MANIPULATING AND MEASURING STUDENT ENGAGEMENT IN COMPUTER-BASED INSTRUCTION

By

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CHAPTER I

INTRODUCTION

This research is based on the observation that many hobbyists spend considerable time and fervent effort learning. Educators often claim that they want to create "life-long learners." Hobbyists seem to be a near perfect example. Given that hobbyists exhibit these exemplary learning goals and behaviors, the factors that drive these hobbyists may hold promise for helping to make classroom instruction more engaging. Perhaps life-long learning can begin in the classroom. This dissertation surveys what motivates hobbyists to learn and then tests whether those motivations can be translated into a computer-based biology curriculum for a 7th-grade science classroom.

A significant component of this work is the development of technologies that can help evaluate the relationship between motivation and learning with understanding. This instrumentation is important because theories of motivation have typically been neutral with respect to learning with understanding. For example, theories of motivation that point to external rewards work equally well for learning to hate as they do for learning biology lessons. Similarly, theories of motivation that point to internal rewards often describe internal states that people desire to achieve, regardless of learning. The educational assumption behind that research is that motivation will drive people to pursue or continue in an activity, but what is missing is a tight link between motivation and specific activities relevant to understanding. The technology developments reported in this dissertation may help researchers determine whether there are forms of motivation that lead specifically to a desire to learn with understanding. These developments include ways to track student engagement from one activity to another, as well as their use of learning resources at different levels of engagement.

To begin the task of isolating likely motivators of understanding, the dissertation provides a review of the motivation literature as it may pertain to hobbies. The motivation literature is categorized according to five theoretical commitments to the source of motivation. These include intrinsic and extrinsic motivation, especially as studied in the classroom. They also include categories of motivational theorizing that assume learning itself is motivating and that social factors regulate motivation. Finally, this review considers a new category of motivation: the desire to produce things. Though the production of artifacts, collections, and performances is clearly motivating to many, and central to most hobbies, it has not be treated as a unique category of motivator, which I propose is an oversight.

Based on the literature review, I developed an on-line survey tool to see what hobbyists in fact believe is important to their participation in hobbies. Hobbyists rated twenty-five factors according to how much each factor contributes to the enjoyment of their hobbies. Similar surveys were given to high school students, once asking about their favorite hobby to check if students and adults have the same motivations for their hobbies, and a second time asking about students' favorite classes, to see whether in-school and out-of-school motivations are similar.

Several factors were consistently rated at or near the top even across different kinds of hobbies. The number one motivation was the opportunity to produce artifacts (construed as outward productions including performances, collections, and objects). Coupled with this was the opportunity to share the artifact. Importantly, near the top was also the motivation to learn the methods necessary to produce the artifact. Thus, the motivation to produce artifacts appeared to be tightly linked with the motivation to learn with sufficient understanding to produce those artifacts.

For instructional purposes, these findings are inconclusive. Though they may describe what makes project-based learning motivating, it is also possible that these motivations to produce and learn exist only in self-selected activities like hobbies or favorite classes. It is still an open question whether instruction can recruit these motivators and succeed in classes where participation is mandatory and students do not get to choose their curriculum as they might with hobbies. Traditional instruction, ironically, often removes these exact sources of motivation by requiring students to do robotic tasks that are not shared with others. Thus, to examine whether these motivators are relevant to curriculum design, I conducted an intervention study that manipulated the hypothesized sources of motivation and determined whether this affected their learning relevant behaviors and outcomes.

The hobby survey yielded two hypotheses. The weak hypothesis is that giving students increased opportunities to create, customize and share would increase engagement. The strong version of the hypothesis posits that this increased engagement will lead to increased attempts to learn. If so, this would be a useful finding both for the design of instruction and for the development of a theory of motivation tied to learning with understanding.

An instructional experiment tested these hypotheses. It used three different activities in NetLogo (Wilensky, 2002) that varied opportunities to create, customize and share simulations on population dynamics. The study yielded positive, though moderate, support for the hypotheses, and provides insight on the future design of tools for relating motivation and learning with understanding.

CHAPTER II

LITERATURE REVIEW

2.1 Existing Research and Literature on Classroom Motivation as it Applies to Hobbies

This study is designed to investigate whether the same factors that make hobbies engaging can be applied in the classroom. A focus on hobbies can also serve as a guide through the vast body of motivation literature. Since hobbies are self-selected and attending school is compulsory, there are necessarily some differences in what motivates participation in each. Whether these findings from outside classrooms can inform instruction is an issue for the later study.

Early research in motivation was focused on using punishment and reward to shape behavior, often in animals. When an action is taken with the purpose of gaining reward or avoiding punishment, the motivation is called **extrinsic.** Some actions, however, provide their own reward. Motivation for these activities is called **intrinsic;** what drives participation in the activity is the activity itself. This distinction, presented here as perfectly didactic, can be more complicated. For example, just as Pavlov's dogs salivated at the sound of a bell, humans can also start to enjoy tasks in anticipation of the rewards they will bring. Study of the effects of intrinsic and extrinsic motivation are central to much of the research in motivation and offer two key categories for considering the allure of hobbies.

In addition to intrinsic and extrinsic motivators, this review of current research and literature identifies three more motivators that may contribute to the enjoyment of hobbies. These are the desire to learn, the desire to be connected to others, and the desire to create a tangible product. These five categories are also central to the survey studies discussed below.

2.1.1 Intrinsic Motivators

Hobbies as a whole are intrinsically motivated—people choose to participate in them during their free time. Existing research identifies control, perception of competence, and appropriate level of challenge as contributing factors to the intrinsic motivation that hobbies provide. These factors likely contribute to the enjoyment of hobbies. In brewing beer, for example, one has control over the process. High quality ingredients are available year round, allowing the creation of virtually any kind of beer. A wide variety of clear goals are available—from simple goals like "making good beer" to more complicated goals like precisely calculating the quantity and strength of beer that is created. Also important in any hobby is that a wide variety of challenges be available. One can start brewing with "no boil" kits which require just mixing water and malt syrup. More experienced brewers typically prefer to make their beer from malted barley, a more complicated and time-consuming process. The variety of methods and tools is such that a motto used by the American Homebrewers Association is "It's not rocket science . . . unless you want it to be." These factors, more fully explored below, intuitively apply to hobbies.

People choose to participate in their hobby and this freedom itself likely contributes to the satisfaction that hobbies provide. The motivating effect of choice has been demonstrated—even with inconsequential choices—as in a study that had children working with puzzles. One group was allowed to choose which three of six very similar puzzles to work with; a control group was assigned which three to use. The group that had been offered the opportunity to choose persisted longer in working with the puzzles and showed more interest in continuing to work with the puzzles (Zuckerman, Porac, Lathin, Smith, & Deci, 1978).

Since having a choice, between even very similar activities, has been demonstrated to be motivating, it is not surprising that having freedom to make more interesting decisions is also motivating. de Charms (1971) had college students play with Tinkertoys either in a **Pawn** condition, where participants were told what to do at each step, or an **Origin** condition where they were free to create their own original model. Those in the Origin condition reported increased liking of the task, were more likely to continue working on the model, chose to complete the model elegantly, and recalled more of the names associated with the model. He also gave a group of randomly-selected sixth-grade teachers six weeks of training designed to provide students a greater sense of control. At the end of the following school year, the students of those who received the training showed a half-year improvement on a math achievement test compared to similar students from the control classrooms; interestingly, the training included no math instruction.

One way of isolating motivating factors is to focus on experiences that people report as satisfying. Rather than starting with a hypothesis about motivation and testing it experimentally, Csikszentmihalyi (1991) developed the "experience sampling method" to see what kinds of activities resulted in the highest engagement. He called the state of being completely engaged in an activity **flow.** In a typical study, subjects recruited from large companies carried a beeper. About seven times each day the beeper activated, prompting the subjects to fill out a survey. The survey, which took 1–2 minutes to complete, asked what the current activity was and the quality of the experience, and included measures of challenges and skills, motivation, concentration, creativity, satisfaction and relaxation (Csikszentmihalyi & LeFevre, 1989). A consistent finding of these studies is that people are most satisfied, or at **flow**, when skill and challenge are balanced (Csikszentmihalyi, 1991).

Though using experience sampling was a new way to demonstrate the importance of challenge, the importance of appropriate challenges was already well documented by experimental means. Harter (1974), for example, had 5th and 6th grade students solve 3-, 4-, or 5-letter anagrams. Using smiles and self-report as measures of enjoyment, she found that enjoyment was highest when the anagrams were neither too easy nor too hard.

Competence, another factor Csikszentmihalyi found to correlate with high engagement, was also recognized by other theories of motivation (e.g. theories of self-determination, Deci, Vallerand, Pelletier, & Ryan, 1991 and self-efficacy, Bandura & Schunk, 1981). Cordova and Lepper (1996), for example, showed that self-perceived competence was a significant predictor of how much students enjoyed a computer-based math game. Similarly, Fredricks et al. (2002) found that self-perceived competence was an important factor in determining whether adolescents remained involved in sports and arts. Self-perceived competence, rather than some objectively-measured sense of competence, is what is important for this effect. In an early study on the detrimental effects of extrinsic rewards on intrinsic motivation, Deci (1971) used a "verbal reward," telling a randomly selected group of participants that their performance was "much better than average." Motivation was measured by the amount of time subjects continued to work on the puzzles after the experiment was apparently over and the experimenter was out of the room. Subjects who were told they were above average continued to show an increase in their intrinsic motivation for this task even after opportunities for further reward were removed. One explanation for this result is that an increase in their perceived competence made the puzzles more fun.

Also affecting one's sense of competence is competition. Clearly, winning bolsters feelings of competence, and losing reduces feelings of competence, but there are also more subtle findings. Competition can direct one's attention to winning rather than how to accomplish the task at hand, so the goal of winning becomes more important than the goal of learning (Ames, 1984).

A slightly different perspective on competence is Bandura's (1994) concept of self-efficacy. Self-efficacy is the belief that one can accomplish the task at hand even in the face of adversity. Self-efficacy is different from competence in that self-efficacious people believe that they can accomplish tasks regardless of their initial competence. Although some people believe that they can succeed regardless of their initial ability, others feel that they will fail regardless of their ability. Learned helplessness (Dweck, 1986) is a state where individuals feel that their actions have little or no affect on their fate or performance.

From the literature reviewed in this section, we can identify three key factors that contribute to intrinsic motivation: choice, perception of competence, and appropriate level of challenge. Though these studies come from laboratory and classroom settings, their findings may also inform what makes hobbies motivation as well.

2.1.2 Extrinsic Motivators

Though participating in a hobby is probably intrinsically motivated, consideration of extrinsic motivators is warranted for two reasons. First, there may be extrinsic reasons for hobby participation. Second, the goal of this research is to make classroom instruction more engaging. Because extrinsic motivation has been central to much motivation research in education, it is worth considering the role that extrinsic motivation may play in drawing people to participate in hobbies, and whether the extrinsic motivators in school undermine attempts to build hobby-like motivations into instructional activities.

Though it seems unlikely that extrinsic motivators are primary motivators of hobbyists, hobbies can provide extrinsic rewards. Hobbies can develop into profitable cottage industries, even though income was not the initial incentive. Conversely, some hobbies may be born of necessity: someone who starts home remodeling to save money may end up with a love of carpentry. At the very least, a hobby may position one for advancement and greater income. Golf, for example, is a hobby that may have considerable extrinsic motivators for men and women working in corporate America. Many business deals are made on the golf course, so that one's professional success may be directly tied to playing golf well enough to play with key decision makers. Similarly, one's social stature can be linked to performance on the golf course. Winning a club championship, especially at a prestigious club, can increase status as well as give one feelings of satisfaction in being better than others.

Extrinsic Motivation in Hobbies

One important concept in motivation relevant to the enjoyment of hobbies is goal orientation. One useful contrast is the degree to which students are interested in learning as compared to their interest in **appearing** to have learned. Students, and presumably hobbyists, with **mastery goal orientation** are interested in developing their skills, understanding their work and achieving a sense of mastery; these students also believe that increased effort will yield increased performance. By contrast, those with a **performance goal orientation** are interested in recognition that they have done better than others (Ames, 1992). These people also have a stronger connection between their ability and their sense of self-worth than do those who are more mastery goal oriented. This contrasting orientation has also been labeled **learning and performance goals** (Dweck, 1986), and **task-** and **ego-involvement** (e.g. Graham & Golan, 1991). These theories explain motivation and performance in classroom situations. It is not clear to what extent individuals are likely to have a performance goal orientation in the context of a hobby or other non-achievement situation; the golf example above suggests one way that hobbies may provide extrinsic rewards, but this may apply to only a few hobbies.

More directly applicable to hobbies and motivation are studies that have looked at the effects of extrinsic rewards outside of the classroom or laboratory. Kasser and Ryan (1993, 1996) found that mental health and well-being were inversely correlated with interest in wealth, fame and image. These self-report measures with both adults and college students showed that those who highly ranked the importance of financial success, social recognition, and personal image, ranked correspondingly lower in measures of mental and physical health. Conversely, those with higher ratings for self-acceptance, affiliation (connections to friends and family), community feeling, and physical fitness, had higher ratings of self-actualization and vitality and reported less depression.

2.1.3 Detrimental Effects of Reward

Perhaps because it is much easier to use reward and punishment as motivators than it is to make activities intrinsically motivating to the entire school population, reward and punishment in schools is prevalent. Great debate continues around the concern that the use of extrinsic rewards in schools has detrimental effects on what few intrinsic motivators may be available in schools (Cameron & Pierce, 1994; Cameron, 2001; Deci, Koestner, & Ryan, 2001; Deci, Ryan, & Koestner, 2001). One of the first studies demonstrating the detrimental effect of reward on intrinsic motivation gave college students an opportunity to solve puzzles (Deci, 1971). One group was paid for the successful completion of the puzzles, a second group was told to solve as many as they could. After the study was apparently over and the experimenter was out of the room, those who received payment for solving the puzzles stopped working on them once the promise of reward was removed. Those who were not financially rewarded, however, were significantly more likely to continue working. The same results were found twenty years earlier in an almost identical study done with monkeys who had shown interest in taking apart puzzles. The group of monkeys who had been given a raisin as a reward for successfully unfastening the puzzles lost interest after the reward ceased. Those who had received no such incentives continued to unfasten the puzzles (Harlow, Harlow, and Meyer, 1950, reported in de Charms, 1971).

In spite of this and many other demonstrations of external rewards reducing intrinsic motivation, some theorists contend that the situations that cause rewards to undermine intrinsic motivation are rare outside of contrived laboratory settings. Using meta-analytic methods, Cameron and Pierce (1994) showed that extrinsic rewards have little effect on intrinsic motivation. Even if extrinsic rewards do reduce intrinsic motivation, Cameron (2001) argued subsequently, rewards are used to entice students to do things that they would not do without rewards, not to entice students to do things that they are intrinsically motivated to do. Partly as a result of Cameron and Pierce (1994), token economies continue to flourish, especially in middle and elementary schools (students earn points for reading books and exchange those points for prizes or opportunities to do "fun" things). Most motivation researchers, however, believe that the undermining effects of rewards cannot be denied and are potentially damaging to students' desire to learn (Deci et al., 2001; Lepper & Henderlong, 2000). One criticism of Cameron's meta-analysis is that many of the studies included in the sample were designed not to test whether there is a detrimental effect of rewards but instead to better understand precisely what kinds of rewards can contribute to the detrimental effects of rewards. (A paper might comprise three studies with increasingly subtle rewards. The fact that in two of the studies the effects of reward were too subtle to be measured does not imply that there is no detrimental effect of reward.) Though using rewards to encourage reading, as in the token economy example discussed above, may encourage some students to read more than they would otherwise; if this comes at the cost of discouraging students from reading when the promise of reward is removed, then such token economies are likely to discourage reading in the long term.

Extrinsic Motivation and Internalization

The explanation of intrinsic and extrinsic motivation provided at the beginning of this section suggested a clear distinction between intrinsic and extrinsic motivation. For the sake of discussion so far, this definition has been sufficient. If rewards and punishments are internalized to varying degrees, it may mitigate the detrimental effects of extrinsic rewards. In addition to the commonly-understood sources of extrinsic motivation like promise of reward or threat of punishment, Deci and Ryan (2000) suggest three other sources of extrinsic motivation: introjection, identification, and integration. (a) **Introjection** entails individuals applying external regulations to themselves, for example to contribute to their self-worth, or avoid guilt or shame. (b) **Identification** is the process through which people recognize the underlying value of a behavior, for example those who recognize exercise as central to being healthy internalize that need and exercise becomes part of their identity, so it becomes more autonomous. (c) Completely internalized extrinsic motivators are said to be **integrated.**

An example of this is a good student for whom doing homework is a part of every afternoon's plans. Not only is the underlying importance of behaviors recognized, but also the activity has become part of one's identity. These extrinsic motivators are examples of how externally-regulated behaviors can seem self-determined.

Internalized extrinsic motivators likely contribute to success in hobbies. Many hobbies have some parts that are less engaging than others, but necessary for participation. In brewing, for example, cleanliness and sanitation, which are not particularly interesting and provide no tangible rewards, are arguably the single most important part of the brewing process. Even the most perfectly brewed beer can be ruined by a piece of unclean equipment (in a particularly tragic example an excellent craft-brewed beer travels across the country in refrigerated trucks only to be ruined by a dirty line between the keg and the faucet that dispenses beer into the glass). A botched recipe, on the other hand, may not produce the desired style of beer, but as long as the equipment that it touches is properly sanitized, the resulting beer will likely be palatable. As a result some brewers come to enjoy carefully cleaning and sanitize every piece of equipment immediately after its use. Finding new ways to get equipment cleaner can become one of the joys of the hobby.

The effects of these different types of extrinsic motivation are largely untested experimentally because identification and integration are difficult to manipulate or even reliably detect. It seems likely that students will learn better if when studying because it is an integrated part of their desire to learn rather than studying merely to avoid punishment. On the other hand, those who study with the intention of doing well on a test attend to their learning differently than those who study to prepare for an activity that provides them with more autonomy, like teaching others (Benware & Dece, 1984; Biswas, Schwartz, Bransford, & Teachable Agents Group at Vanderbilt, 2001).

Extrinsic motivators are not likely a large part of why people participate in hobbies, but they may contribute in some ways. The literature reviewed here suggests that though extrinsic rewards are a large part of motivation in classrooms, extrinsic rewards can remove or reduce the pleasures connected with some activities. Extrinsic motivators can be internalized to varying degrees; these internalizations likely contribute to making less-fun parts of hobbies more engaging.

2.1.4 Learning as a Motivator

There are three other factors that do not fall neatly within the usual extrinsic-intrinsic variable constellation that may also contribute to making hobbies engaging. The first is learning; hobbies often require learning, so learning itself may contribute to what makes hobbies motivating. Next social factors are considered: many hobbies have associated clubs, which may be what attracts people to hobbies in the first place. Finally, I suggest that a compelling motivator in many hobbies is the creation of an artifact.

Many hobbies require learning even to become a novice, and continual learning and practice is required to get better. Generally, those who stay involved in a hobby continue to learn and get better in that hobby. This is a good model for lifelong learning that many educators want to instill in their students. This section looks at some different types of learning that hobbies motivate.

Several different types of learning may be connected with hobbies. People may be interested in simply gaining more knowledge. Some theorists assume that humans have an innate desire to learn (e.g. Dewey, 1922). Many people are interested in learning little-known facts and trivia; sports fans, for example, often delight in being able to recite statistics about players and teams. A corporate trainer has found repeatedly that an effective way to get employees or customers to learn more about a product or corporate process is to create a trivia game like Jeopardy (Prensky, 2001). This desire for knowledge may also attract people to hobbies as an opportunity to learn.

Many hobbies require obtaining and learning about tools. Rock climbing, for example requires many different types of tools—ropes, harnesses, carabiners, and so on—each with different features and trade-offs. Finding the tools that are best for each person and each situation may provide satisfaction, making a hobby more engaging.

Related to learning about tools is learning about methods. Deciding which kind of rope to get is one decision, but learning how to use it is another. Different situations call for different knots; learning which knot to use and how to tie it quickly with different constraints like not being able to see your hands or not being able to move one end of the rope may provide considerable satisfaction.

Inevitable Learning

Many hobbies involve learning, either learning to be better at the hobby, as in chess or home brewing, or learning as a part of the end of the hobby, as in war reenactment or collecting. Many theorists have operated from the assumption that humans innately desire to learn how things work and how to control their environment. Some, like Piaget, have worked from the assumption that as humans develop they inevitably learn. For example as children get older they gain an understanding of conservation of number across different arrangements of objects; this happens without learners knowing what the outcome of their learning will be.

Intentional Learning

Although some learning occurs without goals, most learning is intentional. Since most of what students need to learn in school is not automatically gained by development, learning intentionally is very important in classrooms. Concerned that teachers and students do not focus explicitly enough on what and how they are learning, some researchers have urged teachers to model and help students learn intentional learning (Brown, Ash, & Rutherford, 1993).

In the context of many out-of-school activities, intentional learning seems to come easier, perhaps because the topics are of inherent interest or people intentionally specified learning goals. People enjoy learning various facts that they find interesting or satisfying. Sports fans in general, and perhaps baseball fans in particular, are often fascinated with various statistics and trivia related to the game. They learn their favorite player's batting averages for each year they played, their favorite team's ranking for all of history or the scores of each of the games in the World Series. The popularity of quiz shows on television is evidence that many people enjoy knowing (and presumably learning) trivia. Also compelling for many people is learning facts about their subject of interest. Civil and revolutionary war re-enactors, for example, strive to learn details about the period, the tools and the battles that they emulate.

In addition to learning facts and trivia, people can also enjoy learning about methods and tools. Home brewers, for example, often delight in buying, building, and using the various tools required to brew beer or make brewing beer easier. Similarly, learning about and trying to replicate the methods used to brew unusual or difficult-to-find beers is also an endeavor many find worth their time.

Reading

Related to the pleasures of learning is reading. Many people find reading pleasurable. The size of the magazine rack at a large bookstore is an indicator that reading about one's vocation or avocation is an activity that attracts people for many reasons. Csikszentmihalyi (1991) reports that reading is an activity that often provides flow, but experience sampling can show only correlation, not causation. It is likely that, at least sometimes, this flow is the result of the satisfaction gained in learning from reading. It is less clear that learning contributes to engagement when reading fiction; one appeal of reading fiction may be that it provides a means of escape.

This section has reviewed several theories that assume that learning is intrinsically motivating. Some kinds of learning are an inevitable part of development. More often, especially in schools, learning is an intentional goal of the learner. Also related to learning is reading, an activity that can be engaging as a means of escape, and also as an intentional learning activity.

2.1.5 Social Motivators

The study of motivation started with experimentation on animals. A typical study used food as a reward to train an animal to press a bar or move to a certain part of a cage. The same techniques can also be used to shape human behavior, but there are important differences between humans and animals. For example, when a mouse fails to get a piece of cheese, the other mice do not express disappointment, pity or condolence. Though motivation research has moved far from its behavioral roots and often recognizes social factors, it has not given the same attention to social and cultural factors as have educational and cognitive theorists (e.g. Brown, Collins, & Duguid, 1989; Cobb, 1994). Just as social factors affect learning, they must also have important effects on motivation. One appeal of many hobbies may be an opportunity to socialize. As an example of a hobby that may have a larger social component than most, consider ballroom or swing dancing. An initial appeal of this activity may be the opportunity to belong to a group. These factors and the opportunity for touching may contribute to one's feeling of being liked by others in the group. Having the opportunity to share one's skill with others is an important part of this hobby; dancing alone is not nearly as much fun as dancing with others. Finally, those who are in any group are likely to be interested in helping others to appreciate the hobby—perhaps to expand the group, or perhaps to learn more by teaching (Biswas et al., 2001).

Related to sharing is the basic psychological need for the feeling of belonging to a group. Self-determination theory is based on the assumption that relatedness, competence and autonomy are fundamental human needs (Deci et al., 1991; Deci & Ryan, 2000). Similarly one of the levels in Maslow's (1954) hierarchy is belongingness, a concept that is still recognized as important (Weiner, 1990; Ames, 1992). Relatedness and connection to community have also been found to correlate to mental well-being (Kasser & Ryan, 1993, 1996, discussed on page 8).

Another way to experience relatedness is to share one's work or performance with others. Anderson, Manoogian, and Reznick (1976) report a replication of an earlier study that showed children were less likely to continue to draw with colored markers after receiving an extrinsic reward (Lepper, Greene, & Nisbett, 1973). Expecting to see that the control condition's motivation was unchanged, Anderson et al. (1976) were surprised to find that those in the control group (who received no reward) showed considerably lower interest in using the markers than did those in the treatment groups (who received a reward for part of the study). A second experiment manipulated the control conditions to investigate this phenomenon. In Control 1, as in the first study, the subject worked in a room with the experimenter who said that he was busy and tried to avoid verbal or eye contact with the subject. In Control 2 the experimenter showed some interest in the child's work, but provided no further reinforcement. Control 3 consisted of only the pre- and post-tests with no treatment. Control 2 and 3 had fairly consistent motivation in pre- and post-tests. Control 1, as in experiment 1, showed a significant decrease in motivation. One explanation for this result is that without an outlet to share their work the activity of drawing loses some of its appeal.

As described above, social factors contribute to motivation and satisfaction. Learning theorists increasingly recognize the importance of social factors on learning and cognition, but motivational theorists have not yet embraced these social factors to the same degree. There is a strong desire to belong to a group, so activities that will increase one's belonging to a group are naturally motivating. One way to increase contact and connection with a group is through sharing an artifact or performance.

2.1.6 Creation as a Motivator

Another kind of motivator that seems to have been overlooked in the literature is the appeal of creating an artifact. Many of the theories discussed here can account for how the intrinsic motivation of self-determined creation can be reduced or eliminated, but none considers how or whether creating a product increases intrinsic motivation. Hard work is generally considered more pleasant when there are tangible signs of its completion.

Consider an artist creating a piece of art. First, the artist conceives a piece, exercising his or her autonomy in the design of the piece. The design will also present an appropriate level of challenge—for one artist a paint-by-number canvas with colors of his own choosing might provide the needed challenge while still satisfying the need for self-expression. Another artist might need to stretch canvas and mix her own paints from pigments and linseed oil to provide the same level of satisfaction. Balancing this need for self-expression is one's self-efficacy. An artist does not conceive a piece that he or she does not believe that he or she can create. Once the piece has been created the artist has the piece as a symbol of both their competence and autonomy.

No classroom studies have directly tested the motivating effects of the production of an artifact, but some studies have shown that students like seeing themselves reflected in the work they do and that providing choice can increase motivation. Cordova and Lepper (1996) personalized a computer-based, number line game by modifying the program's story and feedback to include the students' names, friends' names, and favorite food. A second condition allowed students to choose the name of the space ship in the story and to make other choices without educational consequence. Students in both conditions showed significantly increased motivation over a control group, as measured by self-report of liking, enjoyment, and recommendation to friends. Both groups also increased learning and perceived competence.

Perhaps the reason that no education studies have tested the motivational value of the production of an artifact is that it is difficult to know whether participants did anything without something to show for it. Essays written for English or history classes, paintings in art class, even a set of math problems are things that one can touch and hold. Depending on the circumstances and participants, the range of satisfactions derived from the production of such artifacts is widely varied. It is therefore likely that other factors contribute to whether the production of an artifact is satisfying.

Literature in achievement motivation offers little to explain whether creating an artifact results in increased motivation. This section has reviewed some examples that show that personalization of instructional materials can increase motivation. Some might argue that all instruction is for the creation of some artifact, usually a test or a written assignment. Other factors, like the opportunity to use the artifact as a means of self-expression may contribute to making creation in hobbies more engaging that the kinds of creation typically a part of classroom instruction.

Intrinsic and extrinsic motivators and their effects are a central issue of the motivation literature. This review has also considered three other aspects that may contribute to increasing motivation. First, many theorists assume that learning is an innate desire, so the desire to learn may be part of what attracts people to some hobbies. Second, social factors, which are gaining increasing attention from learning theorists, likely contribute to motivation as well. Third, many hobbies have to do with creating an artifact that serves as a means of self-expression. The next section discusses a set of surveys that investigate which combination of these factors actually do contribute to making hobbies engaging.

