preferring more discovery-type or genuine problems. Correspondingly, higher cognitive operations are required to analyze and apply what is familiar about math to what is unfamiliar in more novel problems.

To test these claims, instructional segments were analyzed for their impact on motivation in terms of formats, student and teacher behaviors, social interactions, the types of problems utilized, and cognitive operations.[2]

Instructional formats

Of all the task-related structures, instructional formats are among the most readily identifiable. By their overt behaviors it is not hard to tell when a teacher is presenting material to a class, when students are engaged in seatwork, or when they are called on to recite. Previous research in mathematics classes has established that seatwork and recitation tend to occur more frequently than other formats, at least in self-contained

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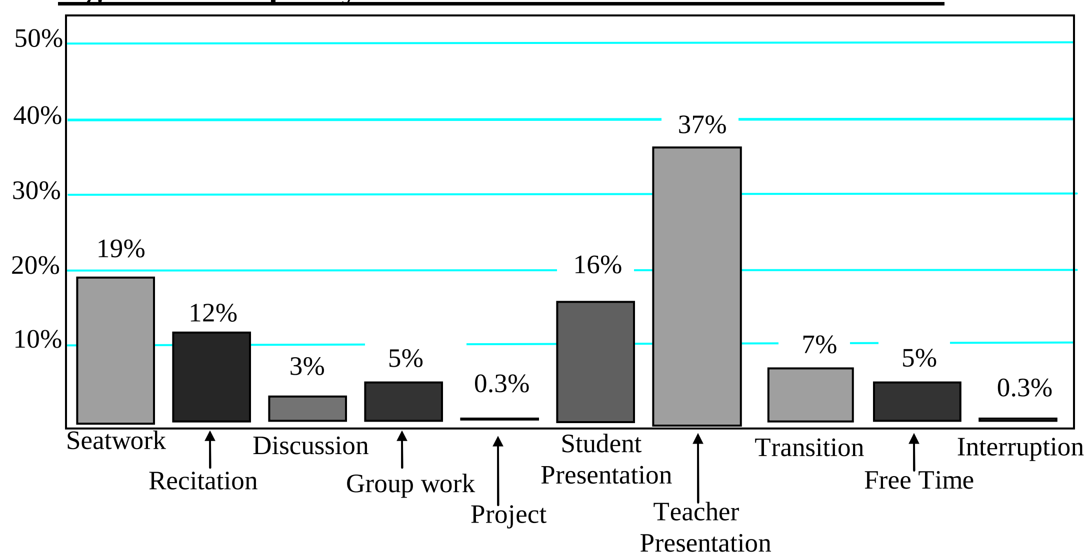
1. When observers were in classrooms, they were unable to determine objectively the clarity of goals, other than if students appeared to be on task or not. The immediacy of feedback also could not be determined from the observations that were made. Therefore, comments on goals and feedback are not included with the findings.

2. Since the physical environment consisted of bare college classrooms which were reassigned on a quarterly basis, these provided little data for the purposes of this research. Students sat where they wished, but other than that neither the teacher nor the students made any changes in the room.

elementary classrooms (Stodolsky, 1988). Available data on higher grade-level classes is scant.

Classroom activities incorporated in the present study included seatwork, recitation, discussion, group work, projects, student presentation, and teacher presentation. Figure 7.1 shows the frequency of the instructional formats that were observed. Several non-instructional formats such as transition, free time, and interruption were also recorded.[3]

Figure 7.1 Frequency and Distribution of Instructional Formats



Teacher Presentation

Teacher presentation dominates the landscape, accounting for more than one third of total class time observed. Lecturing, going over exercises from the book, showing how to do problems at the board, introducing new concepts and talking to the class as a whole

3. Activities such as testing were not included in the observation plan.

constitute the major idioms of teacher presentation. Given that classes met 2.5 hours per week, in order to cover the required material this percentage does not seem remarkable.

Several phenomena were observed concurrently with this format. In terms of behavior, students mainly watched and listened; the teacher was the most active participant. As may be expected, students were less involved in solving problems and interacting with one another. During these segments, students' energy levels appeared to be flat or neutral. They were neither lethargic nor visibly moved. They seemed attentive, however, and seldom required that the teacher interrupt a presentation to address behavior problems. Figure 7.2 shows the frequency of teacher presentation observed in the seven classes.

Figure 7.2 Frequency (%) of Teacher Presentation by Class and Change in Flow

(bars indicate standard errors)

(Total number of observations = 49)

The geometry class taught by Teacher J utilized the most teacher presentation: 47% of the time that an observer was present. Both Math A classes (C, A_1) were were not far behind, occupying 42% of the class time with lecture and demonstration. The classes with the least amounts of teacher presentation were the three Math B classes (B, A_2, Q), averaging 29%, possibly an indication that the faster teachers must go the more they rely on their own presentations. Classes that lost the most flow appear to the left side of the graph.

When the average time invested in teacher presentation is compared between groups, more lecture and demonstration was directed at students in classes that lost flow: 39% compared to less than 33% in the two classes that retained flow. Admittedly, the difference between class groups is not statistically significant ($F = 0.580$, *n.s*), though it may be noted that teachers in classes that lost flow tended to use more lecture and demonstration at the board, leaving less time for more complex activities.

In terms of complexity teacher presentation does not allow as much student control or involvement as several of the other formats. As observations indicate, students were more passive than usual during a teacher's presentation. Their main activity was listening and watching; occasionally the teacher would call on one of them to answer a question. Though not convincing, this finding generally agrees with the view that students afforded fewer opportunities for self-determination become less intrinsically motivated (Deci & Ryan, 1985). It may also promote simplicity rather than complexity in the classroom due to the dominant role of the teacher, discussed below.

