CHAPTER THREE

Classroom Complexity and Flow

Introduced briefly near the end of Chapter 1, classroom complexity was hypothesized to be a contributing factor to intrinsic enjoyment of mathematics. In the pages that follow, the relationship between complexity and flow is examined, culminating in a model of optimal classroom complexity used to investigate the effects of mathematical tasks on students' motivation and achievement. Classroom complexity refers to the structures and interactions inherent in the learning environment through which students realize greater personal integration and differentiation.

Complexity and flow

A fundamental premise of flow--and why people find it rewarding--is its connection to psychological complexity. Not only does flow result in greater integration of differentiated ideas, traits and skills, the process by which this happens is found to be innately pleasurable (Csikszentmihalyi, 1993; Csikszentmihalyi & Larson, 1984). An association between task complexity and intrinsic enjoyment is found repeatedly in studies of flow. Teenagers talented in math (Csikszentmihalyi, et al., 1993), artists who become completely immersed in their painting (Getzels & Csikszentmihalyi, 1976), many of the most creative people of this century (Csikszentmihalyi, 1996), whether they know it or not, enjoy what they do partly because they keep aiming for higher levels of complexity. Tasks that facilitate flow share some important features. Clear goals, immediate feedback and a balance between a person's skills and the challenges of a task were three mentioned in the last chapter. In the context of classroom activities, these can be elaborated upon in terms of cognitive complexity, novelty, locus of control, interaction, and activity selection.

Cognitive challenge

In addition to a person's skills, the gradient of challenges inherent in an activity helps to determine flow (Csikszentmihalyi, 1988b). For example, a person who has begun to master chess will find little challenge in tic-tac-toe, a much simpler activity.

Like games, learning activities may be relatively simple or complex. One of the ways they may place different demands on learners is in terms of requisite cognitive skills. If an activity is not challenging enough, one way it can be made more challenging is by increasing the difficulty of the material.

Another way would be to make the task more cognitively challenging in terms of the thought processes needed to perform the work. Bloom's taxonomy of cognitive operations (Bloom, et al., 1956) provides such an approach. If asking students to recall factual information is not engaging enough, they may be more challenged by an activity that requires them to paraphrase the material, a more complex operation. The real essence of complexity in the taxonomy is that more challenging operations involve an integration of differentiated skills. These begin with knowledge and are followed by comprehension, application, analysis, synthesis and evaluation. Thus, comprehension requires more skills than knowledge, application integrates both knowledge and comprehension skills, and so on. Some have found this a useful tool for analyzing the cognitive demands of math instruction (e.g., Stodolsky, 1988). Others have found a four-stage hierarchy of cognitive skills just as useful (Burns, 1984): new learning, practice, review, and application.

Problem novelty

One of the ways to enhance the difficulty of subject matter and require higher cognitive operations at the same time is through the use of discovery methods. As opposed to presented or known problem solving, discovered problem solving involves novelty,[1] situations that are unfamiliar, in which a correct solution and the process are both unknown (Getzels, 1964). The National Council of Teachers of Mathematics (1996) refers to these as *genuine* problems. Genuine or discovered problem solving may depend on inventing new rules and finding the right ways to apply them.

In known problem solving, the solution may be apparent to all but the problem solver. But there is little novelty since the solution can be known by retrieving the rules from memory and applying them. According to Poincarè (1952), more than sheer memory is

[1] Surprising, novel, fantastic, incongruent or discrepant information in an activity may move students to seek additional information, to explain the unexpected, to resolve inconsistencies, to be imaginative (Bruner, 1977; Malone, 1981; Piaget, 1970). As is true for challenges, optimal discrepancies are believed to be relative to a learner's knowledge. Ideas too unfamiliar will probably not arouse a subject or be rejected; differences too minor will be assimilated or ignored (Berlyne, 1960; Cofer & Appley, 1964; Lepper & Hodell, 1989).

needed to solve difficult problems. An intuitive grasp of how the steps fit together in a meaningful way is equally if not more important. The inventive skills needed to discover solutions to novel problems are among the most complex of all cognitive behaviors (Bloom, et al., 1956).