CHAPTER III

AN INVESTIGATION OF WHAT MAKES HOBBIES ENGAGING

To learn whether the interest and effort that many put into their hobbies could somehow be harnessed to improve classroom instruction, I designed a survey to identify factors that make hobbies appealing. One possibility was that each hobby provides different satisfactions and that only individual differences determined which hobbies were appealing. If this were the case, then there would likely be no usable implications here for easily managed classroom instruction. On the other hand, if a small set of factors were important for most or all hobbies, those factors might be the basis for a set of principles for making classroom instruction more engaging. Individual differences would still explain whether someone was initially drawn to chess or rock climbing, but the satisfactions they found would be similar.

I designed a survey that had hobbyists rate different types of satisfactions that they might gain from their hobby. How much did they enjoy their hobby because they liked participating in competitions, sharing their craft with others, or learning to use new tools?

Based on theoretical findings described in the Literature Review, I focused on five factors that might contribute to the satisfaction derived from one's hobbies. The point of the pilot was not to pit one theory against another. The theories served as a guide for what types of items to include, but it was not crucial that the items fit neatly into only one category or that the categories perfectly represent all of the literature on motivation.

The categories are (a) **intrinsic** motivators such as having appropriate levels of challenge, clear goals, or activities that are an end in themselves; (b) **extrinsic** motivators such as enter or win competitions, to increase social stature, or to be better than others; (c) **social** motivators such as sharing with others, being liked, or stimulating conversation; (d) **learning** goals such as learning to use tools, methods, facts, or have an opportunity to read to learn more about a hobby; and finally (e) an opportunity to **create** an artifact.

To help ensure that people understood what was meant by the name of the satisfactions, each was paired with an example from one of my hobbies, brewing beer. For example, the potential extrinsic motivator "To be better than others" was exemplified by the phrase: "Knowing that I make better beer than many people adds something to my enjoyment of the hobby."

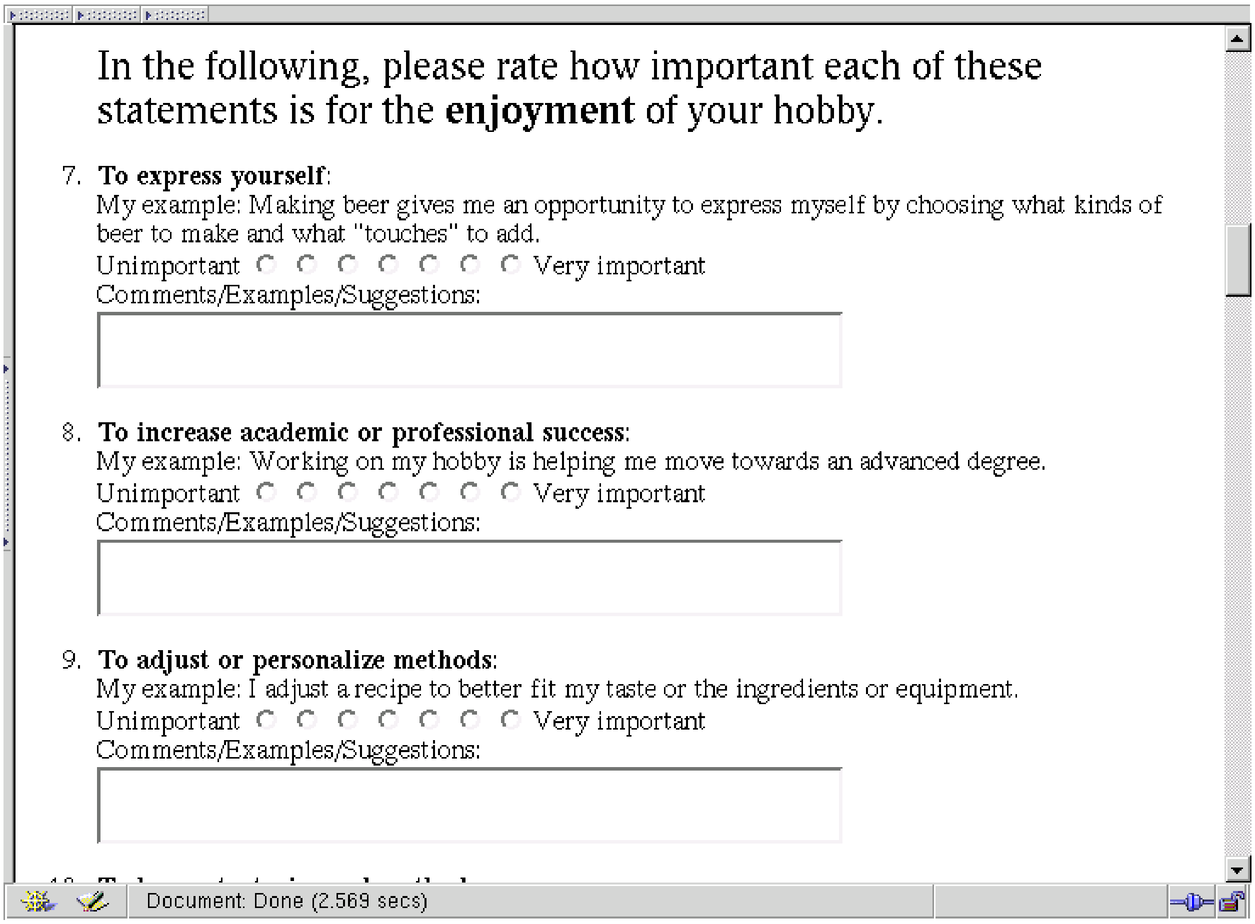
After composing the list of possible satisfactions, I tried a preliminary study with a small sample. A pilot study used a set of twenty-five cards, each containing one potential source of satisfaction and an exemplar. Participants arranged the cards in order of most to least important. From this sample ($n = 12$) it was apparent that people understood the different types of satisfaction well enough, but the rank-ordered data did not effectively capture the results. Also, when ordering the cards, people tended to start by sorting them into two or three distinct piles and ordered the items within each pile almost at random. Having only the rank order made it impossible to evaluate these distinctions. The relevant data were not the rank of the satisfactions but the degree to which **each** was important, so the next study used a Likert scale rather than a rank order.

3.0.7 Study 1—Adult Hobbyists

The next version of the survey was administered over the Web. I and colleagues sent a request for participation to several email-based mailing lists of hobbyists. A total of 328 participants filled out the entire survey.

Delivering the survey over the Web provided several benefits. Most obvious, the data were automatically entered into a database that could be queried by statistical analysis software even as it was being collected. It was also possible to randomly order the sources of satisfaction for each participant, reducing the likelihood of order effects of the items. It was also possible to insure that participants had completed each of the twenty five items.

In addition to twenty five different satisfactions, the survey asked for basic information including their hobby, how long they had been involved in the hobby, how rewarding it was, their gender, and how much time and money they spent on their hobby. Figure 1 shows a screen shot of part of the survey. The entire text of the survey is available in Appendix 1.1 on page 91.


In the following, please rate how important each of these statements is for the **enjoyment** of your hobby.

7. **To express yourself**:
My example: Making beer gives me an opportunity to express myself by choosing what kinds of beer to make and what "touches" to add.
Unimportant ○ ○ ○ ○ ○ ○ ○ Very important
Comments/Examples/Suggestions:

8. **To increase academic or professional success**:
My example: Working on my hobby is helping me move towards an advanced degree.
Unimportant ○ ○ ○ ○ ○ ○ ○ Very important
Comments/Examples/Suggestions:

9. **To adjust or personalize methods**:
My example: I adjust a recipe to better fit my taste or the ingredients or equipment.
Unimportant ○ ○ ○ ○ ○ ○ ○ Very important
Comments/Examples/Suggestions:

Document: Done (2.569 secs)

Figure 1: Online Hobby Survey

Study 1 Results

Table 1 shows results from adult hobbyists. The twenty-five satisfactions are sorted in order from the most to the least important as determined by the average of the ratings for all of the results. At the top of the list are (a) fruits of labor, (b) learn about methods, (c) overcome challenges, (d) an end in itself, (e) share, (f) personalize, (g) opportunities to read and (h) express myself.

Table 1: Adult Hobby Survey Results

	All	Misc	Brewers	Racers	Flyers	Rockets	Musicians
fruits (create)	5.9	5.5	6.1	5.8	6.1	6.3	5.5
methods (learning)	5.9	5.6	5.8	6.6	6.0	5.9	6.3
challenges (intrinsic)	5.8	5.8	5.6	6.5	6.1	6.3	5.5
end (intrinsic)	5.7	5.7	5.9	5.5	5.7	5.5	5.9
share (social)	5.6	5.2	6.1	5.3	5.4	5.9	5.8
personalize (create)	5.5	5.0	5.9	5.2	5.5	5.4	6.3
read (learning)	5.5	4.8	6.0	5.5	5.5	5.4	5.8
express (create)	5.3	5.3	5.4	4.8	5.0	5.5	5.8
help Others (social)	5.2	4.9	5.4	5.2	5.0	5.6	5.5
goals (intrinsic)	5.2	4.7	5.5	6.0	5.1	4.2	5.6
tools (learning)	5.2	4.6	5.3	5.9	5.5	4.5	5.9
nurture (create)	4.9	4.8	5.2	5.1	4.6	4.6	5.1
create (create)	4.9	4.7	5.3	3.8	4.6	5.7	4.8
control (intrinsic)	4.9	4.7	4.9	5.6	5.4	4.3	5.3
unusual (extrinsic)	4.6	4.0	4.6	5.7	4.5	4.2	5.5
facts (learning)	4.5	4.2	4.8	4.4	4.0	4.5	4.9
group (social)	4.4	4.2	4.3	5.0	4.7	4.9	5.0
conversation (social)	4.4	3.9	4.9	4.1	3.8	3.7	4.5
learn (learning)	4.1	3.8	4.5	4.0	2.9	3.5	5.8
better (extrinsic)	4.0	3.8	4.0	5.1	3.5	3.5	4.9
time (intrinsic)	3.6	3.5	3.7	3.6	3.9	3.0	4.7
competitions (extrinsic)	3.3	2.4	3.4	5.7	3.8	2.6	2.2
liked (social)	3.3	3.0	3.4	3.3	3.3	3.1	5.1
stature (extrinsic)	2.8	2.6	2.7	3.4	2.3	2.7	4.7
success (extrinsic)	2.7	2.8	2.6	2.9	2.4	2.3	3.2
Respondents	328	85	136	40	22	31	12

None of the five categories of motivation stands out as the clear winner. Many extrinsic motivators, however, are clumped at the bottom of the list.

The first column (All) shows the average ratings for each of the satisfactions. The Likert ratings for each satisfaction are averaged across all respondents. Subsequent columns provide those same averages for individual hobbies.

Reading across each of the rows shows that there is variability across the different hobbies, but for the most part, satisfactions receive similar ratings across all hobbies. An exception is that motorcycle racers rate the importance of competition high, though it is low for everyone else. Since competition is central to the hobby of motorcycle racing this is not especially surprising, but even for this group, the eight motivators receive high scores.

From this initial survey a few highly-ranked items look as if they might be useful in planning classroom instruction: (a) seeing the fruits labor, (b) having the opportunity to share and (c) having an opportunity to personalize. Similarly, the importance of providing appropriate challenges is already well-recognized. A question is whether these same elements can satisfy in secondary schools.

3.0.8 Study 2—High School Seniors

The results from the adult hobbyists suggested that there were some patterns that might be useful in classrooms, but I suspected that adults might have different types of satisfactions than do high school students. The school culture could also affect the kinds of satisfactions that students take from their work and play. Another concern with the first survey was the possibility that something in the wording of the examples skewed the results. To eliminate these concerns a revised survey for high school students used examples drawn from hobbyists' comments on the previous survey. The extrinsic motivator "be better than others" included this example: "Off road motorcycle riding: I hate to admit it, but yes I do really like that I am good at riding, better than most others. It does add to my enjoyment." The full text of the non-academic activity survey is in Appendix 1.2 on page 97.

If high school students find the same satisfactions in their hobby-like activities as do adults, then these findings could have some bearing on classroom instruction. Even so, another question remains. The factors that provide satisfaction outside of the classroom may be different from those that provide satisfaction in the classroom. For this third version of the survey I included the same 25 satisfactions and generated examples referring to different classes. The extrinsic motivator "be better than others" included this example: "Physics: Since most people find physics difficult, I enjoy it because I can easily outperform my classmates on difficult tests." The full text of the favorite class survey is in Appendix 1.3 on page 103.

The students who participated in this study were seniors enrolled in one of four sections of an Advanced Placement Calculus class at a public school in an affluent district in the San Francisco Bay area. These students had taken their advanced placement test, but had over a month of school remaining. Our group spent nearly three weeks with these students, conducting over half a dozen studies. Students took the two surveys one after the other in a computer lab; which survey they took first was randomly assigned. As in the first study, the order of the items on the test was random. In addition to the personal data, these surveys included student names so that differences could be checked for individuals and those who had not granted permission could be removed from the data.

Study 2 Results

Analogous to Table 1, Table 2 shows the ranking of the satisfactions as determined by the average of all of the high school non-academic surveys. Most of the non-academic activities can be classified as either Sports (e.g. football or basketball) or Arts (e.g. theater, or art). Averages from each of these categories are also shown in the table. The activities that do not fit into the sports or arts categories are included in the hobby column, but are not reported individually, so the number of respondents in the sports and arts columns do not sum to the number of respondents in the hobby column.

The rank ordering of the satisfactions for this high school sample was also similar to the adult hobbyists. At the top of the list are (a) fruits of labor, (b) overcome challenges, (c) an end in itself, (d) learn about methods, (e) express myself, (f) personalize, (g) clear goals and feedback and (h) share.

Ignoring the order, this list is identical to the top eight satisfactions in the adult hobby survey with one exception; "reading" has been replaced with "clear goals." For this high school sample, students were not interested in doing any more reading in their non-academic

Table 2: Student Hobby Survey Results

	Hobby	Sports	Arts
fruits (create)	6.0	6.1	5.9
challenges (intrinsic)	5.8	5.7	5.6
end (intrinsic)	5.6	5.4	6.0
methods (learning)	5.6	5.9	5.2
express (create)	5.3	4.5	6.2
personalize (create)	5.2	4.9	4.7
goals (intrinsic)	5.1	5.7	4.5
nurture (create)	5.0	4.6	5.0
share (social)	5.0	4.3	5.6
control (intrinsic)	5.0	5.3	4.5
unusual (extrinsic)	4.9	5.0	4.7
group (social)	4.9	5.4	4.1
better (extrinsic)	4.9	5.4	4.2
help Others (social)	4.8	4.7	4.7
create (create)	4.4	3.6	4.8
time (intrinsic)	4.3	4.3	4.3
conversation (social)	4.2	4.3	4.2
liked (social)	4.0	4.5	3.5
facts (learning)	3.9	3.9	4.0
tools (learning)	3.8	3.2	4.1
read (learning)	3.8	3.6	4.2
competitions (extrinsic)	3.7	4.1	3.6
success (extrinsic)	3.7	3.7	3.9
stature (extrinsic)	3.6	3.6	3.2
learn (learning)	3.0	3.0	3.1
Number of respondents	67	31	29

Table 3: Favorite Class Survey Results

	Class	Math/Sci	Lang/Hist
methods (learning)	5.2	5.6	4.5
challenges (intrinsic)	5.1	5.7	4.8
fruits (create)	5.1	4.9	5.2
success (extrinsic)	5.0	5.5	5.0
goals (intrinsic)	4.8	5.1	4.6
express (create)	4.7	4.0	5.6
create (create)	4.7	4.9	4.6
end (intrinsic)	4.7	4.4	4.9
read (learning)	4.7	4.1	5.3
facts (learning)	4.6	4.8	4.7
help Others (social)	4.5	4.5	4.9
unusual (extrinsic)	4.5	4.7	4.4
conversation (social)	4.4	3.7	5.6
share (social)	4.3	3.9	4.6
personalize (create)	4.3	4.4	4.5
nurture (create)	4.1	4.1	4.4
control (intrinsic)	4.1	4.4	3.6
time (intrinsic)	4.1	3.8	4.8
tools (learning)	4.0	4.4	3.4
learn (learning)	3.9	3.1	4.5
better (extrinsic)	3.8	4.1	3.3
group (social)	3.7	3.6	3.8
competitions (extrinsic)	3.3	3.1	3.1
liked (social)	3.1	3.2	2.8
stature (extrinsic)	3.0	3.3	2.2
Number of respondents	81	33	18

pursuits; reading is near the bottom of the list. It is not surprising that college-bound students do enough reading for school that they are not looking for more reasons to read. Another explanation is that in the kinds of hobbies that high school students are most likely to have—sports and performing arts—are less directly improved by reading.

For their favorite class, these satisfactions had the highest rank: (a) learn methods, (b) overcome challenges, (c) see fruits of labor, (d) increase academic success,(e) clear goals and feedback, (f) create something new,(g) express yourself and (h) read. Here again the list is quite similar to both the results from the adult hobbyists and the high school non-academic survey. One significant change is that "increase academic or professional success" is now rated highly. In the previous two surveys it was almost at the bottom. The reason that "increased success" is rated so highly for favorite classes but not for non-academic activities is likely similar to the reason that "competition" was important to the motorcycle racers. Just as competition is central to motorcycle racing, increasing your academic success is central to performing well in one's favorite class.

When ranking satisfactions associated with their favorite class high school students include reading as a highly rated satisfaction. This supports the above hypothesis that when reading helps one to do well in one's pursuit, it provides considerable satisfaction.

One concern with using data from the hobby survey to inform instruction in the classroom is the possibility that the two environments are so different that the factors that make hobbies engaging may not exist in classrooms, and if they do those same factors may have different effects in the classroom. However, the strong similarities between student's academic and non-academic satisfactions indicated in these surveys suggest that the potential satisfactions provided by each situations are very similar. The similarity of the results across all three of these surveys suggests that these satisfactions may be useful in classroom instruction.

The adult and student hobbyist surveys suggest three satisfactions that might be useful in designing instruction: (a) seeing the fruits of labor, (b) having the opportunity to share and (c) having an opportunity to personalize. Moreover, **learning methods** was highly rated, suggesting that when these three motivators are in place, students will want to learn the methods necessary to create an artifact they can personalize and share. However, the favorite class survey suggests that two of these items, (a) having the opportunity to share and

(b) an opportunity to personalize, are not important in providing satisfaction to students' favorite classes. There are two possible explanations for these satisfactions missing from the highest-ranked. There might be few opportunities to share or personalize work in school. It is also possible that students have these opportunities, but that in the academic setting they do not provide much satisfaction. I propose that whether these satisfactions can help make classroom instruction more engaging is worthy of further research.

3.0.9 Hypotheses of Engagement for Learning

The findings from these survey studies have limited application due to the sample selection methods. Worse, it is not clear whether the categories and the names used for them are robust. There is a possibility that the respondents were reacting to some peculiarity of the wording of the surveys. To validate these findings other surveys would need to be designed and tested with larger samples. The larger problem, however, is that surveys alone cannot prove whether the findings can be used to design more engaging instruction. So rather than attempt to resolve the problems with the design of the survey, I instead designed a study to test its apparent classroom implications.

The basic implication of these surveys is that producing something according to one's own design is engaging, especially when there is an opportunity to share it. For the classroom there are two versions of this hypothesis, a weak version, that tries to explain when students will be engaged, and strong version that claims that theses facts lead not only to increased engagement in general, but also that this increased engagement will lead to learners working in ways that will increase their knowledge.

These hypotheses are testable. To test the weak version one need only design different types of instruction that vary the opportunities for creation, personalization and sharing and measure student engagement. To test the strong version one needs additionally to measure different types of student behaviors to see if this increased engagement also leads to behaviors that are related to learning.

CHAPTER IV

THE INTERVENTION STUDY DESIGN

4.1 Goals

This study has three goals. First it tests a hypothesis about how to design instruction that is more engaging and motivates learning with understanding. Second, it tests a set of measures designed to monitor engagement in learning activities. Finally, it describes a computational infrastructure with components useful for (a) having students save and share NetLogo programs, (b) integrating research on engagement in classrooms with other interventions, and (c) supporting research of technology in classrooms.

The weak hypothesis tested is that giving students more opportunities to participate in production of artifacts that they can customize and share will result in more engaging instruction. To test this hypothesis I designed three instructional activities using NetLogo (Wilensky, 2002) based on a lesson on the included Wolf-Sheep predation model (Wilensky, 1998). In the activity hypothesized to be least engaging, students run and observe pre-set simulations and record the results on worksheets. A second, presumably more engaging activity, had students manipulate variables with sliders to solve problems with the simulations. In this activity students not only recorded the results of their work on paper, but also saved their programs on a file server (the only changes students could make, however, were the initial numbers of sheep and wolves). In the third, and hypothetically most engaging activity, students could change the programs by adding new features, changing colors, or manipulating variables not accessible without changing the program. Again students saved their work on a file server.

The primary measure of student engagement developed for this study is based on "Experiences that Energize" piloted by J. D. Bransford and D. L. Schwartz (personal communication, September 2002). In pilot studies Bransford and Schwartz had students rate how energized they were at several points in a class by recording their answer on paper. I created a computer-based version of this measure that periodically polled students as they worked on a lesson. This measure is similar to experience sampling (Csikszentmihalyi & LeFevre, 1989). A key difference, however, is that experience sampling polled people about seven times per day and my engagement samples were collected every 4–7 minutes in an attempt to capture moment-to-moment changes in student engagement over the course of an instructional period.

A stronger version of this hypothesis posits that these factors lead not only to increased engagement in general, but also that this increased engagement results in students' increased likelihood to do things that can help them to learn. A secondary measure, designed to test this stronger version of the hypothesis, is a record of resources that students access while working on an assignment. The number of resources that students access is used to measure the degree to which students are trying to learn. Additional secondary measures of learning behavior and outcomes are described in the Methods section.

To collect the data for these measures I developed a set of web-based tools, one for periodic or targeted surveying, one for tracking student access to web-based resources, and one for allowing students to use a web browser to find, run, and view NetLogo programs that have been saved on a file server. Each of these tools is useful not only for studies of engagement, but also for other studies or instructional activities that can benefit from periodic querying, tracking resource use, or viewing NetLogo programs. Others involved in classroom technology research may benefit from the description of how these tools were implemented and used.

4.2 Methods

4.2.1 Participants

I conducted this study in Alegría Spanish Immersion Magnet School.[1] English and Spanish speaking students are mixed together all day. In 1st grade instruction is primarily (about 90%) in Spanish; each year, increasing amounts are taught in English. For example, in 5th grade half of the instruction is in English and half in Spanish. Seventh grade students

[1]The name of the school, teachers, and students have all been replaced with pseudonyms.

participated in this study during their science class, usually taught in Spanish.

Alegría is a year-round school. This school year was August 4 to June 23. I ran the study for the month of May during and after the time that students took their end-of-year standardized test. This time of the year included many special activities like field trips. For the first two weeks of the study, students were involved in standardized testing.

The original plan for this study was to have each of two science classes of about 25 students each for a 100 minute period twice a week. Two weeks before the study was to begin, I learned from the lab manager, Marcos, that the computer lab was available for only 50 minutes a day. Several days before the study was to begin I learned from José, the teacher, that schedule changes resulting from standardized testing in the mornings meant that I would be able to see each class only once a week for the first two weeks. A week into the study, I learned that two days a week students were to be re-grouped, so I would be able to see each class only once a week for the final two weeks of the study. One result of these changes was that I was able to use data from only one class. The effects of this on the design of the study are explained below.

Students usually came to the computer lab during their science class, but several days students instead were pulled out of their electives (including music, dance, voice, and gym). This made it difficult to see that all of the students came to the computer room and also affected how happy students were to come to the computer lab. Those missing French were typically happier in the computer room than those missing PE, for example.

4.2.2 Design

I hypothesized that increased opportunities to create, customize and share would lead to increased engagement and an increase in behaviors associated with learning, like accessing resources. To test this hypothesis, I developed three kinds of instruction using NetLogo (Wilensky, 2002) that varied the opportunities to create, customize and share. These conditions are labeled "Observation," "Simulation" and "Programming."

In the Observation condition, students run a simulation with pre-set parameters and record the results. Students click a button that says "setup" to set up the simulation and another labeled "go" to run it. This condition is similar to many science classroom experiments in which students have little chance to make decisions beyond those required to properly manipulate the apparatus used in the experiment. These materials are described more completely in the Materials section on page 36.

In the Simulation condition, students work with models in NetLogo and have additional control over some of the variables and are asked to manipulate them to make the simulation behave in different ways. After solving the problem students saved their solution on the file server so that they can work on it in later sessions or view it from home via the Netlogo Program Browser. In this condition the changes they make are limited to changing the initial values of the sliders.

The Programming condition asked students to design as many different balanced ecosystems as possible. For each different ecosystem they filled out a worksheet similar to those used in the other activities. Students received a set of resources with instructions for several different ways to change the model. Students were asked to save their programs to the file server and record the file name on the worksheet that described their changes and how the model worked.

The initial design of the study was 2 classes by 3 conditions with each class in each condition at different times as shown in Figure 4. In addition to the full 2×3 cross, the biology content of the conditions and the order of the conditions was varied across the two groups. This design provided some control of effects of content, group, and order of conditions.

Table 4: Initial Design

Content	Class A	Class B
Grass and Populations	Observation	Simulation
Balancing Ecosystems	Simulation (Omitted)	Programming
Reproduction Rates	Programming (Omitted)	Observation

Due to the schedule changes described above the design of the study was changed. Because the schedule changes precluded their participation, two of the class A cells of the model described in Table 4 were omitted from the study. It is difficult to interpret the data from a single cell of one class with the other three cells from the other class, so I report only the procedures, data and materials from the class that was available for all three activities.

The study included several sources of data. The following paragraphs overview these sources. Additional details are included in the Materials section.

Engagement Sampling

Students used the Engagement Sampling Tool to rate their engagement about four times per day. They were asked to click a 7-level Likert scale ranging from "I would rather be doing something else" to "I want to keep doing this." A text box allowing free form answers asked students to describe what they were doing. Additionally, during the intervention I suggested that students could say what they liked or didn't like about the activity.

There was considerable variability in the number of times students filled out the form each day due to several factors: (a) the frequency the form popped up changing as I tuned it to balance getting sufficient data with annoying students by continually asking them to fill out the form, (b) students ignoring the form asking for their feedback, (c) the page that calls the Engagement Sampling Form getting closed (also explains some missing data) (d) the time spent on the activities was different each day.

Worksheets

The students filled out worksheets (described on 34) and included in full in Appendix B) which included both numerical data about the performance of the simulations and questions about how and why populations varied.

Content Tests

Content tests were given before and after each activity. These are shown in Appendix 5.2.3 on page 65. Each activity had a separate test.

Resource Use

During each of the activities students had access to a set of resources via a web page. Each student's use of these resources was recorded with the time and date (see 42 for a full description of the resource tracking software).

Accessing NetLogo Programs from Home

Students had the opportunity to access their programs from home. In the first intervention students were given slips of paper (about 1×3 inches) with the URL for accessing the NetLogo programs that they were using, or had saved. Students who had saved their programs (with different slider values) were instructed to write their number down so that they could find their own programs. Experimenter error resulted in students not being reminded of how to access the resources and student programs in later interventions. Perhaps as a result of this error, only one student access the NetLogo programs from home. This data point is omitted from analysis, though a question from the Engagement Self-Report asks about why students did or did not access the programs from home and is discussed below.

Post-Test Engagement Survey

After students had completed all the activities, they took a post-test in their regular classroom that, in addition to post-test learning measures discussed on the page before, included questions comparing each of the interventions, solicited student input about how to make the instruction more engaging and effective as well as whether and why they had or had not accessed the NetLogo materials from home.

Student NetLogo Programs

For the Simulation and Programming activities, students saved NetLogo programs on a file server. For the Simulation condition the only changes are the initial values of the sliders. For the programming condition students could additionally change the NetLogo code, perhaps adding features like sliders and buttons, changing the colors and shapes of the wolves or sheep, or activating code which adds hunters to the simulation.