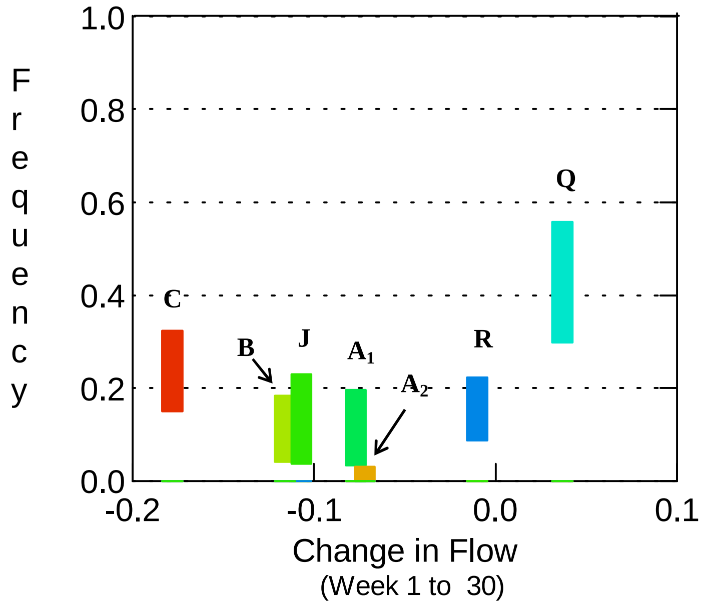
Seatwork

Nearly one-fifth of observed class time was spent doing seatwork. Students were involved mainly solving problems at their desks while teachers usually helped students who sought out their help. To a lesser extent, teachers circulated to see what help they could give. Most seatwork formats involved individuals working separately on the same assignment. Diverse or individualized seatwork was a rarity in talent search classes (i.e., individuals having markedly different work to do). Cases where seatwork lasted less than one minute, for example, if a recitation bogged down and an instructor directed students to solve it on paper, were not considered seatwork but part of the recitation in which it was nested.

Figure 7.3 displays the frequency of seatwork by classes. Teacher Q's students were assigned much more seatwork than any other class, over 40% of the time viewed. Because of this, working alone at one's tablet arm chair appears to impact retention of flow significantly despite the fact that Teachers Q and R differed markedly in their seatwork preferences. The average percentage of time spent in seatwork in classes that forfeited flow was 13.5%, compared to 29.1% in the group that gained (ANOVA, $F = 4.670$, $p < .05$). Although the effect depends on a single class and may be difficult to justify for this reason, Q's was the only class that gained in flow and happened to engage

Figure 7.3 Frequency of Seatwork by Class and Change in Flow

(bars indicate standard errors)



in a great deal of seatwork.

An analysis of the elements of flow--entropy and negentropy--reveals an even more robust effect associated with seatwork. Doing problems at one's desk significantly reduced feelings of frustration in the seven classes observed ($r = -.365$, $p < .01$). There was no correlation between seatwork and negentropy, from which it may be surmised that engaging in seatwork can alleviate frustration but it does not necessarily make mathematics more pleasurable.

The claim that seatwork reduces math frustration may be less counter-intuitive than it seems at first. Because of the accelerated nature of the program, students needed more time than they were accustomed to in order to solve problems. The seatwork that was observed provided time for this purpose. Plus, seatwork was one of the only instructional activities that supported students in the work mode they preferred: studying alone.[4]

From the following example in which seatwork was used to apply conceptual knowledge, students' favorable attitude to the seatwork may be ascertained:

> T_C (Teacher C): 'Turn to page 328, #21. Do it.' For the next six minutes students worked alone at their desks doing a problem for which they had discussed the theory (least common denominator), but this was the first time they were actually attempting to do it. T_C asks if they are having problems after 2-3 Ss (students) asked questions. Most Ss said 'yes!' but they all wanted more time to work on their own, to succeed without being given help or the answer. (Record 18.2, Math A class)

In terms of classroom complexity seatwork may have considerable importance for gifted students. They may experience flow in seatwork because the activity provides them with clear goals and immediate feedback. Interacting with problems seems to be central to their process of learning and discovery. When interviewed, what students mentioned most often about their interest in math was how much they enjoyed working problems on their own outside of class and the insights that came from this activity. In reality, these students routinely engaged in self-imposed seatwork. The lack of variety or social interaction inherent in solitary problem-solving--occasionally punctuated by a teacher's visit--was not perceived negatively. Instead, frustration was reduced, enabling flow. Seatwork in the context of these classes may provide opportunities for greater control, meaningful task involvement and mastery.

In all likelihood, seatwork may have different motivational implications for individuals who possess less natural ability, for whom math problems are a source of confusion rather than informative feedback. In that case, formats with more social support than seatwork may be a necessary escape from the frustration of fumbling around and uncertainty; interaction with others may be the only possibility of informative feedback.

Student Presentations

At times, presentations took place at the teacher's invitation. Otherwise they were spontaneous and student-initiated. Teachers seemed to welcome this initiative and settled easily into an interactive role, remaining more involved than other members of the class but giving the floor to the student presenting. Outside of discussion or free time, this was the only format in which the pacing or the topic was manifestly student controlled. Figure 7.4 displays the incidence of student presentation by classes.

Student presentations accounted for 16% of the segment observations. Supposedly, greater student control is evidenced in this format. Perhaps because it was a gifted program, students did not hesitate to volunteer for work typically reserved for teachers: introducing a topic for the class to consider, going to the board to demonstrate or attempt a solution, challenging the teacher or another student, proposing a rival explanation to a problem. These presentations did not appear to be rehearsed, as giving a report might be.

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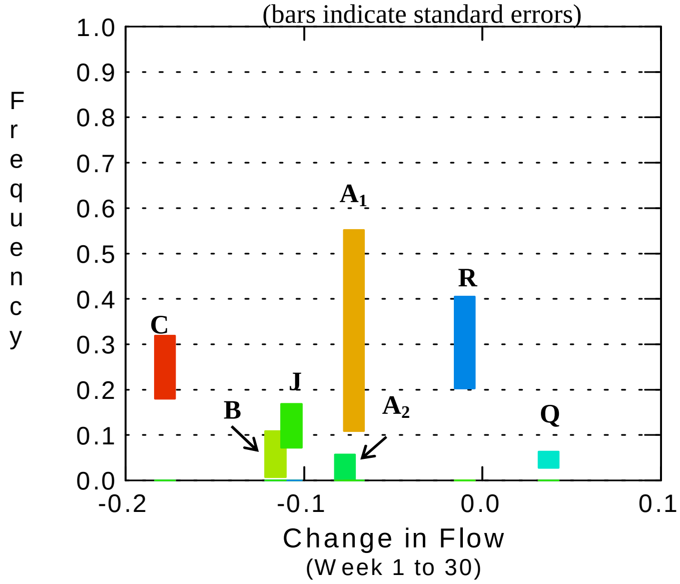
4. Students were asked whether they felt they did their best working alone or with others. Fifty-two students said they felt they did their best work alone; seven indicated they preferred to work with others; 24

Student presentations were not brief episodes but rather periods encompassing several minutes during which the attention of the class was focused on an individual student.