When material is novel, students will probably be more attentive and interested than when material is redundant (Stodolsky, 1988). Although this assumption was not thoroughly tested in Stodolsky's research, it was found that students were more engaged in work that provided them with greater novelty and complexity. Novelty used for its own sake, however, may impede intrinsic motivation if students are distracted from the intended task (Blumenfeld, 1992). In this light, the more appropriate use of novelty is in conjunction with the unknown outcome of the problem rather than its unique delivery.

Corporate complexity

In addition to these internal aspects of the work, other ways to define complexity are suggested by Rathunde's (1988, 1989) analysis of families and flow. Complex families differ from simple ones in terms of *locus of control*, the quality of family members' *interactions*, and their *activity selections*. Inasmuch as the dynamics that make families simple or complex are also part of the classroom environment, these concepts may have corporate motivational significance there as well.

Members of complex families are integrated by a sense of mutual encouragement and support which allows them freedom to develop their individuality. Children are provided with choices and feelings of control, yet they are not left completely on their own.

Complex families support the autonomy of their members. Locus of control is collective rather than coercive or centralized in one individual. Findings indicate that autonomy-supporting experiences in the context of one's family account for more productive and enjoyable work (Csikszentmihalyi, Rathunde, & Whalen, 1993; see also Deci, 1995).

This kind of autonomy depends on each family member's ability to self-regulate plus a strong commitment to interaction. Otherwise the family just becomes more differentiated, possibly fragmented. Family integration occurs through common activities as well as discussion of its goals so that there is clarity, understanding and ownership. Members of complex families listen to each other, finding ways to affirm their differences and still maintain family harmony. Parents serve as models, encouraging interaction and by being thoughtful listeners. Consequently, family members feel that others are responsive to them. By comparison, members of simple families tend to perceive that their opinions do not matter much.

Family complexity is also evidenced by the way time is allocated to activities. Complex families invest proportionately more time in two areas: interaction (communicating, socializing, etc.) and productive work (homework and study). Alternatively, they devote less time to housekeeping routines (eating, dressing, chores, etc.).[2] In this connection, it is not uncommon for gifted children to be excused from doing chores so they can devote more time to their area of talent (Bloom, 1985).

The types of activities which complex families choose to do provide them with greater challenges and generally require more differentiated skills than activities that seem to be preferred by simple families. (These activity selections, especially in the latter's case, may be more by default than by deliberate decision.) For example, one of the more prevalent leisure time activities is television viewing, a simple activity infrequently associated with flow (Massimini & Carli, 1988). Feelings of boredom and apathy are the most prevalent affects for time spent in front of the TV. One reason for this is that viewing encourages passivity. Its requirements are not demanding: sitting still, watching and listening. Besides requiring no special skills, watching television involves practically no challenges--at least as those who watch it report (Csikszentmihalyi, 1993). Not surprisingly, TV provides persons with about as much flow as cleaning the house or trying to sleep.[3] Although talented teens spend a good deal of time watching TV and other leisure pastimes no matter their family context, complex families devote proportionately more time to activities with greater inherent challenges such as communicating and schoolwork than do simple families (Rathunde, 1988).

Classroom complexity

The dynamic tensions which distinguish complex families from simple ones may also be observed in the classroom in terms of locus of control, interactions, and task preferences, in which cognitive challenge and novelty figure prominently. Of all these, locus of control is the most studied motivational dimension. For over twenty years

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[2] The source of this information is Csikszentmihalyi, Rathunde, & Whalen (1993).

[3] Nonetheless, television exerts a strong attraction. Talented teens tend to watch more TV than average teens, but it remains an activity that provides practically no flow (Csikszentmihalyi, Rathunde, Whalen, 1993).

researchers have reached a similar conclusion: intrinsic interest declines when students are made to feel like pawns rather than origins (deCharms, 1968), when teachers exert excessive control over their students (Valås & Søvik, 1993). In the context of instruction, goals and rules, the types of choices students are free to make, and whether feedback is controlling or informative are aspects that may differentiate classrooms in terms of their complexity.[4]

The extent to which interactions take place in a classroom may be another telling sign of complexity. Are students encouraged to share their ideas? Is there a climate of give-and-take among students and between teacher and students? Interactions may be observed in discussions, students working together, times the teacher spends listening to students.