4.3 Materials

A major component of the study was the development of activities and assessments plus the accompanying computer infrastructure that can now be used for future research. This section begins with a description of the activities and then moves to the assessments and the accompanying computer innovations.

Each activity includes four types of curricular materials: (a) worksheets that included instructions and questions, (b) NetLogo programs (sometimes delivered via a web browser rather than the NetLogo application), (c) web-based resources to help students learn biology content and programming, and (d) content tests.

4.3.1 Activities

Each activity is centered around a worksheet that includes a description of what students were to do for the day and tables to fill in and questions to answer. The full text of the worksheets is in Appendix B. The worksheets ask questions about NetLogo programs that, depending on condition, students observe, manipulate, or program.

Activity One—Simulation: Grass and Populations

These activities students use sliders to control the initial populations of wolves and sheep. Unlike the Observation activity, (discussed below) which had students running the simulations as a Java applet in a web browser, in this activity students run the full NetLogo application, potentially giving them access to the program source code. In this activity students were not instructed to change the program, but the full NetLogo environment was necessary to allow students to save their programs.

Instead of just running the pre-set simulations, however, students are given "challenges" to make the simulation behave a certain way by changing the initial population of sheep and wolves. One challenge, for example, asked students to "create an ecosystem that does not allow the sheep population to increase" with the constraints that the initial number of sheep is 300 and the grass feature is turned off. In addition to finding the correct values, students were asked to fill in a table and answer questions. Students were asked to save their version of the program to a file server (though their changes were limited to the values of the sliders).

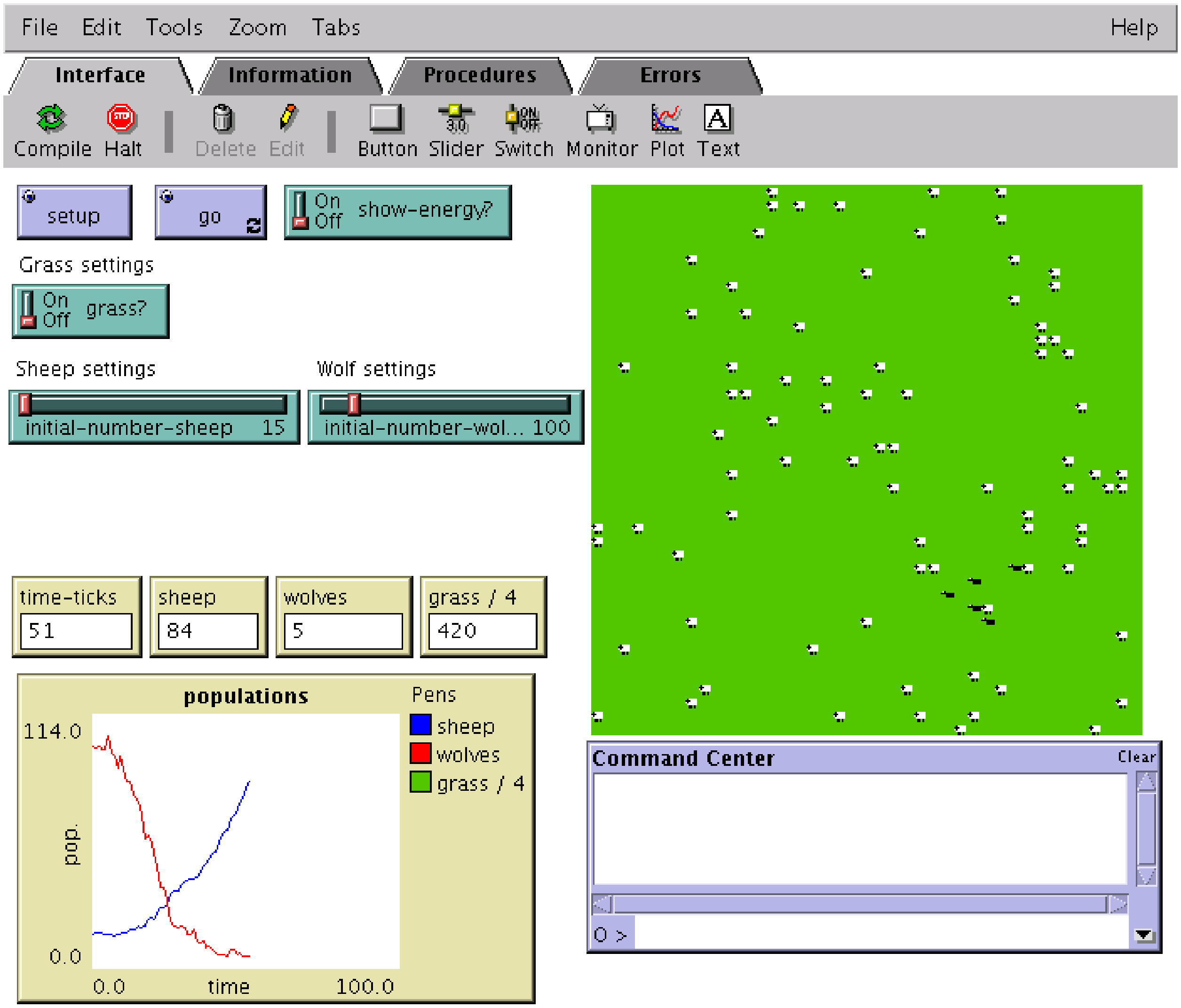


Figure 2: Simulation: Grass and Populations NetLogo Program

In addition to having the NetLogo application running in this activity, students also kept open a web browser that had links to resources that were designed to help students solve problems and answer questions. Having the web browser open provided students with an opportunity to access resources and served the technical purpose of popping up the engagement sampling windows.

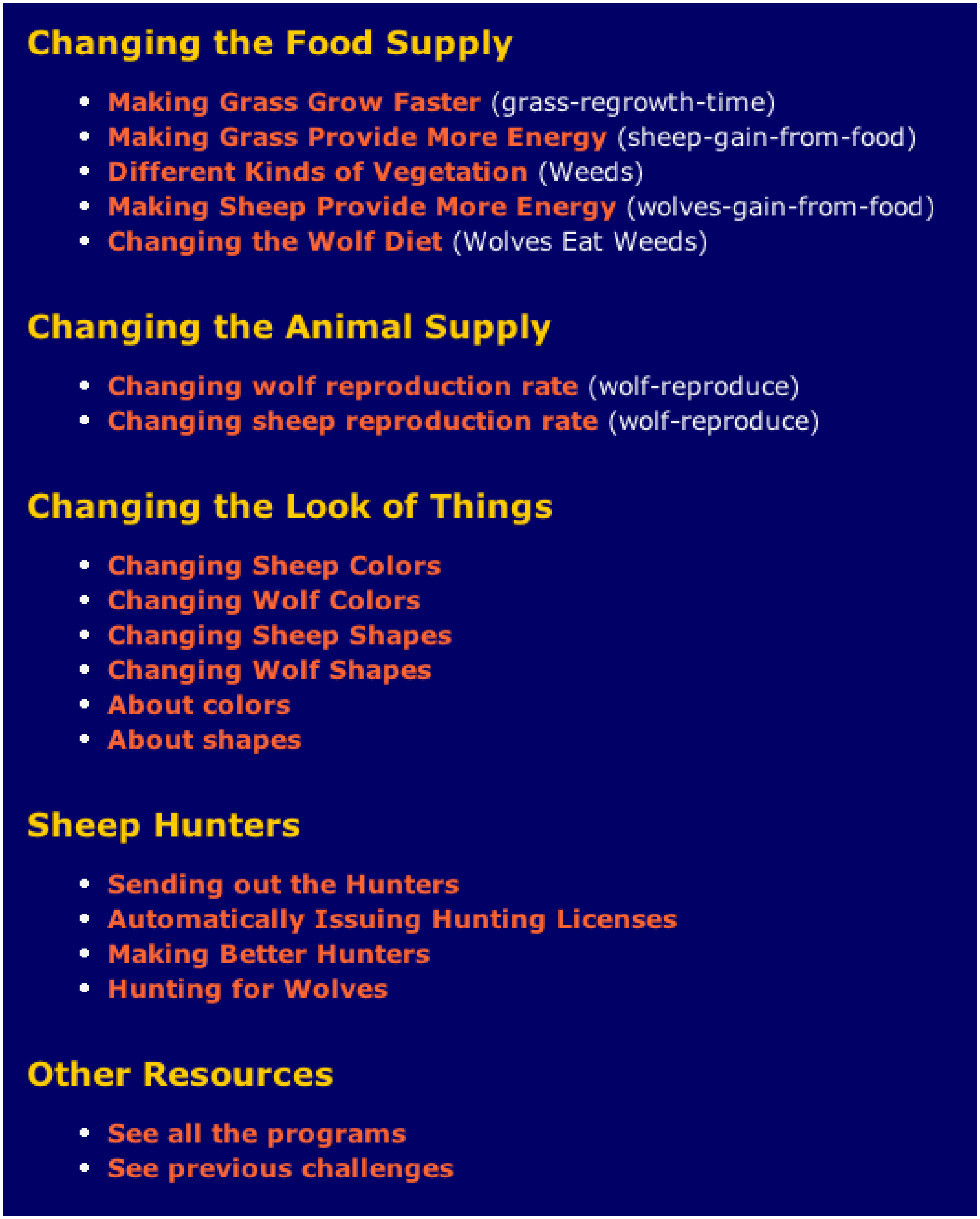
Activity Two—Programming: Balancing Ecosystems

This activity gave students one challenge, to make modifications to a NetLogo program to create as many different ways to balance an ecosystem as they could. Students were given a NetLogo program designed to make it easy to change different features and a web page with links to suggested changes that they might make (see Figure 3). Screen shots of the suggested changes are in Appendix 5.3. The worksheet asks for the filename they used when saving their program to the file server. Students were given four worksheets; extras were available for prolific students, though no student asked for extra sheets. As in the previous activities, students enter values on a table and answer questions about the changes they made and how this ecosystem was good for sheep, wolves and hunters (one suggested modification was to add hunters as a means to control the sheep population).

Activity Three—Observation: Reproduction Rates

This activity was similar to the Simulation activity except that students ran NetLogo simulations in a web browser and the simulation had no values to change. In this activity students had no opportunities to make any changes; they simply clicked “setup” to set the initial values of the simulation and “go” to run it. As in the other activities they recorded their results and answered some questions on worksheets. They were given no opportunities to change or save anything. They filled out a table with values from the simulation and answered questions like “what happened to the wolves?” This activity is similar to a science experiment in which students simply follow the procedures of an already-designed experiment.

Each of the pages that included the simulations also included links to resources and the NetLogo program code. These were available as resources to help students answer the questions. Use of these resources was tracked with the resource tracking tool.



Changing the Food Supply

- **Making Grass Grow Faster** (grass-regrowth-time)
- **Making Grass Provide More Energy** (sheep-gain-from-food)
- **Different Kinds of Vegetation** (Weeds)
- **Making Sheep Provide More Energy** (wolves-gain-from-food)
- **Changing the Wolf Diet** (Wolves Eat Weeds)

Changing the Animal Supply

- **Changing wolf reproduction rate** (wolf-reproduce)
- **Changing sheep reproduction rate** (wolf-reproduce)

Changing the Look of Things

- **Changing Sheep Colors**
- **Changing Wolf Colors**
- **Changing Sheep Shapes**
- **Changing Wolf Shapes**
- **About colors**
- **About shapes**

Sheep Hunters

- **Sending out the Hunters**
- **Automatically Issuing Hunting Licenses**
- **Making Better Hunters**
- **Hunting for Wolves**

Other Resources

- **See all the programs**
- **See previous challenges**

Figure 3: Web Page Offering a Menu of Suggested Changes

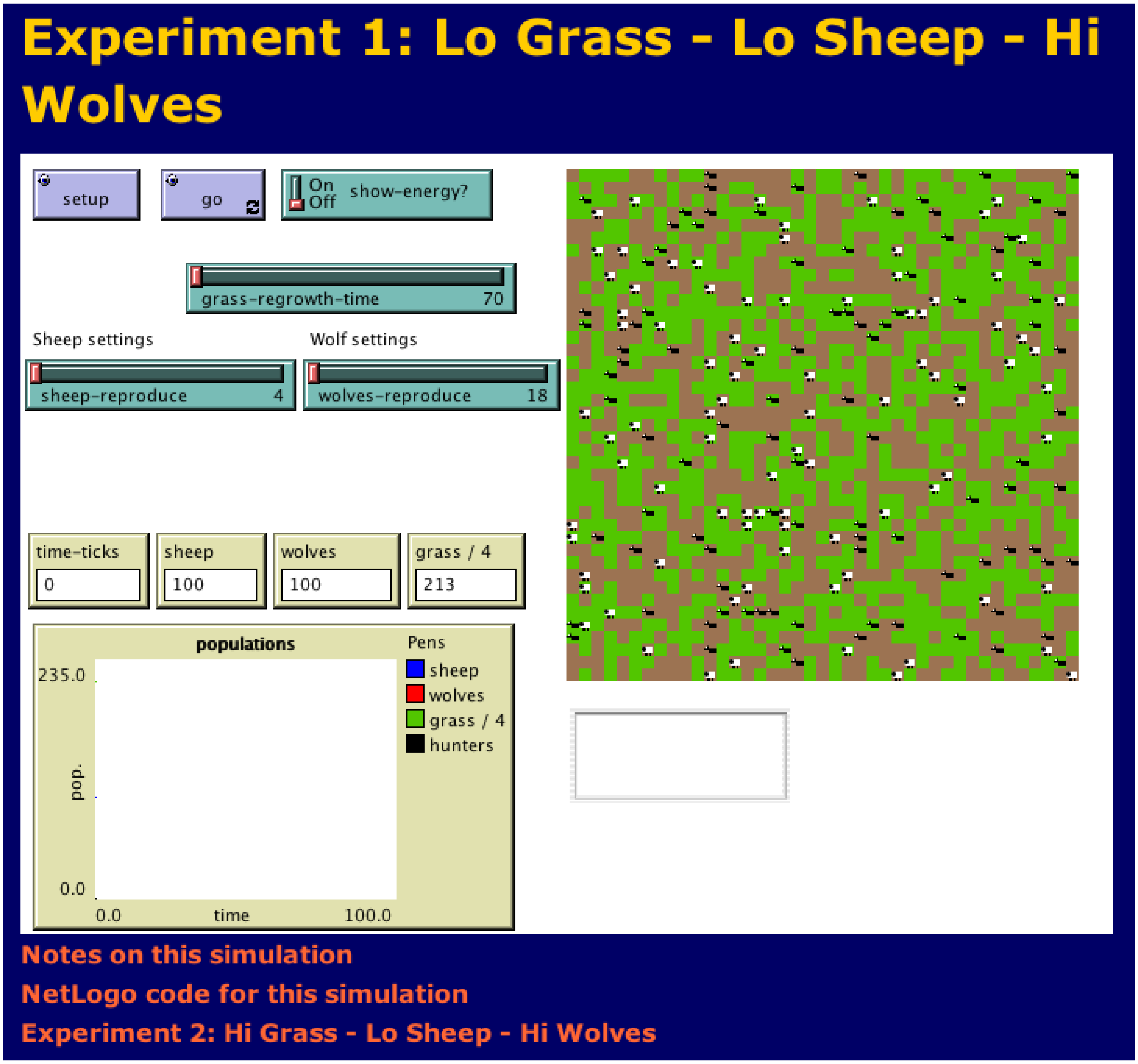


Figure 4: Observation: Reproduction Rates

4.3.2 Measures

Content Tests

At the beginning of the intervention students took a pre-test that included biology content questions and questions about demographics and classroom engagement (discussed below). The first test included items assessing students' understanding of the connections between populations of predators and their prey:

1. Lions do not eat plants. List 3 reasons that plants are important to lions.
2. List 3 reasons that the government sometimes allows hunting .
3. How can too many deer hurt the wolf population?
4. List 3 ways to control the population of deer.

This test was given again as a post-test after students had participated in Activity One to assess their learning during the intervention. The students took the test in the computer lab before starting Activity Two. This and all the tests discussed in this section are in Appendix C on page 124.

Included with the post-test just mentioned was a new pretest for the next activity (on page 126) that included questions about how the simulation is affected by turning on the grass feature and how changing the supply of food would affect the simulation.

After the second activity post-test, students took a pre-test that covered issues related to reproduction rates, the topic of the next activity. It included questions like "Which part of the food chain needs to reproduce the fastest? Explain why." This test was given again after the final, "Observation: Reproduction Rates" intervention.

Information about Student Background

A pretest asked students about their home Internet connectivity and some questions about their engagement during various activities like doing poorly on a test, sharing a good idea with a friend, and making something new and different. This introduced students to the use of the Likert scale engagement questions. This test was administered to all students in the computer lab before they started the first activity and was on the same page with the initial content pre-test.

Post-Study Motivation Survey

As part of the final post-test about reproduction rates, students also answered questions comparing each of the activities to each of the others. For each pair of activities, students were asked what was good about the one they preferred, what was bad about the one they disfavored, and how to improve the activities. To insure that students would understand the comparisons, before the test began, I reminded them that the study was about how to make school more fun and that there were three different activities that they had participated in and the names used to describe them on the assessment. A final page of the assessment included questions about what students' most and least favorite parts of the activities were and how the activities might be changed to make them more fun or increase learning.

4.3.3 Computer Infrastructure

In addition to the curricular activities a computational infrastructure was developed to deliver instruction and collect data. These tools included (a) a tool for periodic surveying student engagement (easily adapted to other questions); (b) a tool for tracking student use of web-based resources, (c) a web interface for browsing NetLogo programs, running them in a web browser, and viewing their source code; and (d) a file server on a laptop for saving student programs. This section will describe the four activities and the computational infrastructure supporting the study.

Engagement Sampling Tool

One of the sources of data for this study is periodic student self-report of their engagement throughout each of the activities. To collect these data I designed and created a web-based tool. It works in two different modes. The time-sample mode opens a new window every x seconds (this study collected data every 4 to 7 minutes). A prompt is presented with a 7-point Likert-scale (an answer is required) and an HTML text area. For this study, the scale was anchored with the statement "I want to do something different" at one end and "I want to keep doing this" on the other. The text box prompt was "Please briefly describe what you are doing now." When the "Submit" button is clicked the student ID, Likert rating, and their description of what they were doing are recorded in a database along with the date and time, time elapsed since the form popped up, and what web browser they were using (sometimes useful in debugging).

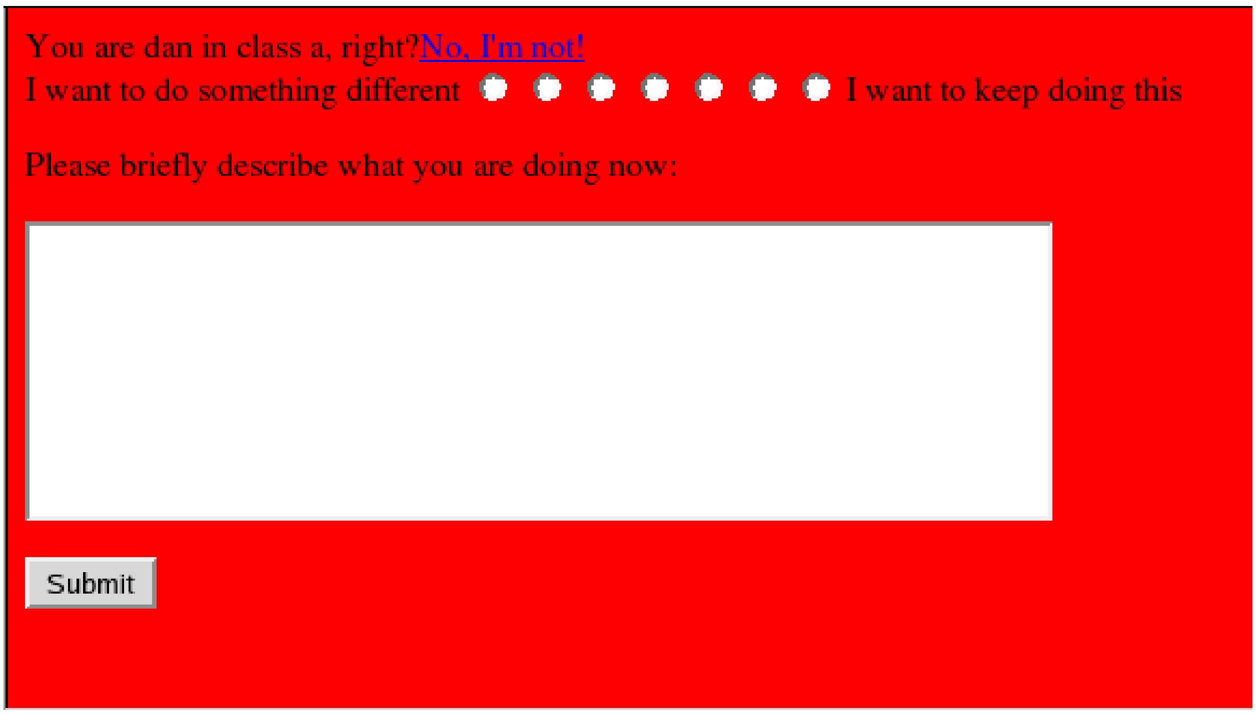


Figure 5: Student Engagement Survey Tool

The engagement sampling software can also be used in a context-sensitive mode. In this mode, a web page designer includes a call to a `eteonce()` function that includes the form on the current page without including the rest of the information from the page. After the student fills out the form the entire page is presented. In addition to the information saved in the other mode, a "context," set by the designer in the call to the `ete-once()` function, is recorded. The intent of this version of the tool is to record the user's engagement at a particular point in the activity. After testing this mode in initially, I decided that using the timed mode would be more effective since each day's activity was essentially the same. In a situation where students would be doing different types of activities during a single day, being able to tie a rating to a particular activity might be useful.

Resource Tracker

Another source of data in this study comes from a tool that tracks when students access resources. One way to do this would be to use web logs, but web logs are problematic for several reasons. First, web pages do not usually require a user to identify him or herself; this problem can be solved, though somewhat tediously, by configuring the web server to require users to log in before accessing pages. Second, web logs will generally contain logs for many pages that are not of interest to a particular project. Finally, one might want to use resources developed by a third party or keep one's own web pages on another server, so web logs would not be available. To solve these problems I developed a resource tracking system.

Since Webliographer already has almost all of the pieces necessary to provide this tracking feature (Pfaffman, 1997), I added a table for students and a modification of Webliographer's hit counting page. To track access to resources one adds the URL to the Webliographer database and then adds links to those resources with URLs like `http://servername/loglink.php?linkname` where `servername` is the name of the Webliographer server and `linkname` is the name used when adding the link to the database. When this link is followed, the server logs the date and time, the student ID, the URL and transparently redirects the user to the desired web page. The information is stored in a MySQL database.[2]

NetLogo Program Browser

One measure of student interest in the activities is whether students access their programs from home. I developed a system that lets students browse the NetLogo programs that have been saved on the file server. The first screen shows the names of all the directories (one per

[2]The Resource Tracker and all of the web-based tools used in this study were developed in PHP. The data saved in MySQL. Both of these tools are available for Windows, Mac OS X and Linux, and so should be easily used in a variety of environments.

student).[3] Clicking on a directory name opens a page that shows a list of the files in that directory. Similarly, clicking on a filename runs that NetLogo program in a browser window and provides links to the NetLogo source code and back to the list of files. See Figures 62–64 in the Appendix for screen shots of each of the pages described above.

A slightly different version of the NetLogo program browser was used to show NetLogo programs for Activities One and Three. This version can display the information portion of the NetLogo program as well as run the program as an applet and show the source code. Screen shots of this are in Appendix E.

File Server

One hypothesis of this study was that increased engagement is a result of being able to create artifacts. To test this, students were sometimes given the opportunity to save their NetLogo programs. Students at Alegría each have an account on an Appleshare file server, but the study required that I be able to have access to all of their programs and be able to put them on the Internet. Rather than work out a way to copy their work from the school's file server, I chose to instead use a laptop as a file server.[4] This provided easy access to the files that they saved and allowed me to copy them to the web server that hosted the NetLogo Program Browser. Since the laptop was not on the network when I was not at the school there was little chance that students would the files outside of the lab. Initially all students used a single username to access the files and each had his or her own directory for saving work. In initial work with the students, someone deleted or moved many of the students' directories (I do not know whether the deletion was intentional), so the additional complexity of individual user accounts and passwords was chosen to give student work better protection. Students logged in using their last name and first initial as both the username and password. This provided little security, but made it difficult for a student to corrupt the work of other students since they would need to log out as themselves and log in as someone

[3] To protect students' privacy, numbered directory names were used. Students were given a slip of paper with the URL of the browser and told to write their number on it. The number showed up on their desktop and all students seemed to know what their number was.

[4] I used Netatalk running under Linux which has no limitations on the maximum number of simultaneous users.

else. At the end of each day a snapshot of all of the files was saved as a permanent record of the state of the files at the end of that day. These data were also copied to the NetLogo Program Browser which ran on my workstation at Stanford.

A valuable side-effect of copying these files to Stanford was that there was a backup of these data. These backups served not only to increase peace-of-mind during the study, but in fact proved useful when the hard drive of the laptop file server used in the study had to be replaced due to failure in the middle of the study.

4.3.4 Procedures and Actual Course of the Study

During the course of this study a number of things changed. This section describes not only the procedures as they were intended to be carried out, but also a description of the classroom environment and the schedule changes that necessitated modifying the procedures almost every day of the study.

About six weeks before the study began students came to the computer lab for two fifty-minute class periods each in March. During these class periods students became accustomed to the NetLogo environment by typing commands into the "Command Center" to create turtles and make them move. Students also used the Engagement Sampling Form both to give them a chance to use the form and to do some testing of the software.

The week before the first intervention, the class that was later removed from the study participated in some introductory activities. The original plan was for both classes to have a week of introductory activities, but another schedule change and miscommunication kept one class from participating in these activities. These two days of activities with the other class proved invaluable in giving the software another test-run. Several problems were discovered and resolved during this extra testing period.

This section describes the order of activities. As described in the Design section, there were three different activities, each taking two days of class time. Class periods were supposed to be fifty minutes, but were usually shorter due to students arriving late (students met in their classroom before walking over to the computer lab). The first day of each activity students took a test and received an introduction to the activity. The second day students continued the activity upon arriving in the computer lab.

Each day of the study I was accompanied by from one or two members of the AAAlab at Stanford University. The classroom teacher was usually not present during the lessons and provided no assistance in classroom management or helping answer student questions. Table 5 shows the calendar of events for the study. The rest of this section describes each day in more detail.

Table 5: Calendar of Events

Tuesday		Friday	
5/6		5/9	Set-up (5 min.) Grass and Populations Pre-Test and Demographic Questionnaire (15 min.) **Simulation:** Grass and Populations (25 min.)
5/13	**Simulation:** Grass and Populations (50 min.)	5/16	
5/20	Grass and Populations Post-Test and Balancing Ecosystem Pre-Test (10 min.) **Programming:** Balancing Ecosystems (44 min.)	5/23	Set-up (6 min.) **Programming:** Balancing Eco-systems (46 min.)
5/27	Reproduction Rates Pre-Test and Balancing Ecosystems Post-Test (16 min.) **Observation:** Reproduction Rates (20 min.)	5/30	**Observation:** Reproduction Rates (<30 min.—students arrived at different times.
6/3	Reproduction Rate Post-Test and Engagement Self-Report (30 min.)		

Activity One—Simulation

Students were pulled from their electives for this class. Students took the pre-test for twenty minutes. After the pre-test I spent 5 minutes showing students how to connect to the file server where they were to save their work with the file name given on the worksheet and how to fill out the forms and read values from the graphs. I did a demonstration in a web browser, which led to some confusion because students were to do **their** work in the NetLogo application and use the web-based materials only as a resources. Students had 25 minutes to work on the worksheets. While students worked we went around helping students understand the assignment by going over what it was that they were to do and showing the places on the worksheets that gave them instructions.

As students left the room they were given a small slip of paper that said "See your programs from home!" with the URL of the lesson. Students with web access at home could use the URL to run their own saved simulations at home.