Students most often assumed the teaching role in the two Math A classes and teacher R's geometry class. In terms of flow changes, classes differed little more than one percentage point in their use of student-based presentations. Although its use would seem to indicate more complexity of roles and shared leadership in the classroom, student presentation appears unrelated to retention or loss of flow.

Figure 7.4 Frequency of Student Presentation by Class and Change in Flow

(bars indicate standard errors)



Recitation

On a fairly regular basis teachers solicited individuals by name to answer questions. These recitations occurred in 12% of the observations. Students' main activity was

said it did not matter to them.

solving problems in their heads, watching and listening to other students recite. Classmates rarely interacted with each other during recitations--at least they were not expected to, though in fact student-generated distractions in the classroom increased during recitations.

Students were called upon by the teacher or volunteered to supply an answer to a question. The type of question varied from open-ended to one-right-answer (usually the latter). Sometimes questions were used to introduce new material, review old material, to define, to apply, or to analyze concepts. In the following transcript, recitation was used to apply a concept covered earlier to a new type of problem:

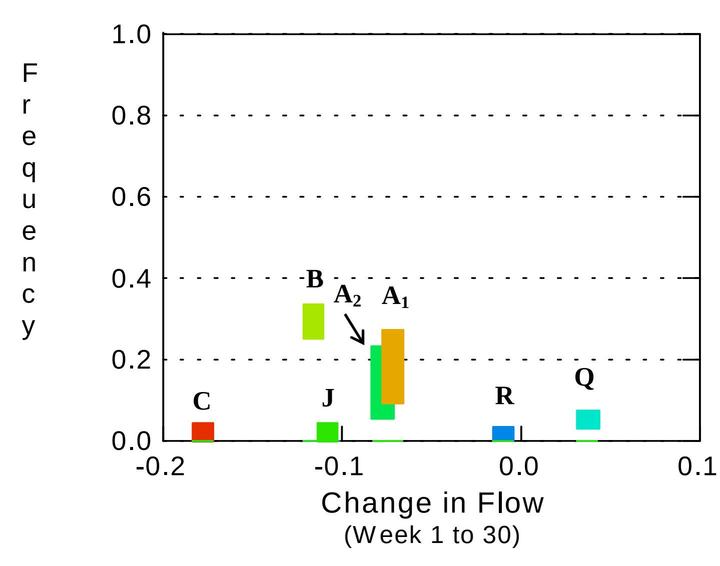
> T_R tosses the chalk to S (student). But S doesn't come up to the board because he says he doesn't know how to solve it. T_R goes to everyone else to see if they can determine how to procede from this point. T_R refers back to an earlier application that will work, saying 'You've got to see this. That's one thing that should've popped into your mind.' S comes up to the board to try a different way to solve it than the one suggested. (Record 14.6, Geometry class)

Most teachers used recitation to elicit feedback from students: to check understanding, to encourage more active participation. "Asking," rather than "telling," was the predominant activity. If the teacher began with a few questions and then shifted into a lecture, it was coded as teacher presentation. If a teacher provided a few sentences of explanation or feedback to a student's response it was considered to be part of the recitation. If the teacher continued to speak past one minute it was coded as teacher presentation. If the student came up to the board and continued to work for more than one minute, as in the case above, the segment shifted from recitattion to student presentation. In some cases, recitations lapsed into discussions as other students began to ask questions or volunteered responses. Figure 7.5 graphically illustrates the frequency of recitation in the seven classses.

The goals of recitation were reasonably clear; students were given explicit questions to answer. Feedback to their responses was usually immediate if they were right. If they were wrong, another student might be asked to try. From the perspective of control, the teacher was in command: choosing the questions, choosing which students to call on and expecting compliance. Because the teacher was the main source of feedback, recitations could be controlling in addition to being informative. Recitations were used, for example,

7.5 Frequency of Recitation by Class and Change in Flow

(bars indicate standard errors)



to monitor student attentiveness and, in a few cases, to rein in students who were daydreaming or talking out of turn. It was at times difficult to distinguish a teacher presentation from a recitation, since teachers also tried to involve students in demonstrations and while they lectured. Therefore, it was decided beforehand that when the interaction between teacher and students asked to recite lasted longer than one minute, it was no longer a lecture.

In terms of flow change, groups differed significantly in their use of recitation. Groups that retained flow averaged recitation 4% of the time; recitation occurred almost 16% of the time in groups that lost flow (ANOVA, F = 7.658, $p < .01$). But as the graph illustrates, only three of the five classes whose flow declined used much recitation. Therefore, the connection between recitation and flow loss may not be as convincing after all. The effect of recitation may be most evident in the context of other formats. In classes that retained flow, recitation occurred the least often. Where flow was depleted, however, it was the third most common format, allowing less time for more interactive formats.

Discussion

Of the remaining three formats, discussion was recorded about 7% of the time in classes that did not lose flow. In classes that did lose flow, discussion was the least common format, occurring only 1% of the time (Figure 7.6). The characteristics of discussion were greater student control of the topic and pacing and substantial interaction between classmates and the teacher. Topics were often introduced by one student and the exchanges that followed involved nearly everyone in an open forum or debate. The teacher was not the only one asking the questions, even though he or she asked most of the guiding questions. The teacher was usually willing to allow students to control the topic. As a result, it was not uncommon for the topic to change one or more times during a discussion. Furthermore, there was no systematic selection of who was expected to participate, which was the case in recitation.