As this implies, the kinds of activities that comprise a typical lesson may serve as a guide to classroom complexity. The types of tasks found and the amount of time devoted to them may reveal preferences that have motivational importance. If a great deal of time is spent in housekeeping duties (e.g., collecting and distributing papers) to the detriment of more challenging work (e.g., tasks that require application-level thinking), then it may be expected that less flow and less learning will take place.

Since the activities found in school are not necessarily the same as those found at home, the kinds of activities that may be considered complex may differ. Therefore, the types of school activities and their potential for complexity are examined in more detail.

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[4] Differentiated classrooms support student autonomy and choices--without a doubt the most consentaneous recommendation made by motivational researchers interested in educational improvement

Classroom activity structures

Classroom activities may be described in terms of structural dimensions. As employed in educational research, a number of these dimensions have been useful in characterizing classroom experience: instructional formats, pacing, task goals, cognitive requirements, types and nature of feedback, teacher and student behaviors, interactions, emotional climate, the physical environment and the materials used (e.g. Berliner, 1983; Burns, 1984; Doyle, 1978; Grannis, 1978; Stodolsky, 1988). As the preceding discussion ought to have made clear, several of these dimensions may directly affect students' experience of flow.

The meta-structure that holds the various dimensions in place is the activity segment. Activity segments reveal how classroom experience is organized, how a lesson is divided into distinguishable parts, without fragmenting the instructional experience into meaningless particles (Stodolsky, 1988).

Instructional formats

An activity segment is usually distinguishable by an instructional format. The main formats that generally occur in school are seatwork, recitations, lecture, demonstrations, reports, group work, discussion, contests and games, testing, checking work, giving instructions, transitions and so on (Berliner, 1983; Stodolsky, 1988). Listing the formats

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(e.g., Flink, et al., 1990; Green & Foster, 1986; Ryan, Connell, & Deci, 1985; Valås and Søvik, 1993). Undifferentiated classes minimize personal choices and self-determination.

used during a class period is a basic way to segment a lesson for in-depth analysis of tasks.

Instructional formats are the building blocks of a lesson. Each format is a unique combination of elements that all formats have in common. Seatwork, for example, may involve students with topics and problems through an organization that includes pacing, goals, cognitive requirements, feedback, teacher and student behaviors, emotional tone, a physical setting and instructional technology. Generally speaking, lecture is comprised of the same elements but configured differently. Whether students find these activities intrinsically rewarding or not depends on the emphasis given to each element and how they all come together.

Pacing

The way time is allocated in the classroom is measured by pacing (Gump, 1967; Grannis, 1978). Pacing helps to establish who controls the rate of work in a segment; pacing may be determined by a teacher, student, a machine (such as a VCR or computer), or by a group of students working cooperatively (Stodolsky, 1988). Pacing intersects with all other segment elements, making it possible to compare the relative use of one format against another, to calculate the amount of time devoted to specific task functions.

Lesson pacing also provides incisive information about locus of control. Recalling Deci's seminal studies (1971, 1972), and many thereafter, individuals who freely chose activities and further exercised their autonomy by determining how long or how fast they would work were more intrinsically motivated. In most students' experience, lesson pacing is determined by the teacher. However, when a class becomes involved in a group discussion or a student makes a presentation, it becomes less clear who controls the clock.

Goals

Formats may also be described in terms of their *goals*, which have significance for flow in terms of clarity. Goals can lack clarity if they are poorly worded or if the work with which they are associated is too challenging. Both conditions are bound to be greeted with confusion on the part of students.

Goals can also convey intrinsic or extrinsic orientations. If in justifying the purpose of an activity it is stated or implied that students are expected to conform to a given standard, self-regulation may be directly confronted. Or if the utility value of the activity is emphasized, for example, doing x number of problems in order to earn extra credit points, once again a potential extrinsic orientation is introduced whether students need it or not to get them moving. On the other hand, if the goal is for students to see if they can discover other ways to solve the problem, that may allow them greater freedom and place fewer obvious extrinsic incentives in their path.

Cognitive requirements

Also relevant to goals and motivation is the implicit task challenge. As indicated earlier in this chapter, one way to gauge this is by ascertaining the complexity of the cognitive operations required. In classroom studies such as Stodolsky's (1988) comparison of fifth grade social studies and math lessons, she was able to identify cognitive challenges across activity segments according to their complexity: those "with no cognitive goal, those emphasizing facts, those oriented to comprehension or concepts, those in which students learned research skills, and those containing application or other higher mental process activities" (Stodolsky, 1988, pages 78-79).