The second day of this activity was three days later. I had expected the other class this day, but had brought this class's materials as well and was able to change the online materials remotely. One problem that arose because of this last-minute change was that the engagement sampling forms were not properly configured and as a result these data were not collected at the beginning of the period. After I corrected the problem, I set the delay period to 4 minutes to make up for the lost data; after a while I changed this delay back to 6 minutes.

The activity lasted 50 minutes. During this time students seemed quite engaged and two students continued working after they had been told to stop. Several students who had finished their work started typing NetLogo commands (that they had learned six weeks before) into the "command center" (the command center is not present in the web-based simulations used in the Observation activity). One student remembered a few commands (to create turtles and make them move forward, for example) and typed them in. Quickly other students noticed that his screen was different and asked him how to do it. Before long about 8 students were typing similar commands. These turtles that they created did not interact with those in the simulation, but co-existed and appeared in a variety of colors. These very visually-different changes were very engaging, but not related to the study of ecosystems.

<u>Activity 2B—Programming</u>

This class was on a Tuesday, one week after these students had done their second day of Activity 1B. Students came to the computer lab instead of their regular science class. Students spent the first 10 minutes of this class taking a two-page content test (Appendix 3.2). I demonstrated what happened in a system with only sheep with the grass function turned off—sheep do not require energy to live and without predators, grow exponentially. I then showed them the same starting conditions with the grass feature turned on—sheep must eat grass to live, so the sheep population and the amount of grass go up and down and stay in balance. (These situations are covered on the pre-test that they took immediately before this demonstration.) I explained to them that their task for this activity was to find as many different ways to create a balanced system as they could. Next I showed them how they could use the resources to learn how to change the reproduction rates. After my demonstration, we walked around the room making sure that students understood the assignment and helping them to follow the instructions to change their programs. Students had 44 minutes for the activity.

Due to experimenter error students were not given slips reminding them that they could see their programs over the web from home.

The second day of Activity 2B was on Friday, 3 days after they had done the first part of the lesson on Tuesday. I showed the programs from a couple of students to the whole class at the beginning of the period. The time available made it difficult to do significant sharing that I hypothesized would have an effect on engagement. Students had 44 minutes to work on their programs. As in the first day of this activity, we moved through the class to keep students on task and answer questions. In this class there seemed to be more examples of students getting together to see what others were doing.

Activity Three—Observation

This activity was 4 days after the previous activity had ended (Friday–Tuesday). Students first took the post- and pre-test for 16 minutes. It took about 5 minutes to explain the activity, hand out the worksheets and get students working. Because another class was coming in to use the lab for testing, students had only about 20 minutes to work on the activity. As in the other activities we went around the class trying to keep kids on task and see that they understood the assignment.

The second day of this activity was 3 days after the first part (Tuesday–Friday). Students had to be pulled out of their electives to attend the class. The classroom teacher was not at school this day, but had instructed the other teachers to release the students from their electives. Seven minutes into the alloted time only 3 students had arrived. I walked around the school looking in classrooms for students that I recognized and trying to entice or coerce the students to attend the final day of the intervention. It was apparent that few of the students were anxious to miss their electives (e.g. dance, music, or singing) to come to the computer lab. Seven students were missing from this final day. Though I have no clear evidence to back up this suspicion, I believe that if the students had been more interested in attending this last class more students would have been in the computer lab sooner. Students had 30 minutes to complete their worksheets.

Post-test

One week after the final activity in the computer lab. Group B took their final post-test and self-report of engagement (Appendix 3.4) in their regular science classroom. They were given as much 30 minutes to finish the test, though most students were finished in 20.

CHAPTER V

RESULTS

This section discusses the analysis of the data and reports the findings. First I report the measures of engagement: the post-test engagement survey and the Engagement Sampling data. These two data measures of engagement do not correlate as expected, but further analysis suggests an explanation. Next, the measures of learning engagement are reported: the worksheets, resource use logs, content tests and NetLogo programs. The presentation of the data are followed by correlational analysis.

5.1 Measures of Engagement

5.1.1 Post-Test Engagement Survey

The set of questions asking students which activities they preferred required no coding. Figure 6 shows that these three comparisons turned out as predicted (programming being most engaging, followed by simulation and finally observation). One concern was that in spite of going over the names I had given each activity before handing out the test, that the students still did not understand the questions. I looked at the students' comments to see whether they suggested that the questions were misunderstood. In his or her explanations for preferring simulation to programming one student explained that (s)he did not know what to do in the programming condition, a reasonable explanation that points to the difficulty of having students do programming with so little time. Two of the remaining three students who preferred simulation over programming claimed that they liked to be able to change things, which was true in both conditions, suggesting that they might have misunderstood the question or had equal affinity for each activity. In the choice between simulation vs. observation, students also gave reasons that were ambiguous or antithetical to their selection. "It was the same thing over and over," was an explanation for preferring Observation, though this explanation seems more with preferring the Simulation activity.

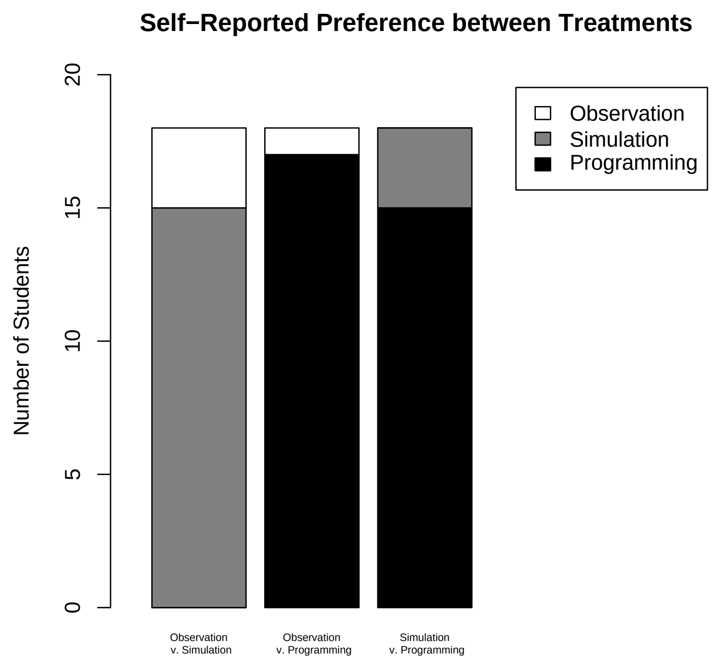


Figure 6: Forced Choice Between Favored Conditions

One student answered all three questions backward of what the hypothesis predicted. This student complained of programming that "some had to die," which was also true of all activities; he reported to prefer observation over programming because "some don't work." The programs all worked until until they had been modified by the students. This student was distracted in class perhaps because of limited English skills.

In addition to looking at the grouped responses to these questions, I also used within-subject analysis to see which students responses were consistent with the hypothesis and to see if any of their answers were consistent with themselves (though none did, a student might answer that $a > b, b > c$ and $c > a$, for example). Figure 7 shows the four different rankings indicated by the answers to the three choices described on the preceding page. 8 possible outcomes were possible from the 3 questions students answered; 2 of those are inconsistent with themselves. Removing the inconsistent possibilities leaves 6 rankings, 4 of which showed up in the data. The predicted order (Programming, Simulation, Observation) was chosen by 13 of the 18 respondents.

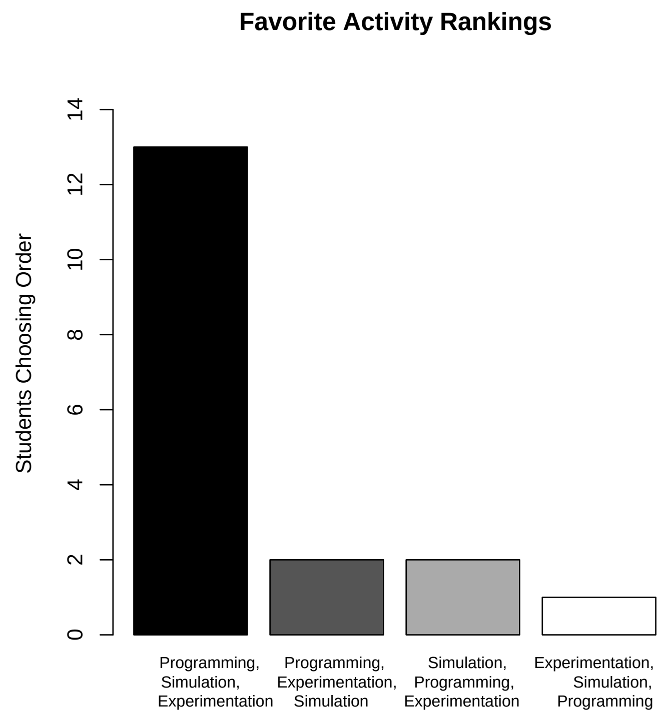


Figure 7: Ranking of Activity Engagement

For each comparison students also reported what they liked about the favored activity and what they did not like about the other. These open-ended responses were transcribed and categorized to create a coding scheme. The coding scheme was designed so that the same codes could apply to both the good things about the favored activity and the bad things about the disfavored activity. For example "you had more fun" for an explanation of what was good was coded the same as "it wasn't as fun" for what was bad about the other activity. As the hypothesis guiding this study predicted, many of the responses had to do with opportunities to change or create things. Half of the codes are for different kinds of change. Table 6 on the next page shows the code names and sample responses for each code. Responses that could fit into more than one category were coded in the more specific category. For example "I liked it because it was more fun than the other one and we did whatever we want" was coded as "Freedom/options" rather than "Fun." Fewer than 10 of the 109 responses could be multi-categorized.

Figure 8 on page 54 graphs comment types for each of the three activities. Each

Table 6: Coding scheme for activity comparison responses

Name	Example
fun/boring/waiting	**Good:** you had more fun **Bad:** it was boring
Clear goals/instructions	**Good:** there wasn't much to remember about it, yet it wasn't boring **Bad:** it was confusing at time, you didn't really know what to do
Filling tables/worksheets	**Good:** (No examples) **Bad:** record the results in the table
Freedom/options	**Good:** you can do whatever you want to make a balanced ecosystem **Bad:** you can't do anything except look and list the results
Change things	**Good:** I like this because you could change things **Bad:** you couldn't change anything
Change slider values	**Good:** the good thing that I liked is that you can change the number of wolves and sheep. **Bad:** you could not even change the sliders
Save changes	**Good:** nthe good thing that I liked is that you can change the number of wolves and sheep. **Bad:** That you can't save your work and the only thing that you do is run the program
Make additions	**Good:** change the program by changing colors, adding hunter, change, etc. . . **Bad:** it is still boring you still can't change the colors or anything except the numbers of animals

comment type has bars to the right and left of zero, indicating that a comment was used as a reason that one activity was preferred or as a reason that an activity was less favored. These graphs include data for all students, not only those who made the choice in accordance with the hypothesis (of Programming vs. Simulation, for example). For example, the left-of-zero "clear goals and instructions" in both of the graphs for Programming refer to reasons that programming was **not preferred,** indicating that Programming was missing this desired quality. Since few students violated the expected pattern (preferring Observation over Programming, for example) their data are included on the same graph.

From these graphs it is plain that reasons having to do with freedom and change (which I believe are closely related to customization) are important to making the activities engaging. The opportunity to make additions to the program is the most frequently mentioned reason for liking programming. This is not mentioned as a missing feature in the Simulation vs. Observation graph since neither activity offers this opportunity. Thus, making additions may have been the property of programming that differentiated it favorably from the other two, and the ability to make changes differentiated both Programming and Simulation from Observation.

5.1.2 Engagement Sampling

During each activity students were presented with a form every 4–7 minutes (depending on external factors as described in the Design section (p. 32). The expectation was that these engagement ratings would follow the pattern shown in the engagement survey data described in the previous section. In the following paragraphs I present the engagement sampling data increasingly differentiated.

At the coarsest level we can compare the mean ratings across condition. Because of the way that these data were collected (with a screen coming up after a period of minutes—sometime after that students noticed the screen and filled it out) there are different numbers of data points for each student for each day. Simply averaging all of the data points would give some students a larger impact on the mean than others. To give each student an equal affect on the mean I first computed the average of each student's engagement sampling ratings to get one mean per student for each of the six days of the study. These means were

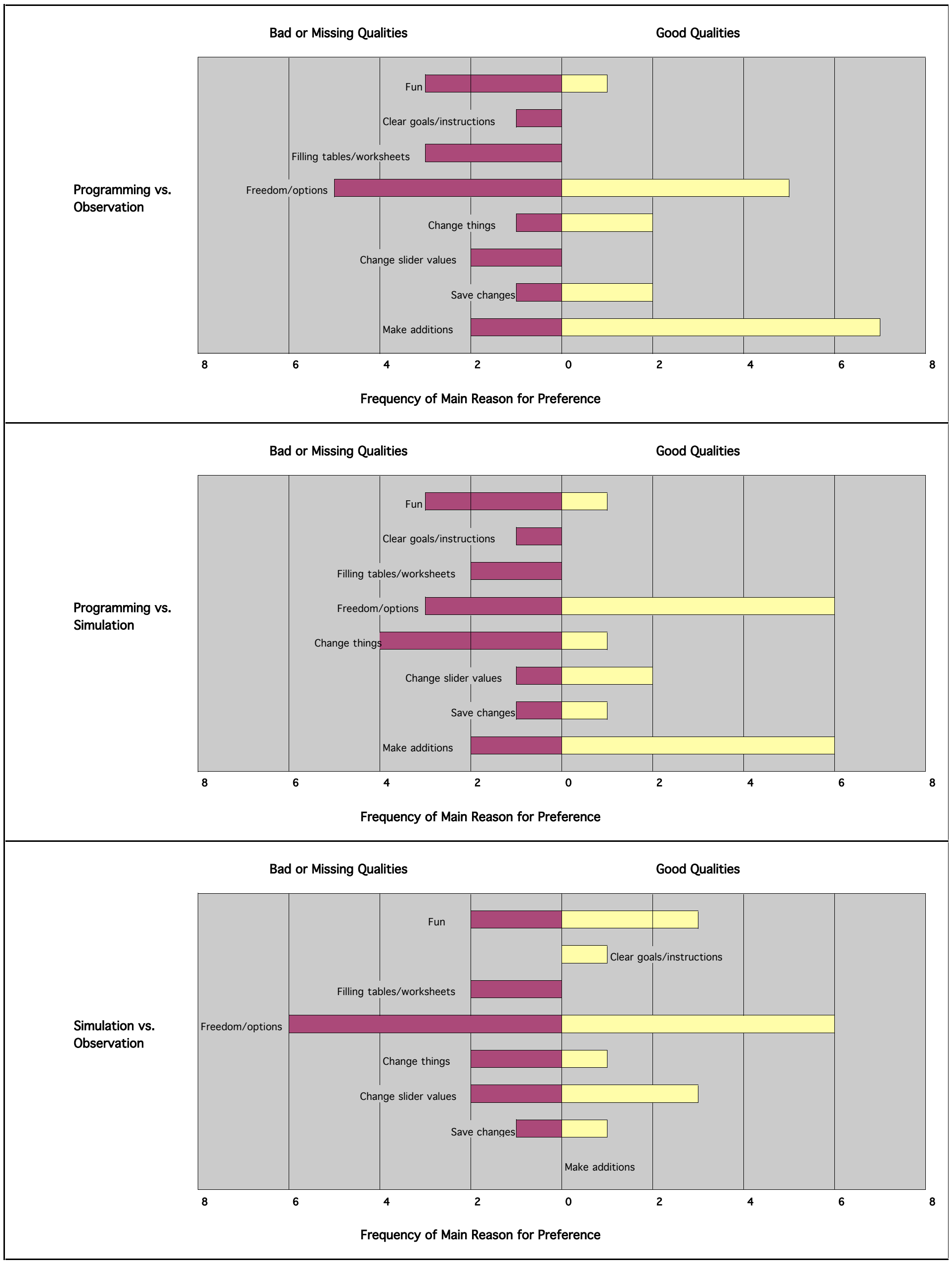


Figure 8: Factors contributing to choice between favored treatments

then averaged for the graph shown in Figure 9. The error bars in this and other graphs indicate the standard error. Consequently these error bars show only the deviation in the means of the student averages; the within-student deviation is not accounted for in this analysis.

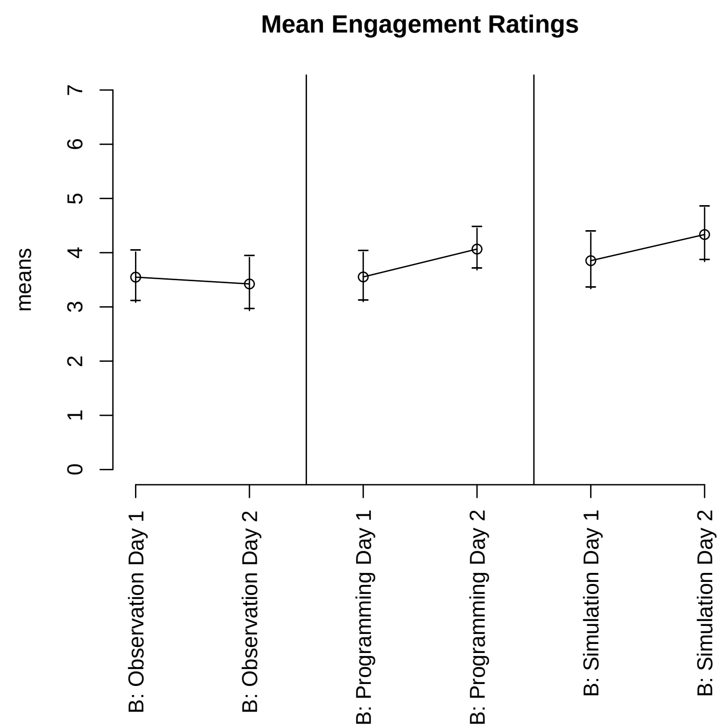


Figure 9: Student Engagement Sampling Means for All Students

The effect of treatment (e.g., programming versus simulation) on engagement is confounded by the fact that each treatment used a different biology content. However, the biology content was similar enough across treatments that I made statistical comparisons of the engagement ratings. In a repeated measures analysis, I compared average engagement ratings for each Day of each activity, yielding a 3×2 factorial. A major limitation of the analysis is that only six of the twenty students participated in all six cells of this statistical design. Consequently, the analysis is of very low power. There was a main effect of Treatment; $F(2,4) = 7.4, p < .05$, but no effect of Day; $F(1,5) = 0.5$ or Day by Treatment interaction; $F(2,4) = 1.8$. I had expected programming to be more engaging than simulation, which would in turn be more engaging than observation. **A priori** contrasts did not support this ranking of conditions; programming ($mean = 4.3, se = .96$) was not significantly different from simulation ($mean = 4.8, se = .81$); $F = 1.6$, but simulation engagement was significantly higher than observation ($mean = 3.9, se = 1.0$), $F = 11.9$.

To include more students in the analysis, I conducted a second analysis that used the average engagement rating for each treatment. This way, students who participated in a treatment for only one day could still be included in the analysis. This increased the sample size to 17 students. As before, there was a significant effect of condition; $F(1,16) = 5.4$, $p < .05, MSe = 1.0$. In the **a priori** contrasts, simulation engagement ($mean = 4.39$) was significantly higher than programming ($mean = 3.76$; $F(1,16) = 6.3, p < .05$). Simulation was also significantly higher than observation ($mean = 3.65$); $F(1,16) = 6.4, p < .05$. So, when using the larger sample, simulation was the most engaging overall, with programming and observation at roughly the same level. These results are distinctly different than the students evaluations of three conditions reported in the previous section. The Discussion section addresses explanations for the difference between "real time" engagement and students' retrospective accounts.

To illustrate how these engagement sampling data compare with the rankings students gave in the post survey, their total means for each activity were compared (the mean of all the engagement samples for both days of the activity, which potentially gives one day a greater influence on the mean than the other). For each of the three comparisons (e.g. Programming vs. Simulation) I counted the number of students whose means followed the predicted pattern (e.g. Programming engagement mean > Simulation engagement mean). For each of the three comparisons there were two ties; one was a student who always rated his engagement at the top of the scale. These data are shown in Figure 10 which does not as obviously follow the predicted pattern as does the post-test engagement survey (Figure 6 on page 50).

Especially striking is that the engagement samples for Programming are almost tied with Observation and lower than Simulation. To look for an explanation for this apparent anomaly I prepared histograms of the engagement sampling ratings for each day. The histograms plot

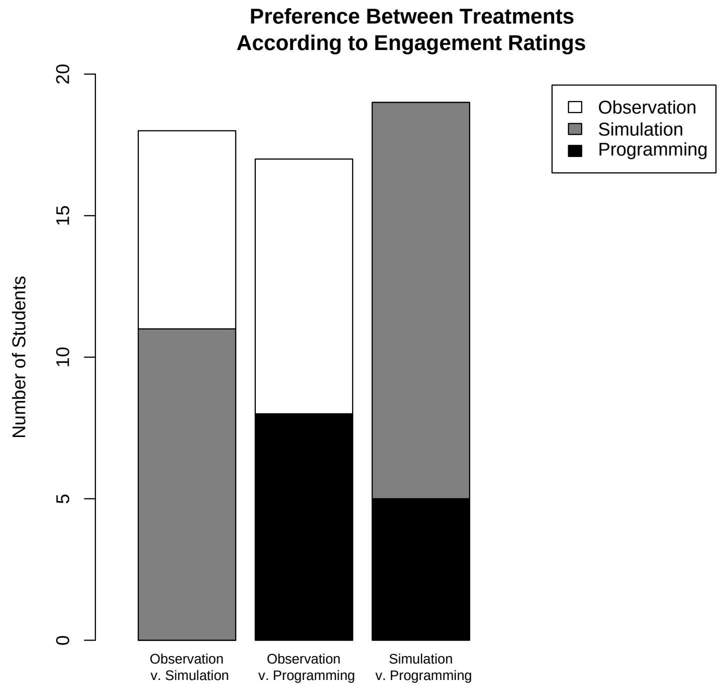


Figure 10: Comparitive Engagement Ratings by Activity

all of the engagement ratings without nesting by student. Figure 11 on the following page shows these six histograms. The distributions of the results are different for each day. For Simulation and Programming there are more results on the higher end on the second day; this suggests that students were more highly engaged when they knew what to do. Both days of the programming activity have more highs and more lows than the other activities, suggesting that in these students went between being frustrated because they were confused and highly engaged as their ability and challenge were in balance.

To look for other patterns in the engagement sampling data, I prepared a graph for each student. To facilitate interpretation of the graphs, I describe one student's in detail. Figure 12 shows the engagement sampling data for student 1. The graph is divided into three sections, one for each activity. The x axis lists the days of the study and each of the engagement sampling ratings is plotted. The ratings are "jittered" so that identical ratings are not invisibly stacked atop on another; the two circles near 5 on day 1 are really both 5s. Thin lines connect the means of the data for each day. In between the two days is the mean

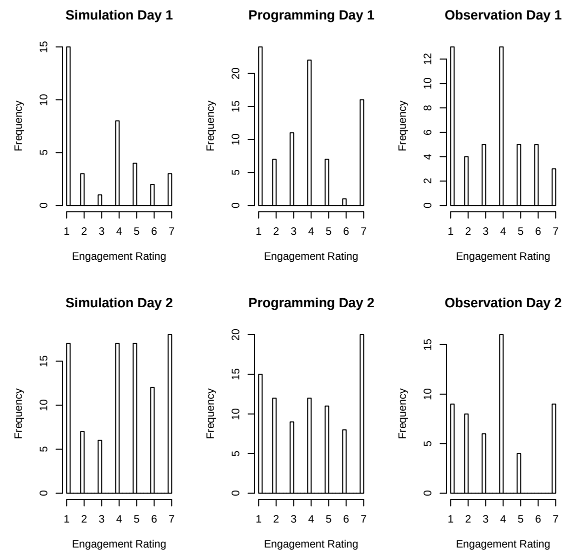


Figure 11: Engagement Sampling Ratings by Condition

of all of the ratings for both days. Thick dashed lines connect these activity means. These lines are color-coded; green (lighter gray on black and white print-outs) indicates that this mean follows the pattern predicted (e.g. Programming higher than Simulation). Figure 13 shows this same graph style repeated for all twenty students in the class.

Correlations among these engagement ratings and the other measures in this study are discussed more fully below, but in looking at all of them the strongest predictor of a student's mean engagement rating in one condition is the mean engagement rating given in the other conditions. These correlations are very strong (.79–.93) and all significant at the $p \leq .01$ level.

The engagement sampling tool included a text box that allowed students to say what it was they were doing at the time, but during the classes I also encouraged students to include information about what was good or bad about what they were doing. Students included some kind of comment about 30% of the time. I devised a coding scheme for these comments by making a list of all the different comments. The first pass through the list yielded 24 different comments (some were similar enough to collapse on the first pass). I then collapsed the list to seven different types of comments. I was especially interested in comments that would help me to understand what it was that students were really rating. Since students

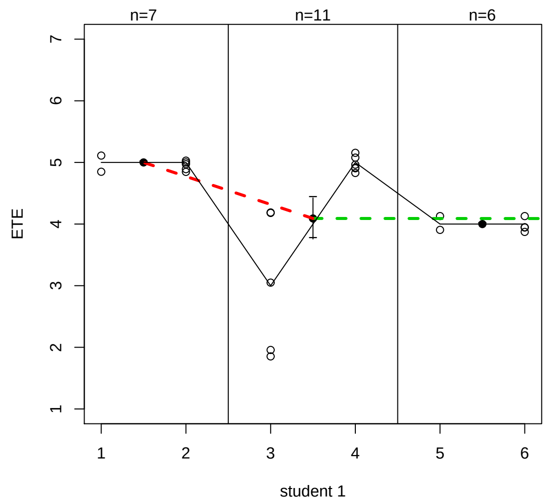


Figure 12: All Student Engagement Ratings Student 1

have no experience with such a tool, a grave concern is whether they are using the rating in the way that I intended.

Figure 14 shows connections between different types of comments and their engagement sampling ratings. Each bar indicates the mean engagement rating of all of the ratings that of that type. The relative means for "bored," "OK" and "fun" suggest that students are indeed using the system as intended. Also, the means in the "annoyed" category suggest that students are rating their engagement in the activity and not their annoyance at having to repeatedly fill out the screen.

Students filled in some kind of explanation about one third of the time for both the Simulation and Programming activity. In the Observation activity the response rate dropped to about one quarter. I was most concerned to get students to respond to the engagement sampling survey at all, and did not require that students, either by programming or strong suggestions, to include this additional information. In future studies, it might be appropriate to use radio buttons or a pull-down list to collect this information. For this case, however, there was no way to know **a priori** what kinds of comments students were likely to make.