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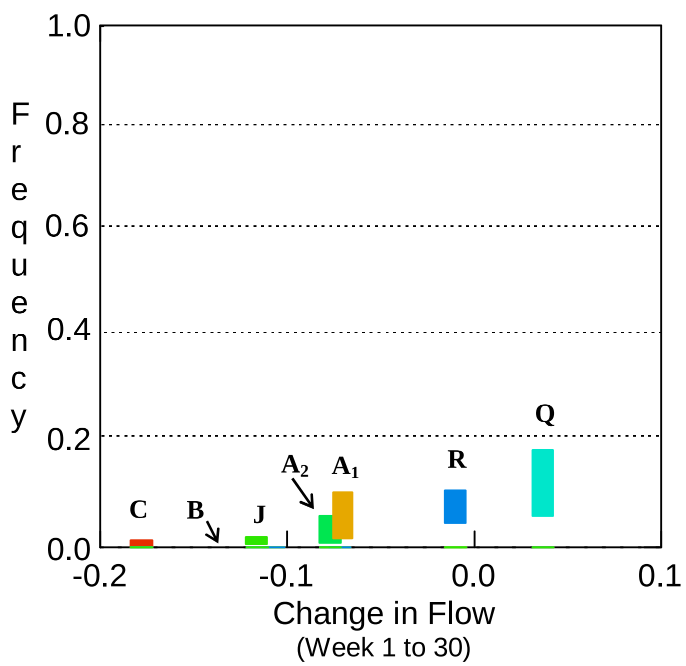
Figure 7.6 Frequency of Discussion by Class and Change in Flow

(bars indicate standard errors)

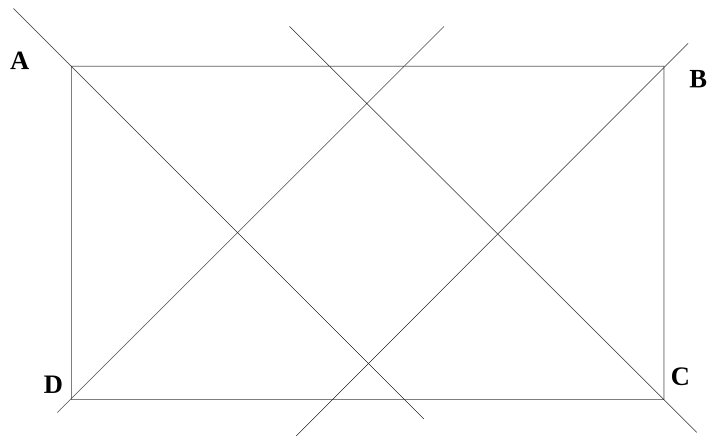


Discussions usually concerned math problems, especially ones that were not easily resolved. Sometimes discussions would take place outside the subject of mathematics, veering off into experiences at school, sports, and other topics of interest. The majority of discussions were observed in Teacher Q's class. The effect of student control may be seen, as on one occasion, a discussion initiated for the purpose of using scientific notation to express the number of drops of water in the oceans and distance in light years, over the course of the next nine minutes strayed to galaxies, to lunar eclipses, to Central Time Zone, to Sunday night news at 10 p.m. and Bears Sunday (at this point the teacher redirected the conversation), to the amount of water flowing over Niagra Falls, and finally to one student's question, 'why don't the falls dry up?' The teacher then moved on and gave a two-minute presentation on simplifying polynomials.

Not all discussions were so disultory. Teacher S's students did not stray far from the topic when someone presented a problem (Figure 7.7) to which he professed not immediately to know the answer. A 24-minute discussion ensued in which the teacher largely turned control over to students in exploring the unknown proof:

> If you don't understand, don't sit there like that. Speak up. You know it's true--but how do you prove it mathematically? (Record 31.8, Geometry class)

<u>Figure 7.7 Classroom Discussion Problem: How can you Prove the Figure Outlined by the Angle Bisectors is a Square?</u>



A number of students attempted to prove that the figure outlined by the angle bisectors was a square, but time ran out and the class had to be dismissed.

Of all the formats, retention of flow coincided most with discussion. The difference between groups was significant ($F = 11.471$, $p < .001$). The effect relative to discussion supports the model of classroom complexity. Not only does discussion afford greater opportunities for student control of the topic and the pacing, it obviously coincides with increased social interaction, posited to be a critical component in group complexity (Csikszentmihalyi, Rathunde, & Whalen, 1993).

Compared to other instructional methods, relatively greater diversity was involved in discussion in terms of student behaviors, problem types and cognitive engagement. In terms of the mathematics, discussions centered on problem types that incorporated greater novelty, or that were more puzzling than those used in recitations or teacher demonstrations. Because of this, students were required to analyze and apply previous knowledge to unfamiliar situations, not just to remember facts. Despite their relative infrequency, discussions appear to have fostered students' intrinsic enjoyment of mathematics according to principles of classroom complexity.

Group Work

In terms of complexity, group work should yield an effect comparable to discussion. Yet this was not the case. Group work generally consisted of teams of two or more students assigned to solve a problem or assist one another. As may be expected, interactions between students were high during these segments. Teachers were typically uninvolved, however, it was not uncommon to see them traveling from group to group. While students could work together and seemed to enjoy it, nine out of ten students felt they did their best work alone. Teachers also commented that their students preferred to work with minimal outside assistance. Since students saw each other only once a week in most cases, their lack of familiarity, in addition to their lack of enjoyment, may help to explain why the relative complexity of group work did not produce the expected effect.

Sometimes projects involved more than one class. Students in the two geometry classes started a session by being given the same assignment. They were directed to work in groups of 3's and 4's to present a solution to the following problem:

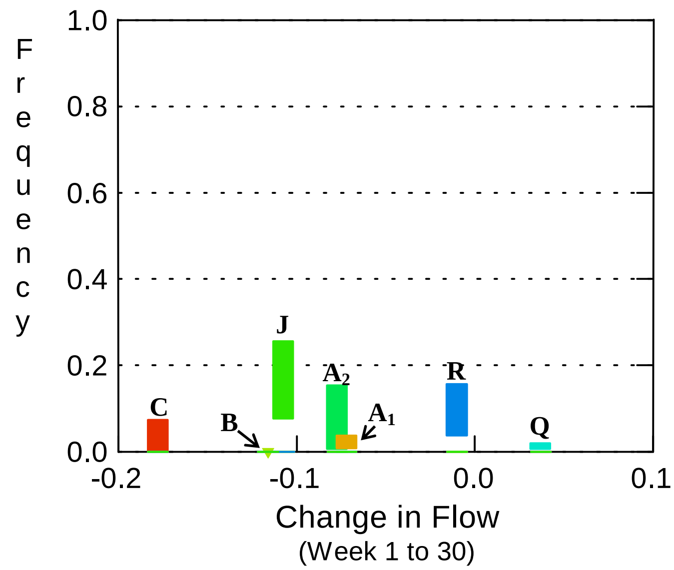
> *Prove the following statements. Using Coordinate and Euclidian approaches, which approach is simpler in each case?*
>
> 1. The segment joining the midpoints of the two sides of a triangle is equal to one-half the length of the third side. (Record 43.1, Geometry class)

After working 14 minutes preparing proofs, students spent the next 10 minutes presenting their results. These presentations were graded; one student in the group presented the Coordinate approach, another the Euclidean. Students were expected to interact, stepping in to challenge a group's proof if necessary. When the teacher caught a mistake before the rest of the class did, they were chided for not being careful observers. In this situation, the pressure to be vigilant and knowing that one's group work was fair game for everyone's critique may also explain why flow was not better retained.