Besides cognitive complexity, another important aspect of challenge is mathematical aptitude. Are the goals set too high or too low for one's ability? Without the potential to perform an activity, the experience is bound to be frustrating, anxiety-producing or even meaningless. With sufficient skills but lacking a challenge, a person will probably become bored. Therefore, students' affective experiences may be relied upon to measure the dynamics between mathematical tasks and aptitude. These may be measured by asking the students about their feelings; they may also be deduced from behaviors.

Feedback

The importance of feedback has already been mentioned. Without immediate or unambiguous feedback it may be very difficult to tell whether one's efforts are on track or not. In this light, a teacher, another student, or a mechanical device can provide the necessary information to determine the accuracy or appropriateness of one's efforts. Often overlooked in classroom research is the possibility that a task may be a source of informational feedback on its own. The involvement of other people may be unnecessary; in fact, the feedback they provide may be controlling in nature and encourage an extrinsic motivational focus. It is also conceivable that no feedback may occur, that no information or external control is forthcoming to guide one's efforts in completing a task. Since access to a student's perception is limited, it is no easy task to tell whether the feedback is perceived as controlling or not. But it may be possible to describe the source of the feedback and its intended purpose.

Observable behaviors

Activity segments also provide information about teacher and student behaviors, which are a potential source of information about locus of control, perceived competence and challenges. In most cases, teachers respond to students and vice versa. Relative to skills and challenges, if students are not "getting it," a responsive teacher may be observed adjusting the difficulty of the task. If the students are doing fine, the teacher may provide little more than passive assistance, co-participate in the activity, or not be involved at all. When things start to go awry, the teacher is likely to attempt to regain control by some observable action.

Student behaviors are also important in making this determination because they can disclose whether an activity holds their attention or not. If something is not interesting because it is too easy, too hard, or not rewarding enough, attention to the prescribed task will dissipate. Instead of reading, for example, students may start to talk or gaze around the room. Some other task that is more interesting will probably divert their attention. If students are interested in a task to start with, however, and then the teacher employs controlling strategies, the more likely it becomes that students' intrinsic motivation will be undermined (Deci, Nezlec, & Sheinman, 1981; Valås & Søvik, 1993). In either case, the actions of teacher and students may be used to interpret the motivational climate of the classroom.

Little more needs to be said at this point about *interaction* except to that it may be observed in certain formats more often, for example, group work and discussion. Interaction may involve as few as two individuals or as many students as there are in attendance.

Clearly, behaviors do not always divulge what classroom participants are experiencing, whether they are really thinking about what they appear to be listening to (Jackson, 1984). But behaviors can act as a barometer by which to tell if tasks are being attended to or not. Tied to observable behaviors is the *energy level* with which students conduct themselves quite candidly. These encompass high energy (when subjects are animated and excited about a task, or in a negative sense, agitated), average energy (the more common passive state of classroom experience), and low energy (a condition in which the approach to work is lethargic and unmotivated). Generally, students' energy levels provide clues to their task interest and the emotional climate of the room.

Physical environment

Finally, every segment has a physical context in which segment elements occur. The classroom environment, instructional media, temperature, time of day and distractions are all part of the milieu that may affect what occurs in a segment. As clinical studies have shown, distractions and discomforts can effectively negate intrinsic motivation (Deci & Ryan, 1985). Moreover, the environment of instruction can say a lot about who is in control and should not go unheeded (Goodlad, 1984). From wall displays to the arrangement and the condition of the furniture, the agenda of control is present in three dimensions. How the room is used is potentially important as well. For example, students who are assigned to seats or who are allowed to sit wherever they want may come to different conclusions about their freedom. Before external locus of control can bring about a loss of intrinsic motivation, however, an individual must perceive a threat to self-determination. Therefore, it cannot be observed what the effect of the physical setting is without also listening to students.

Modeling the optimal task

As this chapter and the one before it have sought to illustrate, there are several ways tasks may predictably affect intrinsic motivation. Basic to the relationship between tasks and motivation is the premise that activities which satisfy the needs for autonomy, competence and self organization are inherently enjoyable, attracting and holding an individual's attention.