From both the weak hypothesis and data from the post-test engagement surveys one would expect that the engagement means to differ across the three activities. The engage-

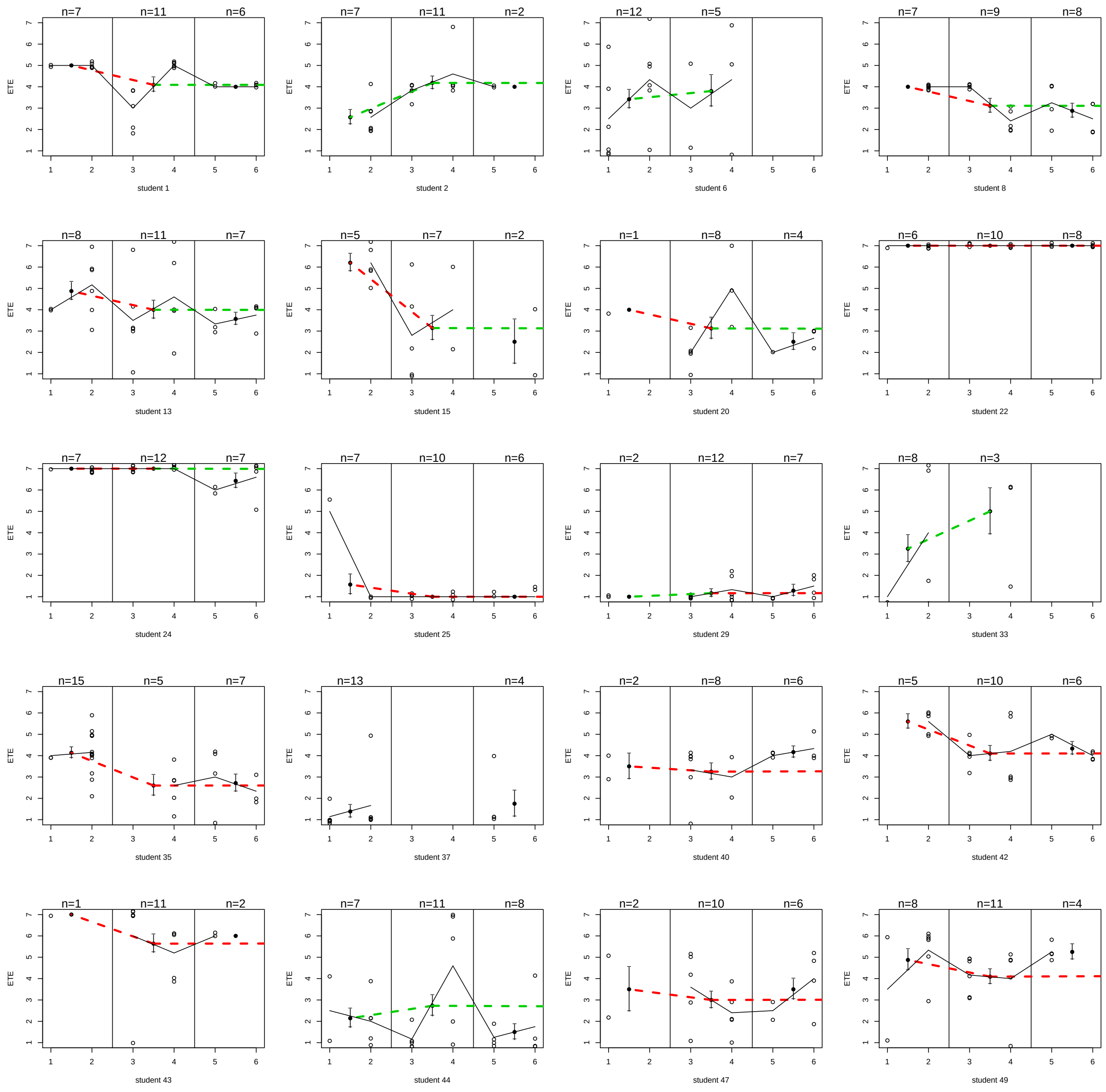


Figure 13: All Student Engagement Ratings for All Students

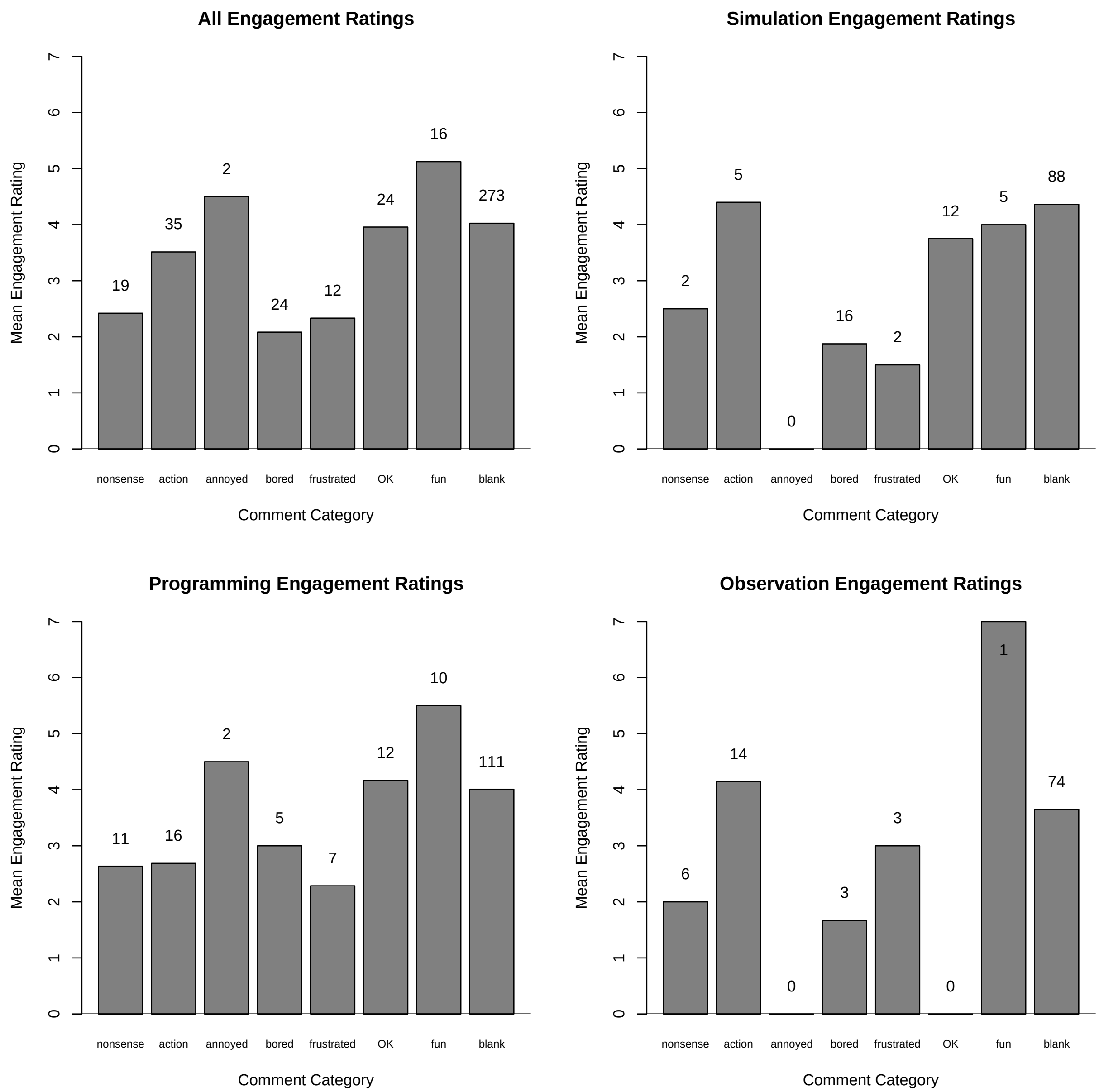


Figure 14: Student engagement rating means for each comment type

Table 7: Engagement Sampling Comments Coding

nonsense	• No comment. • poke
action	• Filling a graph minimun of sheep and Wolfs. • still filling out the packet
annoyed	• Extremely annoying because this screen keeps on popping up! • stop giving so much pop outs every two minutes.! sheeesh
bored	• its really boring its better to read or don't do nothing • its way boring
frustrated	• too slow too much errors (Programming) • u cant even change the settings! (Observation)
OK	• ok • not bad or good
fun	• good • real cool since u can creat ur own images substatuting for wolves and sheep
blank	(no data entered)

ment means, however, are very similar across all three activities (correlation analysis, on page 68, shows that the cross-activity engagement means correlate more strongly than any within-activity measures). One explanation of this finding is that the engagement sampling data are better-used as a minute-to-minute measure than averaged as a whole-activity measure. Activities that are very engaging likely provide higher-highs in engagement, as after a difficult challenge has been solve, as well as lower-lows, as when struggling to make something work. Figure 14 provides some support of this explanation. In the Simulation condition relatively few comments are in the "frustrated" or "fun" category (17% of those responding with a reason) compared to those who responded with comments in those categories during the Programming activity (27%).

5.2 Measures of Learning Behaviors

5.2.1 Worksheets

For each activity, students filled out worksheets as they completed the different tasks. Students received a packet of four worksheets and a cover sheet with instructions. The worksheets were comparable within a packet and across conditions. To examine whether students were completing the worksheets well (and therefore in a position to learn), each worksheet received a score from 0–3 using a rubric. A zero reflected a blank sheet or one with minimal constructive effort. A score of 1 reflected a partial effort with some shortcuts in filling the tables (e.g., copying values from one table to the next) and partial answers. A 2 reflected reasonable efforts that answered the questions literally but with little attention to detail or reasoning about causality. A score of 3 reflected answers that considered the inflections in the population changes and often used explanations that considered ecological factors (e.g., eating their own food supply). Additionally, some students did not complete all the worksheets because they were absent or slow. Therefore, the last worksheet that was attempted in each packet was coded for whether it had been finished or was still in the process of being finished. This makes it possible to examine the quality of answers for those worksheets the children attempted, rather than penalizing them for being absent.

A primary coder scored all the worksheets. A secondary coder coded 25% of the worksheets randomly selected from each condition. The coders had 91.7% inter-coder agreement. The codes from the primary coder were used.

The greatest percentage of completed worksheets was in the simulation activity which had a 76% completion rate as compared with 63% and 35% for the Observation and Programming conditions respectively. Figure 15 shows a histogram of **completed** worksheet scores for each activity. Though the number of completed worksheets in the programming condition is considerably higher, those worksheets were of higher quality. For the Observation and Simulation conditions the proportion of highest-quality worksheets out of those completed was about the same (13.5% and 13.1% respectively) but in the Programming condition 22.2% were scored 3. This suggests that though the programming activity took more time, students' increased engagement was evident in their higher quality of work.

5.2.2 Resource Use

Figure 16 shows the average number of resources used per student across both days. This number does not account for students being absent. This may be significant for the observation condition in which many (7) students were absent the second day. It is also

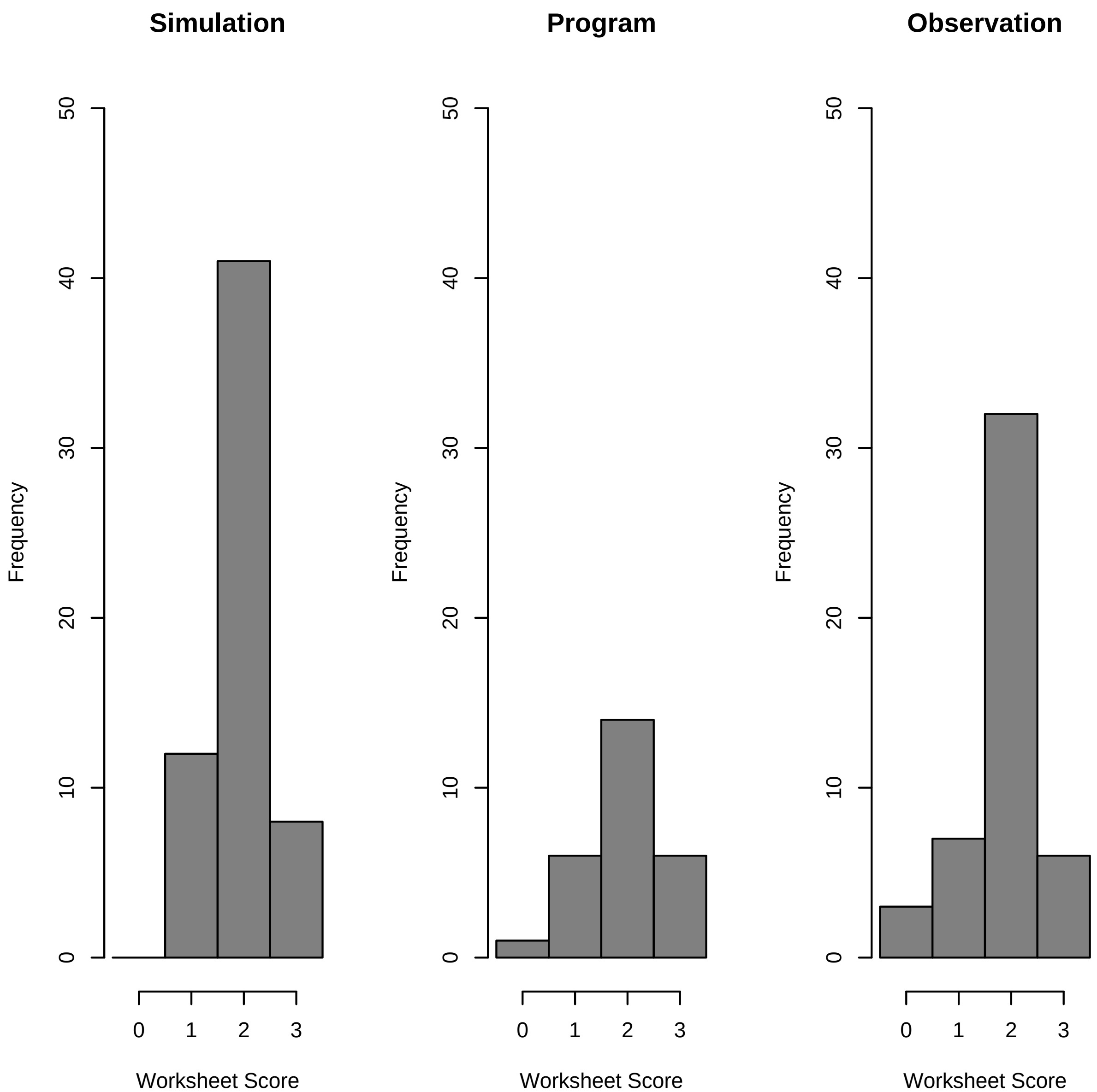


Figure 15: Worksheet Scores

important to note that most students in the Simulation activity were shown how to access the resources individually; this would account for most of the content resources accessed in this condition. It is clear that the programming activity motivated students to investigate the resources provided to help them learn to make changes to their programs. The resource use is split into those resources that explained the biology concepts and those that explained the programming code controlling the simulation.

5.2.3 Content Tests

All content tests were first scanned and saved as PDF documents. I transcribed the answers. In the transcription each test had a header with the student's name and the page of the PDF document that their test began on. After all tests were transcribed, I replaced the students' names with ID numbers and removed all information for those students who had not returned permission forms. Next I grouped the answers by question rather than by student. To develop the coding scheme I collapsed similar answers making marks indicating how many times a particular answer had been given. These initial coding notes show some interesting misconceptions, like the idea that if there are too many sheep, wolves will die because they will get "fat and lazy."

From these initial coding notes, a scheme was devised to give each question a rating from 0–2. I imported all of the answers into a spreadsheet with student ID, question identifier, and the answer on each row. The columns with the student ID and question identifier were hidden and the answers sorted alphabetically. By hiding information about which test the data were from and putting them in a random order, it was possible code to the data without knowledge of whether an answer was from the pre- or post-test. The spreadsheet was coded again by a colleague to test the reliability of the coding method. There was a 87% agreement. Codes from the primary coder were used.

Table 8 shows the results from the content tests. Of the 12 possible points on the test, the highest mean score was about 3.5. None of the pre- to post- means changed significantly. Because the content of each test is different, between-test comparisons are of limited use, though Simulation does go up (in the original design the second class would provide data to reduce the affects of these confounds).

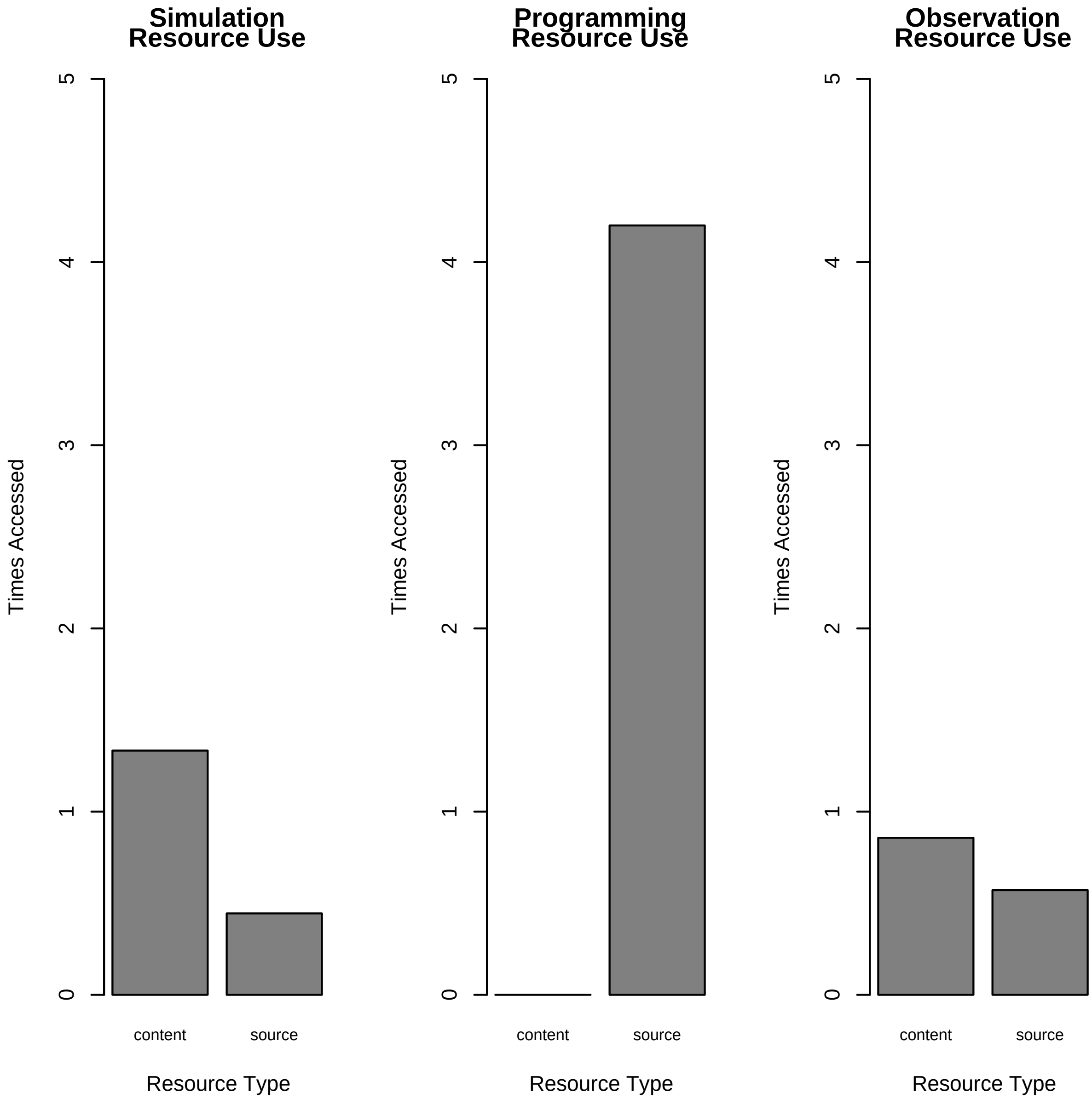


Figure 16: Resource use

Table 8: Content test scores and mean square errors.

	Simulation	Programming	Observation
Pre-Test	1.39(0.30)	3.6(0.46)	2.35(0.36)
Post-Test	2.26(0.35)	3.5(0.38)	2.05(0.34)

5.2.4 Accessing NetLogo Programs from Home

Students were told about the ability to access their programs from home only after the first day of the study and were not reminded on subsequent days. Partially as a result of this, only one student accessed the programs from home. A question on the final post-test asked students whether they looked at the programs from home and the reasons for making that choice. Thirteen students said that they did not access the programs and gave explanations that could be categorized. Seven (53%) gave answers like "didn't want to" or "didn't have time." Three (23%) reported that they had problems with their computer (or lack of one). Another three (23%) reported that they forgot that they could look at the programs or forgot how to. Two students said that they accessed the programs "to see what I had done" or "to see how I am doing." My logs indicate that the "to see how I am doing" student did not look at the programs from home. One explanation was that he was accessing some other information on the web.

5.2.5 Student NetLogo Programs

The programs that students saved were analyzed to look for the kinds of changes that students made and to see whether they created new types of ecosystems from which students could draw new conclusions about what factors keep ecosystems in balance.

Because NetLogo program files, even meta-data like positions of buttons and graphics, are stored as plain text files, a list of the changes that students made to the programs were made with `diff(1)`, a GNU program which shows differences between two text files. This produced a list of all changes between the program that they started with and the one that they saved. I categorized the changes as shown in Table 9. **All** changes were counted, so a single program can have entries in multiple categories. As the table shows, these categories can be further subdivided into three types: (a) changes only to the sliders, exactly as students did in the Simulation activity; (b) visual changes to the program, like colors and shapes, which have no bearing on the performance of the program; and (c) functional changes like adding hunters to the ecosystem or manipulating variables that do not have sliders. Only this final category comprises changes that can result in new kinds of ecosystem which might result in increased learning. It should be noted that the "grass growth rate" change was

Table 9: Types of changes to NetLogo programs.

Type of Change	**Number of Changes**
Changed only sliders (no program code)	
initial wolves	35
initial sheep	30
Visual changes to program	
change color	11
change shape	4
custom-shape	3
Functional changes to program	
grass growth rate	9
add hunters	5
add-weeds	2
other	4

demonstrated to the class at the beginning of the second day of this activity, which likely accounts for most of these changes. Excluding the "grass growth rate" change, only 6 of the 46 programs in the data set had one or more changes in this learning-related category (data in the table can report multiple changes per program). Similarly nearly half (20/46) changed **only** sliders. The paucity of changes that affect how the ecosystems stay in balance is likely due to the short duration of this intervention. If more time had been available for students to learn to make changes and share and discuss them with others there might have been more changes that could have resulted in increased learning.

5.3 Correlations Between Data Sources

The preceding sections have examined the measures one at a time, and compared them by condition. In this section, I analyze the correlations among variables. Of particular interest is whether the primary real-time engagement measure correlated with learning relevant behaviors (e.g., consulting resources), and whether these correlations varied by condition.

To look for correlations, I created a matrix with a single number (a mean or a count) for each of several of the measures for each of the activities for each student. These measures included average engagement rating, frequency of resource use, gain from pre- to post-test, and average completed worksheet score. Additionally, for the programming activity, I found the frequency of different types of changes to the program (described below). Data that were not suitable for the correlation analyses included access from home, which exhibited no variance. Similarly, it seemed unlikely that any useful analysis could come from the NetLogo program categorizations. The full list with abbreviations appears in Table 10.

Table 10: Data Used for Correlations

Engagement Sampling (ES)	The mean of all samples for each activity.
Test Gain (TG)	The pre-test to post-test gain.
Worksheet Scores (WS)	The average of the scores on completed worksheets.
Resource Use (RU)	The sum of the number of content resources accessed and the number of programming resources accessed.
Engagement Average (EA)	The average of the three ES scores.

Given the relatively small differences in engagment ratings across conditions, the first analysis examined whether the students' engagement ratings correlated across conditions. Table 11 on the following page shows an extremely strong correlation between the conditions. This correlation has two non-exclusive interpretations. One interpretation is that students were using the scale differently; for example, one student might have generally used the high end of the scale, whereas another student might have generally used the low end of the scale. Another interpretation is that some students may have been more engaged than others throughout; for example, some may have liked working on computers in general. Regardless, the relatively high correlation among the engagement ratings suggests that it is useful to take statistical steps to examine the variability in engagement rating attributable to the condition. One approach might be to subtract an individual's average engagement rating for a condition from his or her mean engagement rating across all three conditions. A statistically preferred approach is to use partial correlations, where the student's mean engagement rating across all three conditions is controlled for, leaving only the engagement variability associated with the condition to correlate with the other variables. (This is preferred because it is how regressions operate, which would be a useful analysis if there were more subjects). Thus, in the following analyses, I first show the zero-order correlations with the engagement rating, then I show the correlations controlling for the mean level of engagement across the activities. As will be shown, this permits some tentative causal claims.

Table 11: Engagement sampling correlations across conditions.

	Simulation	Programming	Observation
Simulation	—	0.79**	0.82**
Programming		—	0.93**
Observation			—

** Indicates significance at $p < 0.01$

The following tables show zero-order and first-order partial correlations between the engagement sampling means, the worksheet scores, the number of resources accessed, and the pre-test to post-test gains ("TG") for each activity. To reduce the missing data, each table includes all the students who had data for both days of each condition. Had I confined the correlations to those students who were present for all days of all conditions, the data set would be reduced to 6 students. Even so, because of absences these list-wise comparisons are from small samples ($14 \leq n \leq 17$) and few results are statistically significant, in this section I comment on some correlations that are relatively large and theoretically interesting in spite of their lack of statistical significance. Conversely, because there are some missing data, even those results that are statistically significant should be interpreted with some caution. Further research is necessary to confirm or deny the findings suggested by these correlations. Statistical significance is indicated on the tables; unless otherwise mentioned, the results discussed in this section are **not** statistically significant.

Table 12 shows the correlations for the Observation activity ($n = 15$). None of the correlations appears worthy of consideration. The lack of correlation between resource use, worksheet score, and test gain suggests that these indicators of learning were not particularly well-aligned. For example, putting good effort into the worksheet should translate into a good test score, but did not. Also, the resources available for the programming activity provided information about how to change the program, but did not connect these programming changes to their biological implications.

When controlling for the engagement variability attributable to a student's general use of the scale, there is an increase in the correlation between the engagement rating and the number of resources accessed (from .05 to .28). This may mean that students who find Observation more engaging are more likely to use resources. Though a small effect, it gains some meaning in contrast to the Programming condition, described below, where correcting for the effects of the engagement sampling mean **removes** the correlation between engagement and resource use.

Table 12: Correlations for Observation activity. ($n = 15$)

	Zero-Order					Controlling for EA			
	ES	TG	WS	RU	EA	ES	TG	WS	RU
ES	—	-.17	.12	.05	.95	—	-.08	-.17	.28
TG		—	.35	-.27	-.15		—	-.39	-.28
WS			—	-.09	.18			—	-.09
RU				—	-.04				—

ES—Engagement Sampling mean; TG—Post-test Gain; WS—average completed worksheet score; RU—number of resources accessed; EA—average engagement sampling mean

Table 13 shows the correlations for the Simulation activity ($n = 14$). There is a correlation (.52) between access to the resources and the average score on the completed worksheets. This correlation is stable when correcting for average engagement ratings (.53), suggesting that the resources and worksheets were in better alignment for this activity, though neither was in alignment with the test instrument. Notably, there are not correlations involving engagement.

For the programming activity, a strong zero-order correlation exists between the number of resources accessed and the engagement rating ($.52, p < .05, n = 17$, see Table 14 on the next page). However, this correlation greatly diminishes when controlling for the overall engagement level across conditions. (.20, Table 14). The drop in the correlation indicates that variation in the use of resources was not a consequence of changes in engagement due to the programming condition. Instead, students who were generally engaged across conditions were the ones who used the resources. This is a provocative finding because these same

Table 13: Correlations for Simulation activity. ($n = 14$)

	Zero-Order					Controlling for EA			
	ES	TG	WS	RU	EA	ES	TG	WS	RU
ES	—	.03	.34	.01	.93**	—	.14	.03	-.17
TG		—	-.28	-.14	-.02		—	-.29	-.14
WS			—	.52	.36			—	.53
RU				—	.08				—

** indicates significance at $p < .01$

ES—Engagement Sampling mean; TG—Post-test Gain; WS—average completed worksheet score; RU—number of resources accessed; EA—average engagement sampling mean

students did not use resources in the other conditions, as indicated by the lack of correlation. One interpretation is that students who are highly engaged will access resources if they are in a situation where those resources will contribute to making something, but in other less constructive situations, engagement is not related to the use of resources.

Table 14: Correlations for Programming activity. ($n = 17$)

	Zero-Order					Controlling for EA			
	ES	TG	WS	RU	EA	ES	TG	WS	RU
ES	—	-.40	-.38	.52*	.97	—	.22	.20	.20
TG		—	.16	-.33	-.47		—	-.06	-.14
WS			—	-.40	-.44			—	-.23
RU				—	.49				—

* indicates significance at $p < .05$ ES—Engagement Sampling mean; TG—Post-test Gain; WS—average completed worksheet score; RU—number of resources accessed; EA—average engagement sampling mean

The next set of tables reflect a correlation analysis that is only possible for the Programming condition. The Programming activity yielded data on the types of program changes that students made. Correlations between the data reported in the previous tables and the number of programming changes are shown in Table 15. To the three types of changes shown in Table 9 I added another aggregate category which is the sum of the visual changes (colors and shapes) and the functional changes (e.g. adding hunters). This category reflects constructive additions to the program (as opposed to just manipulating the sliders).