On the average, group work was observed 5% of the time, slightly more than discussion. A fraction more group work was conducted in classes that retained flow, but

Figure 7.8 Frequency of Group Work by Class and Change in Flow

(bars indicate standard errors)



the difference was slight (5.1% versus 4.5%, F = 0.028, *n.s.*). Figure 7.8 shows the distribution of group work among the seven classes. The two geometry classes utilized group work the most.

Projects

During only one classroom visit was a project witnessed, a geometric construction involving compass work assigned by Teacher J. As much as the teachers expressed a desire to engage in more projects, they felt constrained by time having only 30 sessions to cover an entire year of high school math. Consequently, they utilized what they perceived to be more efficient methods of instruction: lecture, demonstration, seatwork, and to varying extents, recitation. Projects requiring substantial investments of time were assigned as homework.

Likewise, some of the students interviewed expressed a desire for more projects, as did this seventh grade algebra student who when asked whether he enjoyed the learning activities in the class said: "Not really.... It's always equations, it's not like we're ever doing a project or anything like that... it's mostly equations and homework."

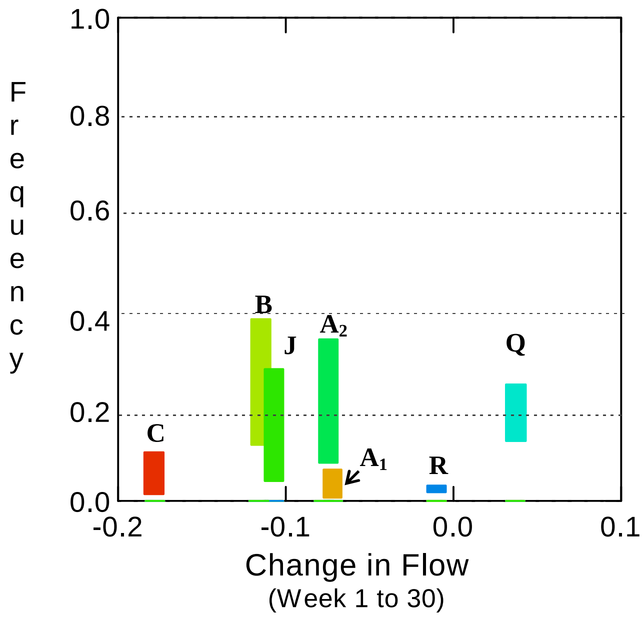
Housekeeping

Finally, a category of formats not ordinarily considered instructional was considered. These are the transitions, interruptions and breaks, the in-between segments. In the present research breaks were not factored in since every class had to take them. Breaks usually lasted 15 to 20 minutes while students visited vending machines to get snacks. Interruptions lasting more than one minute during another format were observed once.

Transitions, on the other hand, were more prevalent. These were times not spent on mathematical tasks, but in moving from one instructional format to another, passing out papers, getting out assignments, putting away books, listening to directions and announcements, in other words, housekeeping.

Since time spent in housekeeping represents time taken away from more intellectual pursuits, classes were compared to determine whether students' flow was negatively affected by greater amounts of housekeeping. Students in classes that lost flow spent

Figure 7.9 Frequency of Housekeeping by Class and Change in Flow
(bars indicate standard errors)



twice as much time involved in housekeeping. The average factor score for housekeeping in classes that retained flow was .021, whereas the average score in classes that lost flow was .046, which is in the expected direction but not a significant difference (F = 1.428, *n.s.*).[5] Figure 7.9 shows that all three of Math B classes and one geometry class spent more time in housekeeping than the others. By contrast, the fastest-paced classes (C and A_1) devoted little time to direction-giving and transitions.

Overview of Formats

These format comparisons become more compelling when viewed as a whole (Table 7.3). As the data from observations reveals, students in classes that devoted more time to

Table 7.3 Univariate ANOVA Differences between Class Groups that Retained Flow and those that Lost Flow

Format	Flow Gain (n=2)	Flow Loss (n=5)	F
Teacher Pres.	.331	.385	0.580
Seatwork	.291	.135	4.670*
Student Pres.	.174	.158	0.054
Discussion	.068	.011	11.471***
Group Work	.051	.045	0.028
Recitation	.040	.158	7.658**
Housekeeping	.021	.046	1.428

* $p < .05$ ** $p < .01$ *** $p < .001$

Note: These means are the percentages of class time students were engaged in the different formats.

discussion and seatwork and less to recitation retained the intrinsic enjoyment of math which they brought with them upon entering the program. Because time was allocated in

5. Group averages are based on factor scores. Three variables loaded on a housekeeping factor: transition, teacher direction giving, and a student cognitive requirement labeled ‘organization.’

this way, in groups that retained flow, teachers tended to spend less time in more formal instructional presentations and students spent less time in housekeeping.

To test the additive effect of complexity in regards to changes in motivation, the sum of the less complex formats (assuming these to be teacher presentation, recitation and housekeeping, as theory suggests) was subtracted from the sum of the more complex ones (seatwork, discussion, student presentation and group work). Table 7.4 shows the difference in complexity even in this small sample of classes to be significant and in the expected direction (ANOVA, F = 6.712, $p < .025$). While there were several significant differences in specific formats between groups, the combined effect of spending more time in autonomy-supporting situations and activities that one enjoys appears to have salient motivational effects.

Table 7.4 Univariate ANOVA Differences for Indices of Classroom Complexity

Complexity Index	Flow Retained	Flow Lost	F
Format Types	1.508	-0.934	6.712*
Problem Types	0.427	-0.248	5.693*
Cognitive Operations	0.047	-0.004	9.831**
Interactiveness	3.807	-2.210	22.056***

* $p < .025$ ** $p < .01$ ** $p < .001$

Note: Means are sums of standardized values. F values of the summed raw scores were virtually no different.