From this discussion of task elements and motivational effects it is possible to distill a model activity, one that optimizes opportunities for flow. Assuming that the prevalence of certain task dimensions (and the absence of others) results in greater intrinsic enjoyment, what was hypothesized at the end of chapter 1 regarding complexity in the classroom can now be stated more precisely.

Simple and complex classes will differ in their use of formats. There will be more opportunities for students to interact and make choices in complex classes. In terms of activities there will be more group work, projects, discussion and student presentations in complex classes. In contrast, formats that limit social interaction and student choices (e.g., teacher presentations, seatwork and recitations) will be more prevalent in simple classes. Just as an emphasis on chores characterizes simple families, grading papers, time spent getting organized and other classroom housekeeping will characterize simple classes.

Because students are afforded more autonomy in the complex classroom, they may behave in ways that are more characteristically reserved for the teacher: initiating discussions, posing new problems, and helping to evaluate solutions. Teachers will recognize and encourage student participation at this level.

There will be greater novelty in the types of problems assigned to students in complex classes. Students will not be given a steady diet of “skill and drill” problems in which an algorithmic procedure is repeated until it is mastered. Novel problems, that is, ones in which the algorithm to use is not predetermined, will be used to integrate mathematical skills. Incentives in the classroom will be based on discovered problem solving. Extrinsic rewards such as extra credit or an emphasis on the long-term, utility value of mathematics (i.e., what good will it be someday) will be subordinate to the intrinsic, short-term satisfaction of discovering solutions and finding new ways to solve problems.

Even though discovery-type problems may be used, student questions and behaviors will not reflect significant confusion about the goals of the activity or what is expected.

Some of the potential confusion should be eliminated when students become accustomed to the use of discovery problems. Before this can happen, the goals of the activity will need to be stated clearly, and if there are questions, the teacher will take care to explain what is expected in a way that results in understanding and acceptance. Ultimately, the goal may be for students to participate in finding new discovery problems to solve.

Feedback in the classroom will be informative rather than controlling, providing insights to the learner on the adequacy of his or her actions. In a more complex environment, feedback will come from sources other than the teacher, for example, other students and the task itself. (If the activity is balanced with the learners' skills, the only feedback necessary may come from the task itself.) Feedback will be immediate to the task, not delayed, except in cases where students are guided to discover solutions on their own. Formats in which students actively engage in focused problem-solving such as seatwork, group work and discussion may be expected to increase perceptions of flow.

More time will be spent in tasks that are appropriately challenging; consequently, boredom and frustration will be minimal. Students will not appear to be anxious or lethargic when tasks are just right for their abilities. Teachers will not have to intervene to correct student behaviors when this balance is achieved. When this balance is optimal, less time will be spent experiencing discomfort or distraction in the classroom, even though those elements may be present. Plus, students will create fewer distractions themselves when their attention is devoted to the task.

Complexity may not depend on *variety*, which is listed sometimes as a possible motivational effect.[5] Flow provides an interesting footnote concerning variety: students who engage in a narrow range of behaviors are not necessarily less motivated. Persons who experience flow are known to engage in the same activity for long periods of time (Csikszentmihalyi & Csikszentmihalyi, 1988). Intense enjoyment does not seem to depend to a great extent on variety alone (differentiation) but on complexity, the integration of differentiated task element and skills in a specific task. Therefore, flow in math may not be related to task variety as much as the judicious selection of tasks.

The purpose of a model task comprised of these dimensions is to test whether or not it helps to explain optimal experience in math. By observing classroom activities, the behaviors of teachers and students, the choices offered and the related events of instruction, it may be possible to determine if students who experience more of these optimal elements of tasks manifest greater levels of flow. It may turn out that certain elements aid in the formation of intrinsic interest more than others. As it is, the model is not expected to be perfect but primarily a tool by which to understand classroom experiences in light of flow and achievement. The findings are reported and discussed in Chapter 7.

[5] For example, Ames (1992) suggested five dimensions of classroom experience that may have motivational importance: variety, novelty, control, challenge and meaningfulness. (Meaningfulness is assumed to be implicit in flow.)