There is a significant correlation ($.55, p < .05$) between test scores and the number of programming changes. Though the ideal for this instruction would be for increased programming to lead to increased test scores, this correlation may be spurious. The programming changes were often irrelevant to the test items, and in general, the correlations between the measures relevant to learning have been quite low. Nevertheless, it is satisfying to think that programming can help students learn about biology.

Table 15: Correlations for types of programming changes vs. other variables. ($n = 14$)

	Zero-Order				Controlling for EA
	ES	TG	WS	RU	ES
Sliders only	.49	-.36	.44	.36	.22
Visual	.02	-.07	-.06	.03	.32
Functional	-.43	.55*	.12	-.45	.12
Additions	-.31	.34	.02	-.31	.49

* indicates significance at $p < .05$

ES—Engagement Sampling mean; TG—Post-test Gain; WS—average completed worksheet score; RU—number of resources accessed; EA—average engagement sampling mean; Sliders only—program not changed; Visual—changes to colors and shapes; Functional—changes to how populations vary; Additions—sum of Visual and Functional

A more striking finding is that once the overall level of engagement is controlled for, there is a sizable correlation between engagement and the number of changes made to the program (.49). This means that the overall level of engagement does not explain the number of changes an individual made. Instead, the number of changes correlates with the component of engagement specifically associated with the programming treatment. One interpretation of this finding is that those those who were more successful in making changes reported higher engagement. Thus, whereas overall engagement seems to cause the use of resources in the programming condition in which resources are useful for making things, making things increases that component of engagement uniquely attributable to the programming condition.

5.4 Discussion

The hypothesis guiding this study posits that increased opportunities to create, customize and share will result in increased engagement. A stronger version of the hypothesis posits that increased engagement should lead to increased attempts to learn the methods necessary for creating and customizing. Both versions of this hypothesis have some support in the data.

Another purpose of this study was to test Engagement Sampling as a measure of student engagement. The data suggest that using the mean of the engagement samples is either not valid or not reliable. I further hypothesize that for this measure to be useful, the moment-to-moment measures of engagement need to be more tightly bound to specific activities.

5.4.1 Data Supporting the Weak Hypothesis

The weak hypothesis predicted that increasing student opportunities to create, personalize and share things would increase their engagement. The Simulation and Programming activities were designed to give students more opportunities to change things in ways that they chose. The Programming activity further allowed students to create new and different ecosystems. The post-test engagement survey clearly supported the weak hypothesis. Students almost uniformly preferred Programming over Simulation and Simulation over Observation.

The post-test engagement survey provides further support for the weak hypothesis. Two reasons predominate the explanations that students gave for why they preferred one activity over another. In all three comparisons about one third of the students responded that they liked having increased choices. This answer is consistent with the hypothesized importance of personalization. In the comparisons involving programming, again about one third of the respondents reported that they liked being able to make additions to the programs, analogous to the create piece of the hypothesis.

The number of additions students made to their programs correlates with their engagement when controlling for the Engagement Sampling mean across all activities. Though this correlation is not statistically significant, there is a statistical explanation. The hypothesis holds that students who are successful at making changes will report higher engagement;

those who are struggling with making changes are more likely to report that they are frustrated. Further research is necessary to validate this finding.

5.4.2 Data Supporting the Strong Hypothesis

The strong hypothesis predicted that increased engagement would result in students working to learn methods that would allow them better to create and customize. The clearest support of this hypothesis is that students who have high engagement sampling are more likely to access resources, but only when those resources enable them to make changes of their own choosing. It is not that students report being more engaged when they have a chance to make changes, but that those who are engaged by the computer-based activities access resources when the resources will help them learn methods to customize their programs. The variation in the engagement within the Programming activity does not help to further explain the increased use of resources in this activity.

Another finding supporting the strong hypothesis is that the number of programming changes students made positively correlates with their test scores ($p < .05$). This finding is encouraging and almost surprising given the weak connections between the types of changes that students might make and the post-test measure. In the programming activity the resources available to students dealt primarily with the procedures of programming, not the implications the simulations had on the biological systems they modeled. With instruction that more tightly bound the programming tasks with the biology content this finding would likely be much stronger.

Another indicator that students were more likely to work at learning when they are able to create things is the finding that their average worksheet score is higher for the Programming activity than for the others. These data are somewhat confounded because the worksheets were not exactly the same across all conditions (though they were coded using the same scale). If the data from the missing class were available it might be possible to make more of this finding.

The strong hypothesis predicts that measures of students' attempts to learn be similar across learning relevant measures. This study found no correlation between the effort evident on the worksheets and the number of resources accessed. Some possible explanations for this finding are that the sample was too small or that the intervention was too short for these measures to work reliably.

5.4.3 Engagement Sampling as a Measure of Student Engagement

This study demonstrates a measure of student engagement intended to make it easier for those designing instructional interventions to measure engagement so that they can have evidence that their materials are engaging or to test for connections between engagement and learning. Because the engagement sampling means do not match those expected by the hypothesis or those reported in the post-test surveys, it appears that using the mean of measures from tool as measure of engagement is problematic. One explanation for this result is that the engagement sampling tool is too fine-grained, that is, one's engagement is not simply the mean of how engaged one feels over time. A better use for this tool would be to use it at times tied specifically to particular types of activities (this functionality is part of the tool). Another possibility is to have a checklist of current activities so that more data could be collected about exactly what the students were doing at the time of each sample.

The histograms of the Engagement Sampling data (Figure 11 on page 58) show that for the programming activity there were relatively more very high and very low scores for the programming activity, suggesting that over the course of making additions to the programs students go through peaks and valleys of frustration and accomplishment. Imagine someone who had only three months to conduct and write a dissertation. Though there might be some peaks when some tangible milestone had just been reached, most of the time this person would likely be clicking very close to the "I would rather be doing something else" end of the Engagement Sampling Scale. Once the experience was over and the dissertation complete, one might look back at the time and remember only the high points like finishing a chapter, or constructing an especially effective graph or example and rate the overall experience as a good one. Less anecdotally, Csikszentmihalyi and LeFevre's work suggests that people are at flow when ability and challenge are at balance. His samples were taken only several times per day; mine were taken several times per hour. It is likely that his respondents were reported their engagement on the activity as a whole rather than exactly how engaged they were at a given instant. A way to test this explanation would be to sample students only once or twice per class in a school day. If this explanation holds, students' scores would more closely resemble those data in the post-test engagement survey.

Another explanation for the means of the engagement sampling measure not corresponding to the expected result is that this activity was just too much fun compared to what students would be doing in their regular class. One student, for example, always gave the highest response. Because of the short duration of the activity there was likely a novelty effect. Perhaps a better way to test this measure would be to use it in an activity that more closely matched what was typically happening in students' classrooms.

CHAPTER VI

GENERAL DISCUSSION

This research started from the observation that many hobbyists spend considerable time and energy learning about their hobbies and that it would be desirable for students to spend the same sustained effort learning how ecosystems stay in balance as do home brewers learning how starches convert to sugar. Survey data from adult hobbyists and high school students suggested that across many hobbies some factors that made engaging activities satisfying were seeing the fruits of one's labor in the production of an artifact that allows for personal expression and being able to share that work with others. Also highly valued **outside of the classroom** were opportunities to learn about the tools and methods needed to be successful in creating an artifact. This coupling of a specific motivation to a specific productive form of learning provides an exciting possibility for improving classroom instruction: unlike a mastery orientation, which is often considered a learner trait, instructors can create opportunities to produce things and thereby motivate learning. Project-based learning is a nice example of using the creation of a product to improve instruction; however a review of motivation literature found minimal direct explanation for why creating artifacts is so satisfying.

Though the findings from the surveys appeared consistent across two populations and both academic and non-academic pursuits a concern remained that though the results appeared to be reliable it was not clear that they were valid. For example, it could be that respondents were reacting to the examples in a way different from that which I had intended. Also, these findings dealt with hobbies and non-academic activities that were self-selected and many of the favorite classes that students listed were electives. Students in an advanced placement calculus class may have different feelings about school than another sample of students. The goal for this work was to look for ways to inform instructional design, so rather than continue to further refine the survey studies I used these data to form a hypothesis about how to manipulate engagement in a classroom and tested it experimentally.

6.1 Hypotheses

Two versions of this hypothesis were tested. A weak hypothesis was that giving students increased opportunities to create, customize and share would increase engagement. A stronger version of the hypothesis posited that this increased engagement will lead to increased attempts to learn, especially when students can learn the tools and methods needed to create new things. I tested this hypothesis with a study that used three different activities that varied the opportunities to create, customize and share.

6.2 Design

Seventh grade students from a Spanish Immersion K–8 school came to a computer lab during science classes. Three lessons were designed that provided varying opportunities for creation, personalizing and sharing in the context of working with biological simulations in NetLogo (Wilensky, 2002). In the hypothetically least-engaging condition students merely ran simulations that offered no opportunities to change any parameters of the simulation and recorded the results of each "experiment" on worksheets. In a lesson hypothesized to be more engaging, students again worked with a simulation and recorded results on a worksheet, but this time were allowed to change various parameters of the simulation to make it behave in particular ways. In this condition, students also saved their new versions of the program (their changes comprised only changing the initial value of animal populations). In the third, and hypothetically most engaging activity, students were allowed to change the simulation programs to affect how they looked and worked as well as fill out worksheets about their performance and save their programs which were published on the Web.

6.3 Measures

Student engagement was measured several ways. One measure used a post-study survey to have students report which activity they preferred (A vs. B, B vs. C, C vs. A). This study also tested two novel measures of engagement and computer-based tools to administer them. An Engagement Sampling method polled students about their engagement at 4–7 minute intervals. This measure provides minute-to-minute information about student engagement over the course of a lesson or activity, which can be different from how one rates engagement on an activity when reflecting on the whole of it. Data for another measure was collected by a tool that tracks access to web-based resources. This measure was used to track the connections between engagement and student attempts to learn.

In addition to the Engagement sampling and resource-tracking tools, several other computer-based tools were developed or configured for the study. A tool for browsing a directory hierarchy of NetLogo programs and running them as applets in a web browser was developed and used to demonstrate student programs in the classroom and allow access to them from home. Student programs were saved on a file server running on a laptop. This allowed the researcher to have complete control over administration of student accounts and afforded the opportunity to back-up the data daily as well as to know for sure that students could not access the data outside the scope of the study.

6.4 Findings

This study yielded two major findings. First, student's retrospective level of engagement is affected by opportunities to create and customize. Students overwhelmingly reported preferring the activities as predicted by the hypothesis. The factor that primarily differentiated Observation and the other two activities was being able to change things that have an effect on how the simulations ran. The factor that differentiated Programming and Simulation was being able to create a new and different program. These support the weak version of the hypothesis. Though further research is needed to better understand exactly what kinds of activities can give students the satisfaction of creating an artifact, this study provides strong evidence that adding these factors to instructional activities can make them more engaging.

The second major finding was that students who are more highly engaged are more likely to access resources but only when those resources can help them to customize and personalize the artifacts that they produce. In the Programming activity resource use correlated with engagement, but in Simulation and Observation activities there was no such correlation. Further analysis of partial correlations suggests that the increased use of resources was related to their overall engagement, not any increased engagement in the Programming activity. This is a departure from much motivational research, which looks only at the factors that affect motivation, not the factors that affect students' motivation to learn. If a goal of education is to shape students so that they will be prepared to learn—prepared not only cognitively, but also instilled with a desire to learn—it is important that educators have techniques that can make students **want** to learn with understanding.

Also reported here is that the data from Engagement Sampling measure did not provide results consistent with retrospective ratings of engagement. The engagement sampling tool gathered data over the course of two days of instruction. The mean of the engagement samples over two days of instruction did not match the results from the student's retrospective reports of their favorite activities.

6.5 Limitations and Suggestions for Improvement

Due to scheduling changes at the school that were beyond the control of the experimenter, several changes were made to the design of the study which significantly weakened the study and consequently the implications of the results need further testing. This section points to changes needed to better test the hypotheses reported here.

The most obvious shortcoming of the modified design of the study is that there are insufficient control conditions and counter-balances. Having two teachers who each taught two sections of the same class would make it possible to control for effects of condition order, teacher effects and effects of instructional content.

One limitation of the work involves student attrition. In addition to losing one class due to a sudden change in the needs of the school, there were very few students who were present for all days of the intervention. As a result, the statistical analyses of the different treatments sometimes included students who had different levels of "dosing" for each of the treatments. Though the significant differences were robust, and unlikely to be affected by attrition, it is an issue that requires attention in subsequent research. The place where the attrition is particularly problematic involves the correlational analyses that depend on within-subject relations in an activity within a lesson and comparisons of these relations across lessons. The loss of students who did not complete each day reduced the sample size, and the unequal samples of data within a lesson also reduced sample reliability. As a consequence, the correlational analyses are prone to one or two data points that can drive the regression function. The raw data did not exhibit outliers that distorted the correlational picture. Nevertheless, the reduced samples, the unequal dosing, and the unequal samples for engagement within a lesson all increase the need for caution when generalizing these findings to other settings.

Problems with the experimental design aside, several other changes emerged from the study as it was carried out. One important change would be to have the intervention last longer. One of the problems with this study, especially in the programming activity, was that students did not have enough familiarity with NetLogo to be able to focus on the implications their changes had on how ecosystems work. Instead students focused only on learning the NetLogo necessary to make their changes. The novelty of changing colors and shapes would wear off, and their proficiency would increase, allowing students to focus on changes that were functional rather than merely visual.

One problem with the materials that is now apparent is that there should be better alignment among the content, the programming activities and the assessments. There were no correlations between the number of resources accessed, the quality of completed worksheets, or the performance on the tests. Closer alignment among these materials should make it easier to find differences in students' knowledge before and after they have worked on an activity, and ideally link motivation to learning behaviors and learning outcomes.

Another improvement would be to integrate it into a larger cycle of instruction on biology that includes external feedback and assessment, reading and lecture. In particular students should have opportunities to share their programs with others. This would allow the NetLogo models to be a way to test hypotheses about how ecosystems work rather than trying to embed all of the biology content into the NetLogo programs.

If students were more familiar with the NetLogo tools and techniques required for programming then the student resources could be more related to the biology curriculum and less related to the details of NetLogo programming. Ideally, the resources explaining the biology content would be necessary to make a program work, effectively making it so learning the biology content would become learning a method for creating an artifact. This is an important change because it would allow stronger conclusions about students' desire to access resources related to learning new methods.

A next step in expanding this study would be to test it in a more authentic classroom context to see whether these methods can be used by teachers to improve their own instruction. The results of this study may have been affected by having a different teacher (me) or working with NetLogo. Also, the instructional activities in this study were designed specifically to test this hypothesis, so the three instructional activities may not be like those designed by teachers specifically for teaching. To test whether these findings can help teachers one might have a teacher adapt his or her regular classroom activities using the techniques suggested by this study. A teacher who taught more than one class per day could teach more than one version of the lesson each day to control for the content confound in this study (as planned in the original design of this study). NetLogo is not an essential part of the study. Teachers could have students produce other kinds of artifacts like PowerPoint presentations, web pages or non-computer-based artifacts like posters, or projects like those in the Jasper Woodbury Problem Solving Series (Cognition and Technology Group at Vanderbilt [CTGV], 1997).

6.5.1 What was Learned about the Engagement Sampling Tool

This study documents the use of a tool for measuring students' minute-to-minute engagement. In its time-sampling mode, the tool yielded data that are not immediately useful in providing teachers or researchers feedback about student engagement. A more useful way to use the tool in the future might be to tie the data collection points more closely to specific instructional activities, so that one can connect individual activities with students' reported engagement. This study's descriptions of the computer infrastructure used like the laptop file server and web-based lesson delivery also provide those designing computer interventions with some examples of tools and methods to support their work.

Activities students enjoy are sometimes highly engaging and sometimes highly frustrating; this is probably due to the level of challenge and clarity of goals varying as they worked on the tasks. Less enjoyable activities—especially in school where one's expectations for engagement are low—are neither engaging nor frustrating. A more effective way to use this measure may be to tie each measurement more closely to a specific moment of activity, either by having students rate their engagement at a particular point in an activity or by having students report more accurately what they are doing when filling out the form. This would enable researchers to better track what kinds of activities—at a minute-to-minute level—result in high levels of engagement. These data may help researchers—or teachers—to gain an understanding of how students are reacting to a lesson more accurately than can be determined by assessing students' body language and facial expressions.

Engagement sampling might also allow researchers to track changes in how students react to certain activities over time. An activity that is at first boring or frustrating might bring more satisfaction over time. Just as home brewers may come to enjoy cleaning and sanitizing equipment over time, students might find some parts of learning that at first seem unpleasant or unnecessary to be an important part of the process and after coming to appreciate that, students might come to appreciate—and rate higher on an engagement sample—activities that they once found frustrating or boring. By carefully mapping engagement samples to particular classroom activities, such changes in how students respond to learning activities might be tracked. Seeing that students start to appreciate parts of learning that they once found distasteful may be an indicator that students are becoming life-long learners.

6.5.2 Tracking Resource Use as a Measure of Engagement

An important aspect of this study was tracking how students used resources. The data show a correlation between students use of resources and their engagement, but only when the resources helped students to make changes to their programs (though the small sample size makes these correlations somewhat speculative). When the resources were only to help students answer the worksheets better, increased engagement did not result in students trying to learn more (as measured by the number of resources they accessed). An implication is that having students create artifacts that allow them some control will encourage them to learn the tools and methods needed to create those artifacts. Conversely, even if students are highly engaged, they are not likely to want to learn unless the learning will help them to create an artifact. A problem with this study is that the programming resources were too loosely connected. For the production of artifacts to lead to increased learning it is important that learning the desired content to be tightly integrated with production of the artifact.

6.6 On the Value of Producing Artifacts

Creating artifacts is an important aspect of increased engagement in this study. Exactly what kinds of artifacts are engaging to produce is an issue that needs further research. Not all artifacts are equally engaging to produce. Students create many artifacts in classrooms: worksheets, papers, pages of identical math problems, papers, class presentations and projects like erupting volcanoes. The engagement students gain in producing all of these artifacts is not the same. Presumably one important factor that differentiates the engagement students have in creating these artifacts is the degree to which students can personalize them. The hobbyists who rated creation highly were not creating worksheets, they were creating objects of their own choosing. This choice is itself a form of self expression. The curricular constraints of classrooms preclude students having full choice over what they create, so it is important to embed opportunities for self-expression into classroom assignments. Findings from this study showed that students will try to learn when that learning will help them to be able to express themselves (as evidenced by the correlation between engagement and access to resources).

Just as creating artifacts is of little value for engagement when there is no opportunity to personalize them, there may be a similar relationship between creation and sharing. Though there is some satisfaction in building or creating something in isolation, sharing it with others provides additional satisfactions. Sharing usually results in feedback, giving the creator a combination of validation for his or her efforts and possible paths for improvement. Also, sharing an artifact of sufficient quality can be a means for gaining membership in a community and influencing the artifacts that others create.

6.7 Towards a Theory of Engagement and Learning

Thus far I have described creating an artifact and having opportunities to share as independent variables that affect engagement and the desire to learn. It seems more likely, however, that the opportunities and desire to create, share and learn are interconnected. Each affects the others, and the balance between them affects engagement. For example, if high stakes sharing and high expectations of the product to be created are present, then the access to skills and resources must also be high or the result will be frustration. Similarly if resources and creation are high the desire to share the artifact will be great; if the person cannot find a suitable outlet for sharing then the desire to create and learn will likely decrease to keep the system in balance.

Different situations will afford different control over how people may affect these variables. As suggested by this study, students typically have little control over their opportunities to share and create in classrooms. This leaves their desire to take advantage of resources for learning low as well. Outside the classroom people often have more control. Someone who has used resources to create an exceptional beer may seek out wider and wider audiences for sharing it.

Precisely how the continua of these variables lay out is a topic for further research, but here I will outline one possibility. I begin by describing three continua and then move to a model of their relations.

Creation is not merely creating something, but creating something that allows the creator to express him or herself. At the low end would be copying something or creating something according to someone else's plan. Making a hamburger in a fast food restaurant might be an example. Further up the continuum would be creating something of one's own choosing that allowed for some personalization: one might choose what cake mix and frosting to buy and might further customize it by adding extra ingredients to the mix and create fancy decorations with the icing. At the highest end of the spectrum would be the creation of something entirely new, for example a chef who finds the freshes ingredients available at the market and then designs a unique recipe to make the most of the available ingredients.

The resources continuum is a combination of competence (internal resources), access to external resources and the ability to make use of the resources. How these three aspects of resources fit together is a topic for further research. At the low end of the continuum would working in an unfamiliar domain without access to external resources like a textbook or the Internet. Farther up the scale would be a competent novice with access to textual resources, like books, or a tutor or mentor who could scaffold their learning to the next level. At the highest end of the continuum would be an expert with extensive experience (internal resources) who additionally has access to materials, information and people (external resources); for example, a named chair in a university.

The sharing continuum probably starts with one's self. One can gain some satisfaction in creating something for one's self, but as one's time, effort and competence grow (s)he looks for ways to share. Further up the continuum of sharing might be sharing with family or friends. A next step out might be a club or affinity group. At the highest level might be public performances or national competitions.

The relationship of these three factors can be envisioned on a three-legged balance (see Figure 17). Each of the legs on this balance represents one of the continua: creation, resources or sharing. When the levels of all of these factors are low, but balanced, people will be engaged (Figure 18). However, as we describe below, it is unstable and easily perturbed. As the levels increase and move further from the center people will also be engaged if they are in balance (Figure 19). However, the further from the center these three factors get, the more stable the balance becomes. (For this physical model, weights at equal distances, but close to the center, are less stable than when the weights are equal distances far from the center.) When the three factors are out of balance the person may be able to adjust the levels of the factors to bring them into balance. If the factors cannot be adjusted to bring the system into balance, the result is frustration.

Different situations place people on different points of the continua. For example, a master chef who enters a televised cooking competition may be high on all dimensions. However, the chef may reside in very different locations when given a model rocket kit for a vacation in some remote location. Presumably, the level of sustained engagement would also differ. When people enter situations in which there is an imbalance, they will try to regain the balance, if possible, by changing their circumstances. For example, they may try for more ambitious sharing situations, if their opportunities for novel production are high. By this account, engagement is similar to flow in that it is a desirable state to maintain (rather than a reward to earn), and given opportunities, people will make changes to achieve the state. However, unlike flow there are more and less stable states of engagement. People will try to expand on dimensions to achieve a balance that can resist small perturbations along the dimensions. The high stability of engagement at the ends of the continua is characteristic of experts who can tolerate the highs and lows of a large undertaking without losing their overall level of engagement. Thus, this theory of engagement is also unlike flow in that it

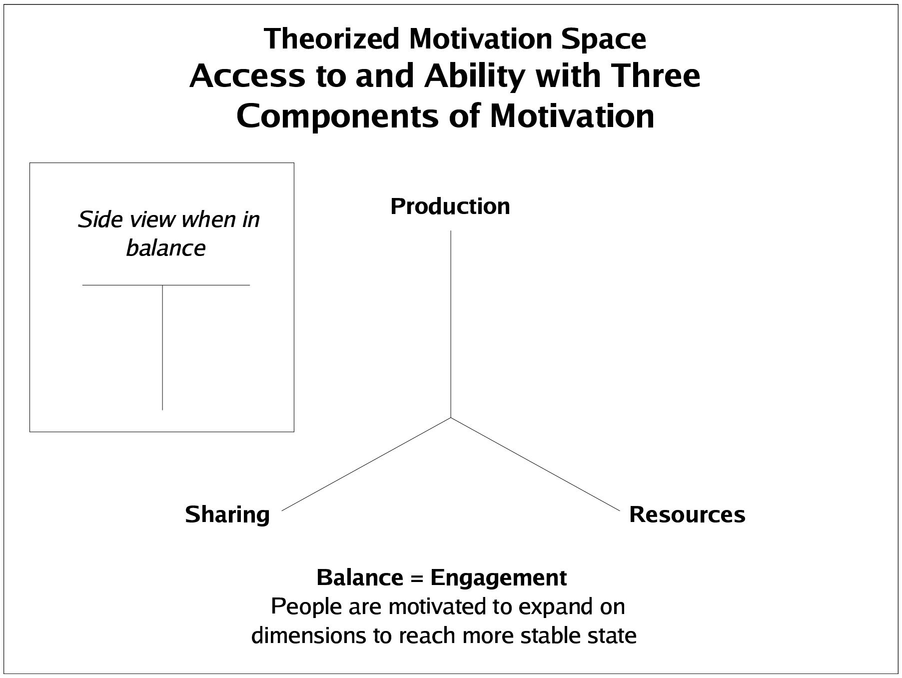


Figure 17: Theorized Motivation Space

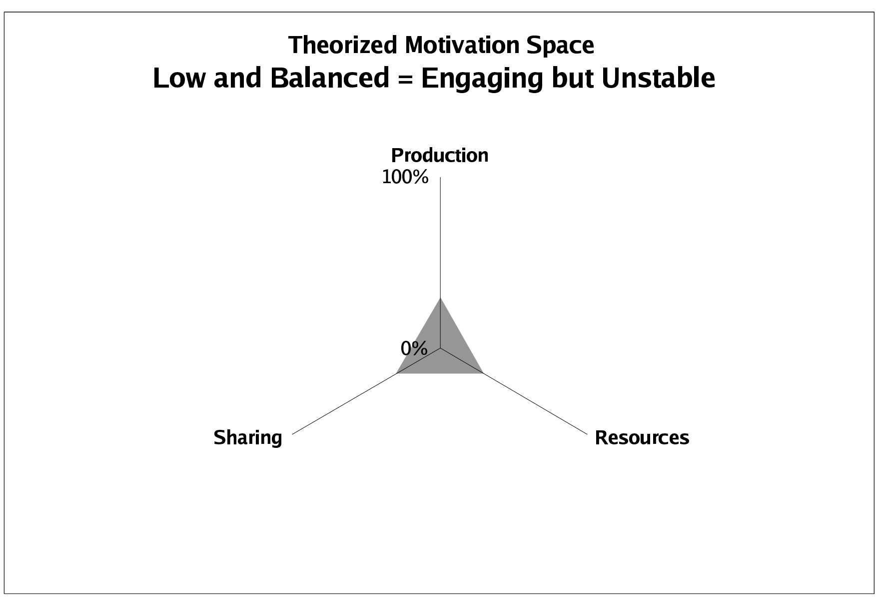


Figure 18: Low Level of Engagement

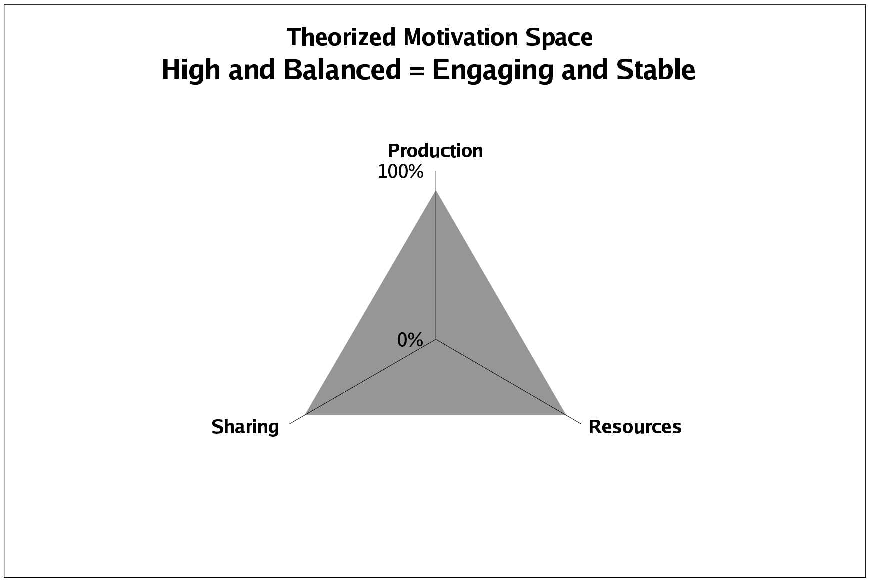


Figure 19: High Level of Engagement

can capture a larger period of time. For example, in the study, the children's moment-to-moment ratings of engagement were not higher in the Programming condition than the other conditions. However, in the end, the moment-to-moment wins and losses had dissolved into the totality of the larger undertaking, they found Programming more engaging.