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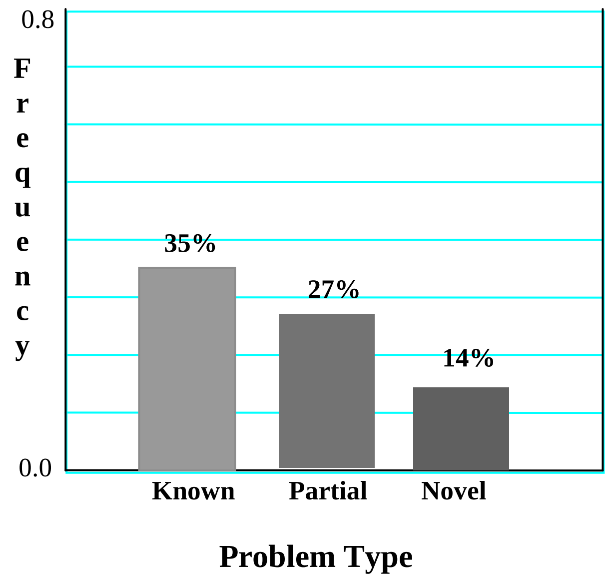
Problem Complexity

Figure 7.9 Distribution of Problem Types in Talent Search Classes

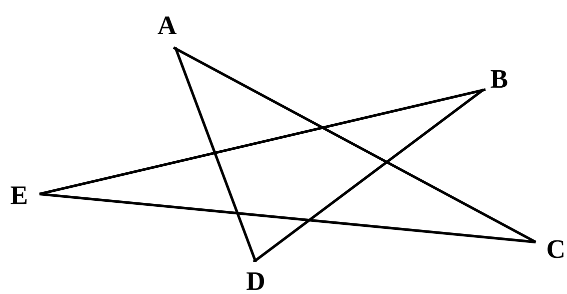


In addition to instructional formats, it is also possible to approach complexity in terms of the types of problems used to instruct. As discussed in chapter 3, novelty was defined in terms of two categories of problems. Problems in which everything is known except the answer were differentiated from problems in which the process as well as the solution are unknown. The first type is usually incorporated in drills and may be observed as students apply algorithms to a series of similar exercises. In the context of solving equations for a single variable, $5 - 2x = 11$ and $8 - 5y = -17$ are examples of known problem solving used for the purpose of mastery.

Over one-third of the total class time was utilized in solving problems of this type (Figure 7.9). For the most part these occurred in the context of recitation, seatwork and in the course of a teacher presentation. One-fourth the time no problems were worked on, mainly during housekeeping segments, some teacher presentations and some discussions.

Not surprisingly, the more novel problems were the least common. Discovered problem solving was observed about 14% of the time.[6] Unlike known problems, these were not preceded by samples or demonstrations to guide students. Many times the students had no idea or little direction where to start; after allowing students to struggle, sometimes the teacher hinted what might be done. For example, the figure in Figure 7.10 was given to students during the sixth meeting of Teacher J's geometry class. After 18 minutes and numerous failed attempts, a few students came to a correct solution. Teacher J felt it was time to move on, so she suggested some things for the rest to try and assigned the problem as homework.

Figure 7.10 Example of a Discovered Problem



Find the sum of the measures of angles A,B,C,D,E.

In a few extreme instances, teachers who used novel problems admitted publicly not to know how to solve the problems--in fact, the solutions may not yet be known. Whenever this happened, the teachers tended to treat students more as equals, expecting them to contribute and to evaluate the suggestions that were made. They were told specifically not to wait for the teacher to approve or to correct--that was their job now. Hence, the traditional teacher-student roles became more blended in the 'think tank'-like atmosphere when genuine problems were used. The level of interaction expected at times like these epitomizes the complex classroom as described in chapter 3.

The majority of novel problems occurred in geometry classes and Math A classes. These teachers preferred to incorporate more challenging problems in their instruction. Novel problems did not originate in the students' texts but from material supplied by the teachers. They were intended to foster insights into the process of doing math, helping students to integrate known principles, applying them in new ways.

In practice, three types of problems were observed. Besides the two above, there were items of a more intermediate difficulty. These were problems that required students to make an intuitive leap from a familiar algorithm to a new type of problem with little prior explanation. The source for these was usually the textbook, the challenge sections following an exercise set or the next section of the book. They required students to apply a known procedure to a new problem formulation. Problems in this category might appropriately be called intermediate or partially novel.

The three problem types were also found to differ in the amount of time they required. For talent search students, known problems took only seconds to solve and typically ten or more might be packed into an instructional segment. Partially novel problems took minutes to solve and there might be two or three of these. Fully novel problems lasted as

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6. Discovered problem solving (Getzels & Csikszentmihalyi, 1976) may require that students invent the processes used to solve the problems. These differ from known-type problems, in which everything but the

long as 40 minutes if nothing else was pressing. Because time was limited, there was only time for one novel problem per segment.

It was hypothesized that exposure to novel problems would be related to positive

Table 7.5 Correlation Matrix for Change in Flow by Problem Type (n = 49)

Problem Type	Changes in: Flow	Entropy	Negentropy
Known	-0.251	0.227	-0.018
Intermediate	0.318*	-0.329**	0.049
Novel	-0.003	0.025	-0.220

* $p < .05$ ** $p < .025$

changes in flow. However, these factors were not correlated ($r = -.092$, *n.s.*). The correlation matrix for problem types and motivational change reveals instead that partially novel problems significantly predicted change in flow (Table 7.5). Furthermore, the tendency was for known problems to increase entropy and for novel problems to decrease negentropy, helping to explain why the coefficient for flow is negative for those two problem types. Not doing math problems was unrelated to flow.

This pattern indicates, that of the three problem types, partially novel problems were optimal for the ability of talent search students. Analysis of variance for problem type shows that the more intermediate discovery type problems were used, the more flow increased (F = 5.693, $p < .025$; Table 7.4). Table 7.5 shows a tendency for students to

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correct is known.