Finally, Figure 20 shows a case similar to the Programming condition in the classroom study. In this case, the opportunities for production and sharing are somewhat higher than the students' abilities to use resources to make the program. One can imagine three alternative options with different implications for the students' engagement. In Option 1, the students are prevented from improving on the resource dimension, either because the distance they have to improve is too great or because they do not have an opportunity or the ability to use the resources. By this theory, the imbalance would cause students to be low on engagement and they would also be frustrated. Option 2 would be to reduce the anticipated level of production and sharing. By hypothesis, this would be more engaging than keeping the imbalance, but it would be unstable and small changes in the environment could upset the engagement. Finally, Option 3 is the one I had hoped the children would be able to follow. To achieve a balance, they would move up the resource continua and learn new methods so they could produce something unique that they could share.

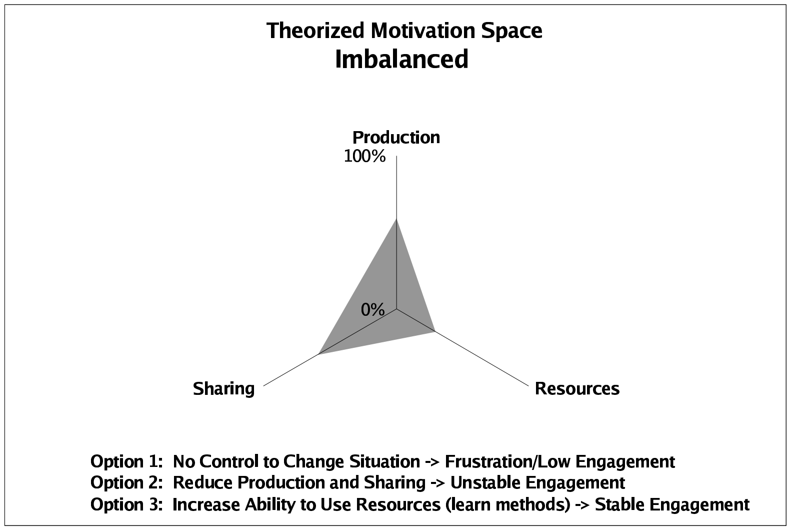


Figure 20: Out of balance

This model suggests a new way to explain motivation in the classroom. Unlike many other theories of motivation, this model addresses specifically how to motivate students to want to learn. Though further research is needed to refine the model and make clear how the factors affect each other, it may prove to be a tool to guide teachers and researchers to design or modify instruction that will be more engaging.

APPENDIX A

HOBBY MOTIVATION SURVEYS

1.1 Adult Hobby Survey

```
Hobby Survey

I am working on a Ph.D. in education and technology. I am interested in
what makes hobbies motivating. Hopefully, your answers can help build
more motivating school lessons.

I want you to think about a hobby of yours.

There are 25 statements below about what might make your hobby enjoyable
to you. Please rate how important they are for your enjoyment. If you
would like to comment about a statement, for example, how or why it is
relevant to you or how it could be made better, please use the comment
box. The questions are given in random order, so if you comment on
another item, please call it by name rather than number.

To help make the statements more concrete, I have included examples of
what I mean from my own hobby--brewing beer.

To protect your privacy, I ask for no information which would allow me
to track you. If you are interested in the results of the survey (which
will be made available at this same URL), you'll be given a chance to
submit your email address after you've completed the survey.

You may have more than one hobby, please choose the one that you find
most enjoyable.

Thanks,

Jay Pfaffman <pfaffman@relaxpc.com>


    NOTE:

This survey uses Javascript to validate that you answered all the
questions (but not the comment fields!). If you don't know what this
means, you can probably ignore this warning and skip the rest of this
paragraph. If you have javascript turned off or use a browser that
doesn't support Javascript you won't be able to submit. I usually avoid
Javascript and all browser-specific stuff, but chose to use Javascript
```

for this application. I don't think it was a horrible decision, but some people have complained, which means others have gone away mad without getting their data submitted.

Questions

1. Your hobby/activity:

2. How many years have you been doing this activity?
   (less than 1) (1-2) (3-5) (6-10) (more than 10)

3. How rewarding would you say your hobby/activity is:
   (Unrewarding) (not very rewarding) (sort of rewarding) (rewarding) (Very rewarding)

4. What is your gender?
   (male) (female)

5. About how many hours per week do you participate in your hobby?
   (Less than 1) (2-5) (5-10) (10-20) (more than 20)

6. About how much money do you spend on your hobby in a month?
   ($10) ($10-$20) ($20-$50) ($50-$100) (more than $100)

   In the following, please rate how important each of these statements is for the *enjoyment* of your hobby.

7. (flow)*To feel time change*:
   My example: It's sometimes surprising to realize that I've spent 8 hours making a batch of beer when it seemed like I just started. Sometimes the few seconds that a particularly tasty beer clings to the palate can seem like minutes.
   Unimportant Very important
   Comments/Examples/Suggestions:

8. (creation)*To find or create something new or rare*:
   My example: Home brewers often make beer in a style that is no longer made or is very difficult to come by.
   Unimportant Very important
   Comments/Examples/Suggestions:

9. (learning)*To learn about tools*:
   My example: There are many tools used in brewing---kettles, fermenters, devices to chill boiling beer, mills to crush grain, kegs, taps, and so on.

Unimportant Very important
Comments/Examples/Suggestions:

10. (social)*To use the hobby to stimulate conversation*:
    My example: When people learn that I brew beer they are often interested in talking about it.
    Unimportant Very important
    Comments/Examples/Suggestions:

11. (flow)*To overcome new challenges*:
    My example: One brewing organization has the motto ''It's not rocket science. Unless you want it to be.'' There are easy ways to make beer, but there is plenty of room to use increasingly advanced techniques so that every batch potentially holds new challenges.
    Unimportant Very important
    Comments/Examples/Suggestions:

12. (flow)*To have clear goals and feedback*:
    My example: When making beer, I know what I want, and I know when I've got it. When I taste my beer, I know whether it's good.
    Unimportant Very important
    Comments/Examples/Suggestions:

13. (extrinsic)*To increase academic or professional success*:
    My example: Working on my hobby is helping me move towards an advanced degree.
    Unimportant Very important
    Comments/Examples/Suggestions:

14. (learning)*To know the little-known facts and stories around your hobby*:
    My example: In brewing it's interesting to know that there is cumin in Delirium Tremens, or that Fritz Maytag who owns the Anchor Brewing Company got his money from his family's appliance business.
    Unimportant Very important
    Comments/Examples/Suggestions:

15. (learning)*To read about my hobby*:
    My example: I enjoy reading books and magazines to learn more about beer and brewing techniques.
    Unimportant Very important
    Comments/Examples/Suggestions:

16. (extrinsic)*To enter competitions or win awards*:
    My example: Winning a 1st place prize or being at the top in a

competition is a rush.
Unimportant Very important
Comments/Examples/Suggestions:

17. (social)*To be liked*:
My example: When I come to a party with a keg of home brew people think I'm pretty cool.
Unimportant Very important
Comments/Examples/Suggestions:

18. (flow)*To do something as an end in itself*:
My example: Though brewing obviously has a product, at least some parts of the process are fun in and of themselves. It's still amazing to me that mixing water and grain and waiting a while magically changes stuff that tastes like oatmeal into sugar. It's also pretty fun to just watch the yeast do their work and convert the sugar into alcohol.
Unimportant Very important
Comments/Examples/Suggestions:

19. (social)*To belong to a group*:
My example: I joined a home brew club, and participate on a list where people discuss brewing.
Unimportant Very important
Comments/Examples/Suggestions:

20. (creation)*To nurture or sustain to completion or maturity*:
My example: Once the beer is in the fermenter I work to see that the process is completed successfully by being sure that the unfermented beer remains at a proper temperature.
Unimportant Very important
Comments/Examples/Suggestions:

21. (social)*To help others appreciate or participate*:
My example: As a home brewer, part of my mission is to show people that beer is at least as interesting to taste and enjoy as wine.
Unimportant Very important
Comments/Examples/Suggestions:

22. (creation)*To adjust or personalize methods*:
My example: I adjust a recipe to better fit my taste or the ingredients or equipment.
Unimportant Very important
Comments/Examples/Suggestions:

23. (extrinsic)*To do something that few others know how to do*:
My example: One thing I like about brewing is that relatively few

people do it.
Unimportant Very important
Comments/Examples/Suggestions:

24. (creation)*To see fruits of labor*:
My example: I get to drink that first beer from a new batch.
Unimportant Very important
Comments/Examples/Suggestions:

25. (extrinsic)*To be better than others*:
My example: Knowing that I make better beer than many people adds something to my enjoyment of the hobby.
Unimportant Very important
Comments/Examples/Suggestions:

26. (creation)*To express yourself*:
My example: Making beer gives me an opportunity to express myself by choosing what kinds of beer to make and what "touches" to add.
Unimportant Very important
Comments/Examples/Suggestions:

27. (learning)*To know about dates, places, people, things*:
My example: Brewing is full of information about the history of brewing, the beer styles and their development.
Unimportant Very important
Comments/Examples/Suggestions:

28. (learning)*To learn strategies and methods*:
My example: In brewing one needs to know different techniques for converting different grains into a good brew.
Unimportant Very important
Comments/Examples/Suggestions:

29. (social)*To share what you've done*:
My example: A big part of the fun of making beer is sharing it with others.
Unimportant Very important
Comments/Examples/Suggestions:

30. (flow)*To feel a sense of control*:
My example: I am able to control all the ingredients and stages of beer making. In everyday life, I am also driven by outside demands.
Unimportant Very important
Comments/Examples/Suggestions:

31. (extrinsic)*To gain social stature*:
My example: Brewing makes me more important and gives me respect

from people who otherwise not want to associate with me.
Unimportant Very important
Comments/Examples/Suggestions:

Finally, I plan to use this data to help design instruction and future studies. One concern with collecting data on the web is that I cannot tell to what extent people have answered accurately or whether they got tired and clicked randomly. Do you think it is you'd give similar responses if you were to do this again?

32. Not a chance I doubt it Maybe probably definitely

I don't think I need any comments from you, but if there's something that you want me to know, feel free to put it here. I promise I'll read it. Comments:

1.2 Student Hobby Survey

Hobby Survey

We are working to understand more about why people choose to spend their free time on particular activities and to what extent some of those same characteristics could apply to time spent in school. *We'd like to answer this survey twice, once for a hobby and once for the class or subject that you enjoy the most.*

For our purposes, your hobby is a non-academic activity that you spend a significant amount of time on. Some examples might be playing chess, video games, role-playing games, or a sport. Perhaps you play a musical instrument or spend a lot of time listening to music in a principled way. Maybe you follow sports with great attention.

There are 25 statements below about what might make your hobby or favorite class enjoyable to you. Please rate how important they are for your enjoyment. If you would like to comment about a statement, for example, how or why it is relevant to you or how it could be made better, please use the comment box. The questions are given in random order, so if you comment on another item, please call it by name rather than number.

To help make the statements more concrete, I have included examples of how these aspect apply to various hobbies.

Thanks,

Jay Pfaffman <pfaffman@relaxpc.com>

Questions

1. Name:

2. Your hobby or activity:

3. How many years have you been doing this activity?
   (less than 1) (1-2) (3-5) (6-10) (more than 10)

4. How rewarding would you say your hobby/class is:
   (Unrewarding) (not very rewarding) (sort of rewarding) (rewarding) (Very rewarding)

5. What is your gender?

(male) (female)

6. On average how many hours per week do you participate in your hobby/class?
   (Less than 1) (2-5) (5-10) (10-20) (more than 20)

   In the following, please rate how important each of these statements is for the *enjoyment* of your hobby/class.

7. (learning)*To read about my hobby*---Model rocketry: I really enjoy reading, and seeing, other people's rockets, whether I get to see them fly or not. I usually try to get an idea for my next rocket.

   Unimportant Very important

   Comments/Examples/Suggestions:

8. (learning)*To know about dates, places, people, things*---Fantasy Baseball: having a knowledge of all the players in the Major Leagues is crucial to your team's success.

   Unimportant Very important

   Comments/Examples/Suggestions:

9. (learning)*To learn about tools*---Baking: When I see some new kithchen tool in a store, I'll start looking for recipes so I can use it.

   Unimportant Very important

   Comments/Examples/Suggestions:

10. (learning)*To learn strategies and methods*---Rock Climbing: Gotta keep learning new strategies to get better on the wall.

    Unimportant Very important

    Comments/Examples/Suggestions:

11. (learning)*To know the little-known facts and stories around your hobby*---Motorcycle Roadracing: It's fun having the inside scoop, and having that feeling of 'I know something the average street rider/racer wannabe doesn't know'.

    Unimportant Very important

Comments/Examples/Suggestions:

12. (extrinsic)*To increase academic or professional success*---Golf: Golf is a common means of business networking.

    Unimportant Very important

    Comments/Examples/Suggestions:

13. (extrinsic)*To be better than others*---Off road motorcycle riding: I hate to admit it, but yes I do really like that I am good at riding, better than most others. It does add to my enjoyment.

    Unimportant Very important

    Comments/Examples/Suggestions:

14. (extrinsic)*To enter competitions or win awards*---Model Rocketry: I confess I was not hot on this originally, but with time, I've gotten addicted to contest rocketry, as a way of exploring the challenges and to find new things.

    Unimportant Very important

    Comments/Examples/Suggestions:

15. (extrinsic)*To do something that few others know how to do*---Playing guitar: It wouldn't be special if everyone could do it.

    Unimportant Very important

    Comments/Examples/Suggestions:

16. (extrinsic)*To gain social stature*---Golf: There is a certain amount of status in the golf club, associated with being better, and it is objectively measured.

    Unimportant Very important

    Comments/Examples/Suggestions:

17. (social)*To be liked*---playing guitar: Showing up at a party with a guitar and playing songs makes people think I'm cool.

    Unimportant Very important

Comments/Examples/Suggestions:

18. (social)*To share what you've done*---Model Rocketry: I enjoy helping others with the hobby. Since model rocketry is somewhat of a niche hobby, every time I help someone else I get a satisfying feeling of contributing to the continuation and longevity of this activity which I enjoy so much.

    Unimportant Very important

    Comments/Examples/Suggestions:

19. (social)*To belong to a group*---Bicycle Racing: Riding for a cycling team provides commeraderie and friendship with people that share the same goals and aspirations.

    Unimportant Very important

    Comments/Examples/Suggestions:

20. (social)*To help others appreciate or participate*---Motorcycle Racing: I enjoy helping others decide whether they're interested in racing, and helping them get into it if they want to.

    Unimportant Very important

    Comments/Examples/Suggestions:

21. (social)*To use the hobby to stimulate conversation*---Bicycle Racing: Bike racing gives me stories to tell and a way to communicate with strangers.

    Unimportant Very important

    Comments/Examples/Suggestions:

22. (creation)*To see fruits of labor*---motorcycle racing: I enjoy seeing my work pay off, and I enjoy seeing others improve whom I have taught.

    Unimportant Very important

    Comments/Examples/Suggestions:

23. (creation)*To adjust or personalize methods*---radio control sailplanes: I prefer building my planes versus buying prefab. That way I can make it my personal best.

Unimportant Very important

Comments/Examples/Suggestions:

24. (creation)*To express yourself*---Motorcycle Racing: It is unusal to be female in this male dominated sport, and I like the shock value that goes with it.

Unimportant Very important

Comments/Examples/Suggestions:

25. (creation)*To find or create something new or rare*---motorcycle restoring: Every custom streetbike and every racebike I've built has been one of a kind - no one else has one like mine.

Unimportant Very important

Comments/Examples/Suggestions:

26. (creation)*To nurture or sustain to completion or maturity*---Model/High Power Rocketry: I like to finish my rockets as close to 'perfect' as possible. A nice shiny smooth paint finish before I fly them for the first time.

Unimportant Very important

Comments/Examples/Suggestions:

27. (flow)*To get lost in time*---Video games: Sometimes I'll think that I've been playing for like 30 minutes and look at the clock to see that it's 5 hours later.

Unimportant Very important

Comments/Examples/Suggestions:

28. (flow)*To feel a sense of control*---Motorcycle Roadracing: Controlling the bike at insanely high speeds in, through, and out of curves adds pride to the simple adrenalin rush we seek. Being my own mechanic, driver, accountant, etc. is like controlling the process to get me to the races.

Unimportant Very important

Comments/Examples/Suggestions:

29. (flow)*To overcome new challenges*---Model Rocketry: I love a good challenge and model rocketry can provide whatever degree or level of challenge you want. I enjoy setting new goals and finding ways of meeting them.

    Unimportant Very important

    Comments/Examples/Suggestions:

30. (flow)*To do something as an end in itself*---Model Rocketry: I really enjoy the process of building my rockets. It's an escape of sorts.

    Unimportant Very important

    Comments/Examples/Suggestions:

31. (flow)*To have clear goals and feedback*---Motorcycle Roadracing: Ultimately I want to win. Measuring my progress with lap times, feedback from others, as well as my level of calmness during races/practice is very important.

    Unimportant Very important

    Comments/Examples/Suggestions:

    Finally, I plan to use this data to help design instruction and future studies. One concern with collecting data on the web is that I cannot tell to what extent people have answered accurately or whether they got tired and clicked randomly. Do you think it is you'd give similar responses if you were to do this again?

32. Not a chance I doubt it Maybe probably definitely

I don't think I need any further comments from you, but if there's something that you want me to know, feel free to put it here. I promise I'll read it. Comments:

1.3 Student Class survey

Favorite Class Survey

We are working to understand more about why people choose to spend their free time on particular activities and to what extent some of those same characteristics could apply to time spent in school. *We'd like to answer two very similar surveys, one for a hobby and this one for the class or subject that you enjoy the most.*

There are 25 statements below about what might make your favorite class enjoyable to you. Please rate how important each is for your enjoyment. If you would like to comment about a statement, for example, how or why it is relevant to you or how it could be made better, please use the comment box. The questions are given in random order, so if you comment on another item, please refer to it by name rather than number.

To help make the statements more concrete, I have included examples of how these aspect may apply to various subjects.

Thanks,

Jay Pfaffman <pfaffman@relaxpc.com>

Questions

1. Name:

2. Your favorite class:

3. How many years have you been taking this class?
   (less than 1) (1-2) (3-5) (6-10) (more than 10)

4. How rewarding would you say your class is:
   (Unrewarding) (not very rewarding) (sort of rewarding) (rewarding) (Very rewarding)

5. What is your gender?
   (male) (female)

6. On average how many hours per week do spent on this class?
   (Less than 1) (1-3) (3-5) (5-10) (more than 10)

   In the following, please rate how important each of these statements is for the *enjoyment* of your class.

7. (learning)*To read about my favorite subject*:---English: I enjoy reading novels and short stories

   Unimportant Very important

   Comments/Examples/Suggestions:

8. (learning)*To know about dates, places, people, things*:---History: I like knowing when things happened and who did them.

   Unimportant Very important

   Comments/Examples/Suggestions:

9. (learning)*To learn about tools*:---Chemistry: It's fun to work with all of the different tools like bunson burners, scales, and pipettes.

   Unimportant Very important

   Comments/Examples/Suggestions:

10. (learning)*To learn strategies and methods*:---Math: I enjoy learning and mastering different techniques and operations for manipulating numbers.

    Unimportant Very important

    Comments/Examples/Suggestions:

11. (learning)*To know the little-known facts and stories around your subject*:---Computer Science is fun because I get to learn lots of things about computers that most people will never know.

    Unimportant Very important

    Comments/Examples/Suggestions:

12. (extrinsic)*To increase academic or professional success*:---Math: Because math comes easy for me, it's a great way to boost my scores to help me get into a good college.

    Unimportant Very important

    Comments/Examples/Suggestions:

13. (extrinsic)*To be better than others*:---Physics: Since most people find physics difficult, I enjoy it because I can easily outperform my classmates on difficult tests.

    Unimportant Very important

    Comments/Examples/Suggestions:

14. (extrinsic)*To enter competitions or win awards*:---Debate: I like being on the debate team because it gives me a chance to enter competitions.

    Unimportant Very important

    Comments/Examples/Suggestions:

15. (extrinsic)*To do something that few others know how to do*:---Latin: I like Latin because the complicated declensions and tenses are something that few people master.

    Unimportant Very important

    Comments/Examples/Suggestions:

16. (extrinsic)*To gain social stature*:---Math: Begin good at math gives me a chance to help my friends learn things that the teacher can't explain to them which has made me a little more popular with some people.

    Unimportant Very important

    Comments/Examples/Suggestions:

17. (social)*To be liked*:---English: English class gives me an opportunity to make some jokes so that people can see how funny I am.

    Unimportant Very important

    Comments/Examples/Suggestions:

18. (social)*To share what you've done*:---English: I've written a few poems and short stories for English that I'm proud of and like hearing what my friends think of them.

    Unimportant Very important

Comments/Examples/Suggestions:

19. (social)*To belong to a group*:---Computer Science: CS is fun because it's a small class so we get pretty close, plus the nature of having to complete programs on a deadline forces us to spend a lot of time together.

    Unimportant Very important

    Comments/Examples/Suggestions:

20. (social)*To help others appreciate or participate*:---English: I really like literature and enjoy discussing it in class to help others learn to appreciate it too.

    Unimportant Very important

    Comments/Examples/Suggestions:

21. (social)*To use the class to stimulate conversation*:---English: Reading lots of different kinds of things in English class is cool because it often gives you something to talk about besides the latest episode of "Friends"

    Unimportant Very important

    Comments/Examples/Suggestions:

22. (creation)*To see fruits of labor*:---Math: After finishing a long math homework assignment I like looking back and seeing my work, all neat and perfect.

    Unimportant Very important

    Comments/Examples/Suggestions:

23. (creation)*To adjust or personalize methods*:---Computer Sciene: I enjoy CS partially because I've created my own set of procedures that I reuse from project to project.

    Unimportant Very important

    Comments/Examples/Suggestions:

24. (creation)*To express yourself*:---English: I like English because it gives me a chance to put my own spin on the things that we have read.

Unimportant Very important

Comments/Examples/Suggestions:

25. (creation)*To find or create something new or rare*:---Geometry: Geometry is fun because proofs have many solutions and I enjoy finding the most elegant and creative solutions.

    Unimportant Very important

    Comments/Examples/Suggestions:

26. (creation)*To nurture or sustain to completion or maturity*:---Economics: I enjoyed the end-of-semester project in economics because I was able to spend a lot of time getting a substantial piece of work over a long peiod of time.

    Unimportant Very important

    Comments/Examples/Suggestions:

27. (flow)*To get lost in time*:---English: It doesn't happen all the time, but sometimes the things we read in English are so engaging that I read for hours without noticing the time passing.

    Unimportant Very important

    Comments/Examples/Suggestions:

28. (flow)*To feel a sense of control*:---Computer Science: I like working with computers because they always do what I tell them to do, even if I tell them wrong.

    Unimportant Very important

    Comments/Examples/Suggestions:

29. (flow)*To overcome new challenges*:---Math: Math can be fun because each new chapter provides a different set of problems to understand and master.

    Unimportant Very important

    Comments/Examples/Suggestions:

30. (flow)*To do something as an end in itself*:---English: I enjoy

reading, writing, and talking about things that I've read, so English class is quite enjoyable.

Unimportant Very important

Comments/Examples/Suggestions:

31. (flow)*To have clear goals and feedback*:---Math: I like math because most problems have a fixed answer, so the work I do is clearly right or wrong.

    Unimportant Very important

    Comments/Examples/Suggestions:

    Finally, I plan to use this data to help design instruction and future studies. One concern with collecting data in schools is that I cannot tell to what extent people have answered accurately or whether they were bored clicked randomly. Do you think it is you'd give similar (not exactly the same) responses if you were to do this again next week?

32. Not a chance I doubt it Maybe probably definitely

I don't think I need any further comments from you, but if there's something that you want me to know, feel free to put it here. I promise I'll read it. Comments:

APPENDIX B

WORKSHEETS

2.1 Activity 1—Simulation: Grass and Populations

Name ___________________ Class: ___________

In this set of activities, you will use NetLogo to simulate ecosystems. The goal is to determine what makes an ecosystem balance. For each simulation challenge, you will design a simulation to meet a certain goal and fill in some information in the worksheet. If you are interested, each web page describing the simulation challenge also has a link that provides information about the biology of each simulation (click on "Notes on this simulation"). There are also links that show the NetLogo code for each simulation.

Connecting to the File Server

1. Go to the Chooser and click on Appleshare
2. Click on the **Adelante Main** group
3. Select the **Stanford** server
4. Username: Your lastname plus your first initial (John Smith would be smithj—no spaces, no capitals)
5. Password: Same as your username

You will be saving your simulations on the file server and will be able to access them in later classes or from home over the Internet.

Getting Hints and Instructions

For each of these challenges you'll be able to get hints and information about the simulations from the Internet. You can find these instructions at http://aaalab.stanford.edu/models/.

Note:

Please write your name on every page. They're stapled now, but they might get separated in the future.

Be sure to save your simulation before going to the next page!

Name ___________________ Class: ___________

Challenge1--Many wolves and few sheep.

For this challenge you'll be starting with the simulation called "wolves.nlogo" (on the server) and changing initial values of some variables to demonstrate certain effects.

Run the simulation (by clicking "setup"then "go") . Each time waiting until the results are clear.

1. **Changing only the initial number of wolves, create an ecosystem that does not allow the sheep population to increase.**

   Rules:

   a) Initial-number-sheep = 300

   b) grass is **off**

2. Run your model several times to make sure that it always (or at least usually) does what you want it to.
3. Fill in the table below with an example of how the system usually runs.
4. When you have your solution, save it as `challenge1.nlogo`. (Use **File/Save As)**
5. Answer the questions below

	Typical Performance	
	Wolves	Sheep
Starting Population		
Maximum Population		
Time of Maximum Population		
Minimum Population		
Time of Minimum Population		

a) What usually happened to the wolves?

b) Why did it happen to the wolves?

Be sure to save your simulation before going to the next page!

Name ___________________ Class: ___________

Challenge 2: Few Wolves and Many Sheep

1. **Create an ecosystem that allows the sheep to increase at first, but die out in the end.**

   Rules:

   grass is **off**

2. Run your model several times to make sure that it always (or at least usually) does what you want it to.
3. Fill in the table below with an example of how the system usually runs.
4. When you have your solution, save it as `challenge2.nlogo`. (Use **File/Save As**)
5. Answer the questions below

	Typical Performance	
	Wolves	Sheep
Starting Population		
Maximum Population		
Time of Maximum Population		
Minimum Population		
Time of Minimum Population		

b) What happened to the wolves?

c) What was different about this simulation from the last one?

c) Why did this new pattern happen?

Be sure to save your simulation before going to the next page!

Name ___________________ Class: ___________

Challenge3--Many wolves and few sheep with grass.

1. **Changing only the initial number of wolves, create an ecosystem that does not allow the sheep population to increase**.

   Rules: (same as Challenge 1, but turn on grass)
   a) Initial-number-sheep = 300
   b) grass is **on**

2. Run your model several times to make sure that it always (or at least usually) does what you want it to.
3. Fill in the table below with an example of how the system usually runs.
4. When you have your solution, save it as `challenge3.nlogo`. (Use **File/Save As)**
5. Answer the questions below

	Typical Performance	
	Wolves	Sheep
Starting Population		
Maximum Population		
Time of Maximum Population		
Minimum Population		
Time of Minimum Population		

A. What happened to the wolf population?

B. How was this different from the same simulation without grass?

C. Why did this happen?

Be sure to save your simulation before going to the next page!