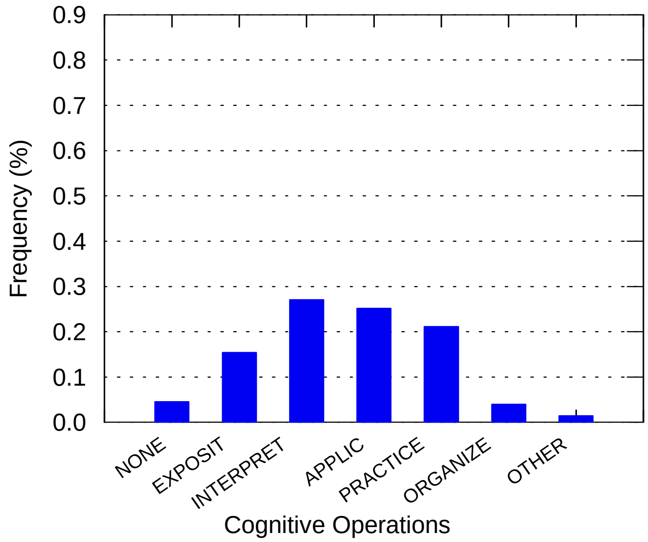
experience less flow when more known problem types are used (r = -0.251, *n.s.*). Novel problems may have been perceived as being too hard. Consequently, students' perceived competence suffered (r = -0.298, $p < .05$). Students felt the most competent working on moderately complex problems that did not overwhelm them with novelty.

<u>Cognitive Complexity</u>

To determine whether cognitive complexity was involved in changing perceptions of flow, classroom activities were coded according a hierarchy of cognitive skills similar to those described by Bloom, et al. (1956) and Burns (1984). For the present purposes, five levels were identified: exposition, interpretation, application, invention and evaluation. In addition, segments intended for practice/mastery and others that involved no cognitive operations related to math (such as breaks), those related to organizational chores (such as filing papers), and others which fit none of the existing categories were also recorded.

The relative frequency of the operations is graphed in Figure 7.11. Fairly minimal amounts of time were spent in activities that were not math-related ("none," 5%), housekeeping ("organize," 4%) and "other" (2%), in which case observers were uncertain about the level of cognitive operation that was intended. Neither invention nor evaluation were recorded, purportedly the most complex operations. However, the use of complex problems would indicate that higher cognitive processes such as invention must have been used. Observers were uncertain how much time was devoted to invention and chose to code the time spent on novel problems conservatively as application.

Figure 7.11 Frequency of Cognitive Operations across Math Classes



Exposition, the most basic of the operations, occupied 15% of the class time observed. Students were required to listen and watch as new information was shared, usually by the teacher. Students were queried intermitantly by the teacher to check their understanding. In the taxonomy of educational objectives the corresponding level is *knowledge*, evidenced by remembering or recalling facts, methods, and so on. Students did not do much problem solving during exposition. Their energy tended to be neutral; rarely was excitement demonstrated.

With few exceptions, exposition was followed by *interpretation*, aimed at making sense of the new knowledge, seeking out its relation to previous material.[7] In this case the primary vehicles of interpretation were teacher presentation, student presentation, group work, projects, and discussion. As a result, interactions became more common.

7. In Bloom's taxonomy, the corresponding level is *comprehension*.

Translating the new idea into familiar words or symbols, making inferences, generalizations, and making predictions based on the new understanding were considered part of this operation. As Bloom pointed out, this is "probably the largest class of intellectual skills and abilities emphasized in schools" (1956, page 89). Such was the case here as interpretation absorbed 27% of class time.

Slightly more than 25% of the time students were involved in *application*, seeing how to use the comprehended knowledge. High levels of problem solving and interaction corresponded with application activities. At this level students were involved in analysis of concepts and the discoveries that were made. These in turn were applied to a variety of problems in teacher presentation, group work, projects, seatwork and discussion. Because analysis almost always occurred in the context of application, these two categories which are separate in Bloom's taxonomy were grouped together here.

From here it was not uncommon for students to be assigned practice exercises to master the materials. While this does not necessarily represent a higher level of cognitive functioning, it incorporates the levels mentioned thus far. Since practice, being observed 21% of the time on the average, was most often carried out in the context of seatwork, observers were uncertain what cognitive level was represented. Therefore, this category eludes placement in the cognitive hierarchy. The teacher's main function during practice was to provide help if students sought it.

A significant relationship was uncovered between cognitive operations and changes in flow. Again grouping classes by those which retained intrinsic interest in math and those that did not, Teacher Q's and Teacher R's classes were found to engage in application activities 36% more often than other classes. Proportionately more time was invested in exposition and practice among groups in which flow diminished, which implies that greater challenges than knowledge and comprehension are needed to keep talented students intrinsically motivated. On the basis of cognitive complexity ranging from exposition/knowledge to application, groups differed significantly: standardized values 0.047 as opposed to -0.004, a difference with an F value of 9.831 and a probability coefficient less than .01 (Table 7.4). Assuming that tackling novel problems represents even higher cognitive demands, one could expect to obtain a similar result for more complex cognitive operations to that for more complex problem types in Table 7.4.

Interactive complexity

If a family is thought to be complex because of the quality of its members' interaction (Rathunde, 1989), the classroom in which teacher and students freely interact and exchange divergent points of view may likewise be complex. The sharpest differentiation between simple and complex classes is shown by the frequency and level of the interactions that were observed. Except for seatwork, formats which accounted for gains in flow were highly interactive. Problems which were more discovery-oriented also encouraged greater amounts of dialogue, stating of opinions and argumentation. Twice as much interaction was found in classes that supported students' intrinsic motivation ($F = 22.056$, $p < .0001$; Table 7.4).

Discussion

The reasons given for the decline in math interest that often starts with the transition to junior high school include a greater emphasis on teacher control, less positive student-teacher relationships, fewer opportunities for student decision-making and self-regulation, task structures that treat classes as a whole rather than students as individuals, public evaluation of work which encourages social comparison, the use of lower-level cognitive skills and higher standards for judging students' competence (Eccles & Midgley, 1989). Although in several ways the talent search experience is unique, the present findings support many of these claims. Classes in which teachers exercised more control, where students were provided with fewer opportunities for self regulation, tasks were structured for conformity, and lower-level thinking skills found more frequent use, flow was put at risk.

The types of formats, problems and intellective challenges in which students engaged significantly impacted their motivation by means of complexity and individuals' activity preferences. As indicated, the basis for this outcome would appear to be the additive effect of tasks structured to promote student autonomy, interaction, genuine problems and higher level thinking skills. While a few factors such as discussion and application were certainly more prevalent in classes that retained flow, it is overly optimistic to pretend that intrinsic enjoyment was affected by a few minutes of discussion here and there. The changes in motivation are more believable when the factors are viewed all together.

A combined index for classroom complexity was created by standardizing and adding the indices for format complexity, problem complexity, cognitive complexity and the extent of interaction in the classroom. The effect of these complex experiences on changes in flow was considerable: $F = 35.503$, $p < .001$ (one-way ANOVA).[8] Students who participated in classes that engendered student control, utilized genuine problems and higher-order thinking skills appropriate to their level of skill, and were more at liberty to interact with their classmates, experienced significantly more intrinsic enjoyment of math than students in classes that were more teacher-dominated, in which lower-level thinking skills and exercise-type problems predominated, and in which there was less opportunity for interpersonal communication. Nonetheless, on the basis of this data, flow was profoundly affected by instruction.

As expected, simple and complex classes differed in their use of formats, from which followed a kind of domino effect. The types of activities emphasized in simple classrooms, e.g., recitation and lecture, allowed for less student interaction and self-regulation, maintained a level of thinking focused on knowledge and comprehension but less on application, presented problems more as drills rather than opportunities for discovery. Presumably, many of these activity choices were made on the basis of time, a precious commodity in an accelerated environment. But as this indicates, implicit in the choice of simple formats are elements known to undermine intrinsic motivation: tasks that do not present enough challenge, expectations of conformity rather than

8. The mean complexity (z) score for students in classes that retained flow was 1.939, compared to -1.102 for students in classes that lost flow.

individuality, and controlling feedback (Csikszentmihalyi, 1990a; Deci, 1995; Nicholls, 1984b; Ryan, Connell, & Deci, 1985).

Complexity and Course Evaluations

Possibly for these reasons, when asked to evaluate the learning activities in their classes, ratings given by students in the less complex environments were significantly lower.[9] Furthermore, instructional activity ratings at mid-year were found to predict changes in flow that occurred over the next 15 weeks (r = 0.277, p < .025; df = 71). Not only did less complex activities evoke weaker positive reactions from students, these activity preferences were related to decreases in flow. On the other hand, students who were involved in more interaction via discussion, group work, student presentations, greater problem novelty and higher-level thinking skills liked the experience better and their intrinsic enjoyment of math decreased little, if at all.

Students in complex classes tended to like their teachers more.[10] One way to interpret this finding is to say that students' opinions about their teachers were influenced by the type of classroom experiences they were provided. Equally likely is the view that activity preferences depended on qualities of the teacher, for example, an instructor's respect for her students. Cross-lagged path analysis of this data confirmed that the best predictor of end-year teacher preferences was mid-year activity preferences (Figure 7.12). A point

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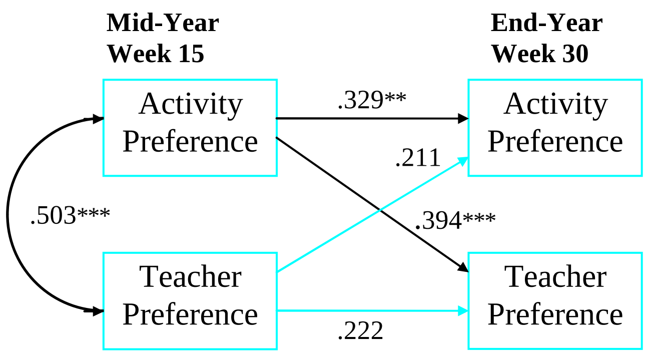
9. On a scale of -1 to 2, where 2 = really liked, 1 = liked, 0 = O.K. and -1 = did not like, simple classes rated activities 0.870, compared to 1.187 in complex classes, (F = 7.297, p = .010).

value of 0.394 ($p < .001$) was obtained for the path from mid-year activity preferences to year-end teacher preferences. On the other hand, teacher preferences at mid-year did not predict end-year task enjoyment (point value = .211, *n.s.*). Task enjoyment shaped

Table 7.12 Path Analysis Results (RAMONA) for Teacher and Activity Preferences from Mid-Year to End-of-Year (1993)



** p < .001 *** p < .0001
Test Statistic = 10.25, $p < .001$
n = 74

students' opinions of their teachers, not the other way around.

Predicting Changes in Flow

To test which was the better predictor of change in flow, both of these preference variables plus subject matter preferences and grades from the same point during the year were entered simultaneously into a regression on flow change. Subject matter perceptions were entered to account for students' liking of the course content; grades were entered to account for the possible effect of achievement on flow. As Table 7.6

10. Using the same scale from 2 to -1, the mean rating for teachers in complex classes was 1.505

Table 7.6 Results of Regression on Changes in Flow (1993)

	r	final β	t
Task Preferences	0.277	0.350	2.328*
Teacher Preferences	0.191	0.059	0.442
Subject Matter Preferences	0.040	-0.210	-1.493
Achievement [a]	0.143	0.147	1.242

R squared = .121
* $p < .025$
[a] second quarter grades

shows, the only significant effect was for activity preferences. Controlling for these preferences, perceptions of the teacher were unrelated to motivational changes, as were subject matter preferences and grades. While perhaps a modest effect ($t = 2.328$, $p < .025$), activity preferences were without rival in predicting higher levels of flow.

Predicting Achievement

Consistent with the findings in chapter 6, achievement during 1993-94 did not affect flow. But was achievement affected by changes in motivation? Since flow at the beginning of the year predicted grades received that year ($r = .404$, $p < .001$; Table 6.2), students who experienced increased flow should have earned better grades. Adjusting for first quarter grades, analysis of covariance reveals that students who gained in flow earned final quarter grades half a letter grade higher than students who lost flow.[11] While

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compared to 1.422, F = 5.533, $p = .023$.

11. Results of ANCOVA: Students who lost flow (n = 22) earned B-'s on the average (2.82); students who gained flow (n = 16) earned B+'s (3.149). Students who maintained comparable levels of flow (n =

the difference between a B+ and a B- is not significant statistically (see footnote), to many gifted students it is a meaningful difference. As this analysis suggests, complex task experiences encouraged higher levels of flow, better liking of learning activities and teachers, and even higher grades to some extent.

To conclude, by far the majority of studies of intrinsic motivation have shown that intrinsic motivation suffers rather than improves as a result of an educational experience (e.g., Eccles & Midgley, 1989). When it has improved, the factors responsible have been identified as autonomy support and more student involvement in learning (deCharms, 1976). In the present case, task complexity is also supported empirically as an ameliorating factor.

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33) earned B's (3.026). While these results are in the expected direction, they are not significantly different ($F = 1.195$, $p = .309$). Final grades were used instead of GPA to avoid problems of multicollinearity with first quarter grades.