Name ___________________ Class: ___________

Challenge 4: Adding grass to the Many Sheep simulation.

1. **Create an ecosystem that runs for at least 1000 time-ticks without either the sheep or the wolves dying off.**
   Rules:
   None

2. Run your model several times to make sure that it always (or at least usually) does what you want it to.
3. Fill in the table below with an example of how the system usually runs.
4. When you have your solution, save it as `challenge4.nlogo.` (Use **File/Save As**)
5. Answer the questions below

	Typical Performance	
	Wolves	Sheep
Starting Population		
Maximum Population		
Time of Maximum Population		
Minimum Population		
Time of Minimum Population		

b) What happened to the wolf population?

c) How did this simulation behave compared to the others?

d) Why does the grass make a difference in this simulation?

Be sure to save your simulation before going to the next page!

2.2 Activity 2—Programming: Balancing Ecosystems

Name ____________________ Server number: A_____

Energy and Reproduction Challenges

In this set of activities, you will use NetLogo to simulate ecosystems. The goal is to determine what makes an ecosystem balance. You will save each version of your program on the server.

Connecting to the File Server

1. Go to the Chooser and click on Appleshare
2. Click on the **Adelante Main** group
3. Select the **Stanford** server
4. Username: Your lastname plus your first initial (John Smith would be smithj—no spaces, no capitals)
5. Password: Same as your username

You will be **saving your simulations on the file server** and will be able to access them in later classes or from home over the Internet.

Getting Hints and Instructions

1. For each of these challenges you'll be able to get hints and information about the simulations from the Internet. You can find these instructions at http://aaalab.stanford.edu/models/.

Note:

Please write your name on every page. They're stapled now, but they might get separated in the future.

Name ____________________ Server number: A_____

Customizing Your Program: A Balancing Act

For this challenge you'll be starting with the simulation called "p2.nlogo" (on the server) to try to find different ways to make it balance.

The goal: Find as many ways as possible to create a stable ecosystem.

Rules:

Your system must run twice to 500 clock-ticks.

FILENAME: ______________________

	Trial 1		Trial 2	
	Sheep	Wolves	Sheep	Wolves
Starting Population				
Maximum Population				
Minimum Population				
Typical Population				

1) Describe your solution (mention *all* variables changed):

2) How is this solution good for sheep?

3) How is this solution good for wolves?

4) How is this solution good for hunters?

2.3 Activity 3—Observation: Reproduction Rates

Name ____________________

In this set of activities, you will use NetLogo to simulate ecosystems. The goal is to determine what makes an ecosystem balance. For each experimental simulation, you need to fill in some information in the worksheet. If you are interested, each web page that has a simulation also has a link that provides information about the biology of each simulation (click on “Notes on this simulation”). There are also links that show the NetLogo code for each simulation.

Today you won't be using the NetLogo appication, but instead will use NetLogo programs in a web browser. Go to http://aaalab.stanford.edu/logo/ to begin.

Name ____________________

1) Experiment 1: Lo Grass - Lo Sheep - Hi Wolves

Run the simulation (by clicking “setup”then “go”) twice. Each time waiting until the results are clear.

	Trial 1			**Trial 2**		
	Wolves	Sheep	Grass	Wolves	Sheep	Grass
Grass Regrowth time				Grass Regrowth time		
Reproduction rate						
Maximum population						
Max Pop. time						
Minimum population						
Min. Pop. Time						

What happened to the wolves?

What happened to the sheep?

Why did this new pattern happen?

Name ____________________

Experiment 2: Hi Grass - Lo Sheep - Hi Wolves

Run the simulation (by clicking “setup”then “go”) twice. Each time waiting until the results are clear.

	Trial 1			**Trial 2**		
	Wolves	Sheep	Grass	Wolves	Sheep	Grass
Grass Regrowth time				Grass Regrowth time		
Reproduction rate						
Maximum population						
Max Pop. time						
Minimum population						
Min. Pop. Time						

What is different about this simulation than the last one?

What happened to the wolves?

What happened to the sheep?

Why did this new pattern happen?

Name ____________________

Experiment 3: Hi Grass - Lo Sheep - Lo Wolves

Run the simulation (by clicking “setup”then “go”) twice. Each time waiting until the results are clear.

	Trial 1			**Trial 2**		
	Wolves	Sheep	Grass	Wolves	Sheep	Grass
Grass Regrowth time				Grass Regrowth time		
Reproduction rate						
Maximum population						
Max Pop. time						
Minimum population						
Min. Pop. Time						

What is different about this simulation than the last one?

What happened to the wolves?

What happened to the sheep?

Why did this new pattern happen?

Name ____________________

Experiment 4: Lo Grass - Lo Sheep - Lo Wolves

Run the simulation (by clicking “setup”then “go”)   twice. Each time waiting until the results are clear.

	Trial 1			**Trial 2**		
	Wolves	Sheep	Grass	Wolves	Sheep	Grass
Grass Regrowth time				Grass Regrowth time		
Reproduction rate						
Maximum population						
Max Pop. time						
Minimum population						
Min. Pop. Time						

What is different about this simulation than the last one?

What happened to the wolves?

What happened to the sheep?

Why did this new pattern happen?

APPENDIX C

TESTS

3.1 Demographic Questionnaire and Grass and Populations Pre-Test

- Group A took this test day A1, 5/09.
- Group B took this test day B1, 5/13.

Name: Date:

1. How many days a week do you use the Internet at home?

0	1	2	3	4	5	6	7

2. If you use the Internet at home, do you have to "dial-up" (make a phone connection?)

   Yes No

3. How do you feel during a math test that is going badly?

I want to do something different	1	2	3	4	5	6	7	I want to keep doing it

4. How do you feel when you are sharing a good idea with a friend?

I want to do something different	1	2	3	4	5	6	7	I want to keep doing it

5. How do you feel when you are making something new and different

I want to do something different	1	2	3	4	5	6	7	I want to keep doing it

6. Lions do not eat plants. List 3 reasons that plants are important to lions.

7. List 3 reasons that the government sometimes allows hunting

8. How can too many deer hurt the wolf population?

9. List 3 ways to control the population of deer

3.2 Grass and Populations Post-Test and Balancing Ecosystems Pre-Test

Name ____________________ Class: ___________

1. In the Sheep/Wolf simulation, exlain what happens to the sheep population when the grass turned off and there are no wolves.

2. In the Sheep/Wolf simulation, explain what happens to the sheep population when the grass turned on and there are no wolves.

3. If a system with only grass and sheep is in balance, explain what would happen to the sheep population if the grass started growing back faster.

4. What different things might happen in a wolf/sheep system if the wolves could also eat and gain energy from grass?

3.3 Reproduction Rates Pre-Test and Balancing Ecosystems Post-Test

Note: Also includes Balancing Post-test given a 3rd time. These data are ignored.

7A-final includes reproduction and grass.

Name: ____________________ Class: ___________

1. Try to design a balanced eco-system. Choose how fast the grass, sheep, and wolves need to reproduce to make it balanced:

	Reproduction Rate (choose one)		
	High	Low	Doesn't Matter
Grass			
Sheep			
Wolves			

Why did you choose this answer?

2. Which part of the food chain needs to reproduce the fastest? Explain why.

3. Why do you think elephants only have one baby every four years?

4. Circle the one of these that is at the bottom of its food chain:

   Sharks, seahorses, seaweed, fish.

   Explain why you chose your answer.

Name: ____________________ Class: ____________

5. In the Sheep/Wolf simulation, explain what happens to the sheep population when the grass turned off and there are no wolves.

6. In the Sheep/Wolf simulation, explain what happens to the sheep population when the grass turned on and there are no wolves.

1. If a system with only grass and sheep is in balance, explain what would happen to the sheep population if the grass started growing back faster.

2. What different things might happen in a wolf/sheep system if the wolves could also eat and gain energy from grass?

Name: ____________________ Class: ___________

3. Lions do not eat plants. List 3 reasons that plants are important to lions.

4. List 3 reasons that the government sometimes allows hunting

5. How can too many deer hurt the wolf population?

6. List 3 ways to control the population of deer:

3.4 Reproduction Rate Post-Test

Name: ____________________ Class: ___________

1. Try to design a balanced eco-system. Choose how fast the grass, sheep, and wolves need to reproduce to make it balanced:

	Reproduction Rate (choose one)		
	High	Low	Doesn't Matter
Grass			
Sheep			
Wolves			

Why did you choose this answer?

2. Which part of the food chain needs to reproduce the fastest? Explain why.

1. Why do you think elephants only have one baby every four years?

2. Circle the one of these that is at the bottom of its food chain:

   Sharks, seahorses, seaweed, fish.

   Explain why you chose your answer.

3.5 Post-Test Engagement Survey

VS

Working with Sliders	Changing the Program
• Use sliders to make the system perform in a certain way • Save your program to the server • record your results in the table	• Develop different ways to make a system that balances • Change your program by changing colors, adding hunters, changing `grass-regrowth-rate`, etc. • record your results in the table • Save your program to the server

1. Circle the activity you liked better:

   Working with Sliders **Changing the Program**

2. What was **good** about the one you liked?

3. What was **bad** about the one you **didn't** like?

4. How would you make them better?

VS

Changing the Program	**Running Experiments**
• Develop different ways to make a system that balances • Change your program by changing colors, adding hunters, changing `grass-regrowth-rate`, etc. • record your results in the table • Save your program to the server	• Run the simulation with the sliders pre-set • record your results in the table

1. Circle the activity you liked better:

   Changing the Program **Running Experiments**

2. What was **good** about the one you liked?

3. What was **bad** about the one you **didn't** like?

4. How would you make them better?

VS

Running Experiments	**Working with Sliders**
• Run the simulation with the sliders pre-set • record your results in the table	• Use sliders to make the system perform in a certain way • Save your program to the server • record your results in the table

1. Circle the activity you liked better:

   Running Experiments **Working with Sliders**

2. What was **good** about the one you liked?

3. What was **bad** about the one you **didn't** like?

4. How would you make them better?

1. Did you look at your NetLogo programs on the web?

   YES **NO**

   Why or why not?

2. What was your favorite part of the activities we did with NetLogo?

3. What was your **least** favorite part of the activities we did with NetLogo?

4. How would you change the NetLogo activities to **make them more fun?**

5. How would you change the NetLogo activities to **make you learn more?**

APPENDIX D

CONSENT FORMS

4.0.1 English

For questions about the study contact:
Professor Daniel Schwartz, Stanford University
Phone (650) 736-1514

You are invited to participate in a research study on learning. You and your classmates will work on new kinds of science and mathematics lessons with the computer. Afterward, we will see how much you have learned by giving you new problems to solve and asking questions. We will also videotape the class so we can see how everyone works with the computers. By participating, you will help us figure out how to teach students in schools across the country.

The study will last for approximately 10-15 hours. It should be fun and help you learn, and it should not cause you to feel uncomfortable.

As part of this research project, we will make a videotape recording of students participating. These videotapes serve as data will only be seen by the research staff. However, if you further consent, the tapes may be seen by other researchers and may be used to help disseminate the work. Your name would not be identified. We would like you to indicate what uses of this videotape you consent to by initialing below. You are free to initial any number of spaces from zero to all of the spaces, and your response will in no way affect your credit for participating. We will use the video only in ways that you agree to. If you do initial any space below, the project director is committed by scientific standards to retain the tapes as data for a ten years, after which time, they will be destroyed.

We hope you agree to participate. All your work will be kept private. When we present the results of the study, nobody will know that you were involved. You can always change your mind at anytime and withdraw your consent. You can refuse to answer specific questions. If you decide that you do not want to participate, we will not use your work or videotape in our research. There is no payment for participating. Your decision whether you want to participate will not change your grade in the class.

If you have any questions about the study, or if you are not sure you understand this form, please ask your teacher, your parents, or the research staff to help explain.

If something about the study bothers you and you do not feel comfortable telling your teacher or research staff, you may call the Administrative Panels Office of Stanford University, Stanford at (650) 723-2480.

Please initial all those uses of video that you accept.

The videotape can be studied by the research team for use in the research project.
please initial: _________

The videotape can be shown to subjects in other experiments.
please initial: __________

The videotape can be used for scientific publications.
please initial: ____________

The videotape can be shown at meetings of scientists interested in education and technology.
please initial: __________

The videotape can be shown in classrooms to students.
please initial: _____________

The videotape can be shown in public presentations to nonscientific groups.
please initial: ______________

The videotape can be used on television and radio.
please initial: __________

I have read the above description and give my consent to participate in the study and for the use of the videotape as indicated above.

SIGNATURE: _____________________________

DATE ____________

Print your name clearly: _____________________________

Approval Date: October 25, 2002
Expiration Date: October 25, 2003

FOR QUESTIONS ABOUT THE STUDY, CONTACT:
Professor Daniel L. Schwartz, School of Education, 485 Lasuen Mall, Office 304. Phone 736-1574.

DESCRIPTION: Your child is invited to participate in a research study on ways to help students learn mathematics, science, and logical thinking that are fun and effective. As part of the regular classroom activities, your child will work with computer programs that they teach, called Teachable Agents. Afterward, they will see how well their agent performs, and they will have a chance to revise their agent to do better. To better understand the effects of these tools on your child's learning, we will ask your child to answer paper and pencil questions about what they have learned.

RISKS AND BENEFITS: The benefits of this study are that participants should learn more about math, science, computers, and logical thinking. We do not foresee any risks or discomforts. There is no payment for participating in this research. The decision whether or not to participate in this study will not affect student grades or participation in other activities. Students will have an opportunity to complete other class work if you would prefer they not participate.

TIME INVOLVEMENT: Your child's participation in this experiment will last approximately 10 to 15 hours over several days.

VIDEOTAPING: As part of this research project, we will make a videotape recording of students participating in the study. These videotapes serve as data and will only be seen by the research staff. However, if you further consent, the tapes may be seen by other researchers and may be used to help disseminate the work. Your child's name would not be identified. We would like you to indicate what uses of this videotape you consent to by initialing below. You are free to initial any number of spaces from zero to all of the spaces, and your response will in no way affect the credit for participating. We will only use the videotape in ways that you agree to. If you do initial any space below, the project director is committed by scientific standards to retain the tapes as data for ten years, after which time, they will be destroyed.

SUBJECT'S RIGHTS: If you have read this form and have decided to participate in this project, please understand that participation is voluntary and you have the right to withdraw your consent or discontinue participation at any time without penalty. Your child has the right to refuse to answer particular questions. You and your child's individual privacy will be maintained in all published and written data resulting from the study.

If you have questions about you or your child's rights as a study participant, or are dissatisfied at any time with any aspect of this study, you may contact - anonymously, if you wish - the Administrative Panels Office, Stanford University, Stanford, CA (USA) 94305-5401 (or by phone (650) 723- 2480 - you may call collect).

Please initial all those uses of video that you accept.

The videotape can be studied by the research team for use in the research project.
parent please initial: __________

The videotape can be shown to subjects in other experiments.
parent please initial: __________

The videotape can be used for scientific publications.
parent please initial: __________

The videotape can be shown at meetings of scientists interested in education and technology.
parent please initial: __________

The videotape can be shown in classrooms to students.
parent please initial: __________

The videotape can be shown in public presentations to nonscientific groups.
parent please initial: __________

The videotape can be used on television and radio.
parent please initial: __________

I have read the above description and give my consent for my child's participation in the study and for the use of the videotape as indicated above.

The extra copy of this consent form is for you to keep.

PARENT SIGNATURE
________________________________ DATE _____________

YOUR CHILD'S NAME

____

Approval Date: 10/31/02
Expiration Date: 10/30/03

4.0.2 Spanish

Si tienes preguntas sobre el estudio llama a:
Profesor Daniel Schwartz, Universidad de Stanford
Teléfono: (650) 736-1514

Estás siendo invitado/a a participar en un estudio de investigación sobre el aprendizaje. Tú y tus compañeros trabajarán en nuevos tipos de lecciones de ciencia y matemática con la computadora. Después, para ver cuánto han aprendido, les daremos nuevos problemas para resolver y les haremos preguntas. Además vamos a filmar la clase, así podemos ver como todos trabajan con las computadoras. Con tu participación, nos ayudarás a darnos cuenta de cómo enseñar a los estudiantes en las escuelas en todo el país.

El estudio tomará aproximadamente 10-15 horas. Debería ser divertido y ayudarte a aprender, y no debería causar que sientas ninguna incomodidad.

Como parte de este proyecto de investigación, filmaremos a los estudiantes que participen. Estas filmaciones sirven como datos y sólo serán vistas por el equipo de investigadores. Sin embargo, si nos das permiso, las filmaciones pueden ser vistas por otros investigadores y pueden ser usadas para ayudar diseminar el trabajo. Tu nombre no sería identificado. Nos gustaría que nos indicaras para cuáles usos de esta filmación nos das permiso poniendo tus iniciales abajo. Eres libre de poner tus iniciales en cualquier número de espacios, desde cero a todos los espacios, y tu respuesta no afectará de ninguna manera tu mérito por participar. Usaremos la filmación sólo en las maneras para las cuales nos des permiso. Si pones tus iniciales en algún espacio abajo, el director del proyecto, de acuerdo con las reglas científicas, debe conservar las filmaciones como datos por diez años, después de los cuales serán destruídas.

Esperamos que estés de acuerdo con participar. Todo tu trabajo se mantendrá privado. Cuando presentemos los resultados del estudio, nadie sabrá que tú has estado involucrado/a. Puedes siempre cambiar de opinión en cualquier momento y retirar tu consentimiento de participar. Puedes negarte a responder cualquier pregunta específica. Si decides que no quieres participar, no usaremos ni tu trabajo ni tu filmación en nuestra investigación. No recibirás pago por participar. Tu decisión de si quieres participar ó no no cambiará tu nota en la clase.

Si tienes cualquier pregunta sobre el estudio, o si no estás seguro/a de si entiendes este formulario, por favor, pídele a tu maestra/o, tus padres, ó los investigadores que te expliquen.

Si te molesta cualquier cosa sobre el estudio, y no te sientes cómodo/a de preguntarle a la/el maestra/o ó a los investigarores, puedes llamar a la Oficina de Paneles Administrativos (Administrative Panels Office) de la Universidad de Stanford al (650) 723-2480.

Por favor, pone tus iniciales para todos los usos de la filmación que tú aceptas.

La filmación puede ser estudiada por el equipo de investigadores para uso en el proyecto de investigación.
Por favor pone tus iniciales: __________

La filmación puede ser mostrada a participantes en otros experimentos.
Por favor pone tus iniciales: __________

La filmación puede ser usada para publicaciones científicas.
Por favor pone tus iniciales: __________

La filmación puede ser mostrada en reuniones de científicos interesados en educación y tecnología.
Por favor pone tus iniciales: __________

La filmación puede ser mostrada en clases a los estudiantes.
Por favor pone tus iniciales: __________

La filmación puede ser mostrada en presentaciones públicas a grupos no científicos.
Por favor pone tus iniciales: __________

La filmación puede ser usada en la televisión y la radio.
Por favor pone tus iniciales: __________

He leído la descripción arriba y doy mi consentimiento para participar en el estudio y para los usos de la filmación de acuerdo a lo indicado arriba.

FIRMA: ________________________________

FECHA: ________________________________

Escribe tu nombre en letra de imprenta claramente: ______________________________

Fecha de aprobación: 25 de Octubre de 2002
Fecha de vencimiento: 25 de Octubre de 2003

SI TIENE PREGUNTAS SOBRE EL ESTUDIO CONTACTE A:
Profesor Daniel L. Schwartz, School of Education, 485 Lasuen Mall, Oficina 304.
Teléfono: (650) 736-1574

DESCRIPCION: Su hijo/a está siendo invitado/a a participar en un estudio de investigación sobre maneras de ayudar a los estudiantes a que aprendan matemática, ciencia, y razonamiento lógico de una manera divertida y eficaz. Como parte de sus actividades habituales en la clase, su hijo/a trabajará con programas de computación que enseñan; estos programas se llaman Teachable Agents. Después, veremos qué tan bien anda el programa y tendremos la posibilidad de revisarlo para que ande mejor. Para entender mejor los efectos de estas herramientas en el aprendizaje de su hijo/a, le pediremos a su hijo/a que conteste preguntas en papel y lapiz sobre lo que ha aprendido.

RIESGOS Y BENEFICIOS: Los beneficios de este estudio son que los participantes deberían aprender más sobre matemática, ciencia, computadoras, y razonamiento lógico. No anticipamos ningún riesgo o incomodidad. No hay pago por participar en esta investigación. La decisión de participar ó no participar en este estudio no afectará las notas de los estudiantes o su participación en otras actividades. Los estudiantes tendrán la oportunidad de completar otro trabajo escolar si Ud. prefiere que no participe.

DURACION: La participación de su hijo/a en este experimento llevará aproximadamente 10 a 15 horas distribuídas en varios días.

FILMACION: Como parte de este proyecto de investigación, filmaremos a los estudiantes que participen en el estudio. Estas filmaciones sirven como datos y sólo serán vistas por el equipo de investigadores. Sin embargo, si nos da su permiso, las filmaciones pueden ser vistas por otros investigadores y pueden ser usadas para ayudar diseminar el trabajo. El nombre de su hijo/a no sería identificado. Nos gustaría que nos indicara para cuáles usos de esta filmación Ud. da permiso, poniendo sus iniciales abajo. Está libre de poner sus iniciales en cualquier número de espacios, desde cero a todos los espacios, y su respuesta no afectará de ninguna manera el mérito por participar. Usaremos la filmación sólo en las maneras que Ud. esté de acuerdo. Si pone sus iniciales en algún espacio abajo, el director del proyecto, de acuerdo con las reglas científicas, debe conservar las filmaciones como datos por diez años, después de los cuales serán destruídas.

DERECHOS DE LOS PARTICIPANTES: Si ha leído este formulario y ha decidido participar en este proyecto, por favor comprenda que la participación es voluntaria y que tiene el derecho de retirar su consentimiento o dejar de participar en cualquier momento sin penalidad. Su hijo/a tiene el derecho de negarse a responder preguntas especifícas. Su privacidad individual así como la de su hijo/a será mantenida en todos los datos que se publiquen y escriban como resultado de este estudio.

Si tiene cualquier pregunta sobre sus derechos ó los de su hijo/a como participante en el estudio, ó está disatisfecho/a en cualquier momento con cualquier aspecto de este estudio, puede contactar – anónimamente si lo desea – a la Oficina de Paneles Administrativos (Administrative Panels Office), Stanford University, Stanford, CA (USA) 94305-5401 (ó por teléfono (650) 723-2480 – puede llamar por cobrar).
Por favor, ponga sus iniciales para los usos de la filmación que Ud. acepta.

La filmación puede ser estudiada por el equipo de nvestigadores para uso en el proyecto de investigación.
Por favor ponga sus iniciales: _________

La filmación puede ser mostrada a participantes en otros experimentos.
Por favor ponga sus iniciales: _________

La filmación puede ser usada para publicaciones científicas.
Por favor ponga sus iniciales: _________

La filmación puede ser mostrada en reuniones de científicos interesados en educación y tecnología.
Por favor ponga sus iniciales: _________

La filmación puede ser mostrada en clases a los estudiantes.
Por favor ponga sus iniciales: _________

La filmación puede ser mostrada en presentaciones públicas a grupos no científicos.
Por favor ponga sus iniciales: _________

La filmación puede ser usada en la televisión y la radio.
Por favor ponga sus iniciales: _________

He leído la descripción de arriba y doy mi consentimiento para que mi hijo/a participe en el estudio y para los usos de la filmación de acuerdo a lo indicado arriba.

La copia extra de este formulario de consentimiento es para que Ud. se la quede.

FIRMA DEL PADRE/MADRE/TUTOR: _______________________________

FECHA: _______________________________

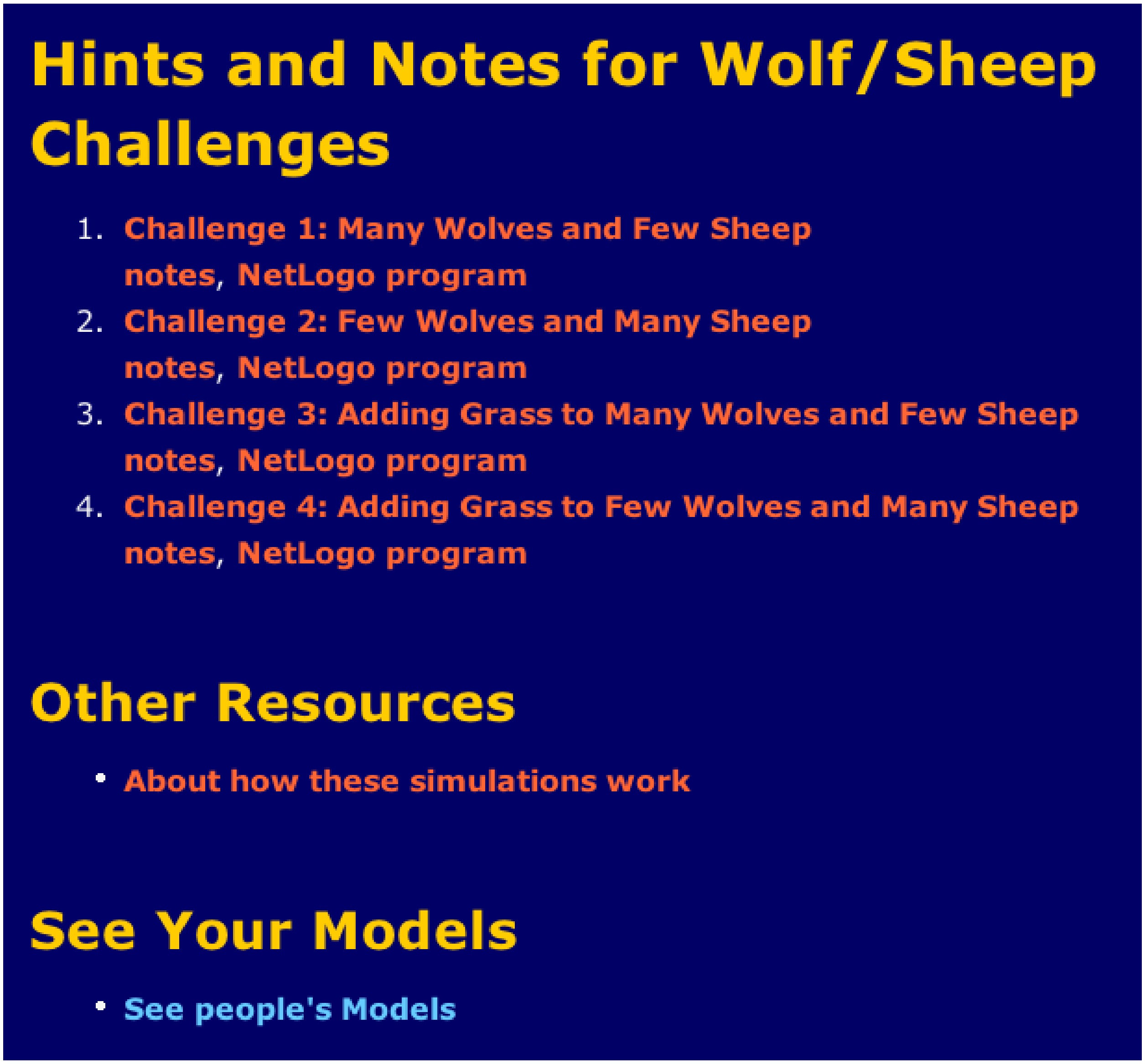
Nombre de su hijo/a _____________________________

Fecha de aprobación: 31 de Octubre de 2002
Fecha de vencimiento: 30 de Octubre de 2003

APPENDIX E

NETLOGO PROGRAMS AND SUPPORTING WEB PAGES

5.1 Simulation Activities



Hints and Notes for Wolf/Sheep Challenges

1. Challenge 1: Many Wolves and Few Sheep
   notes, NetLogo program
2. Challenge 2: Few Wolves and Many Sheep
   notes, NetLogo program
3. Challenge 3: Adding Grass to Many Wolves and Few Sheep
   notes, NetLogo program
4. Challenge 4: Adding Grass to Few Wolves and Many Sheep
   notes, NetLogo program

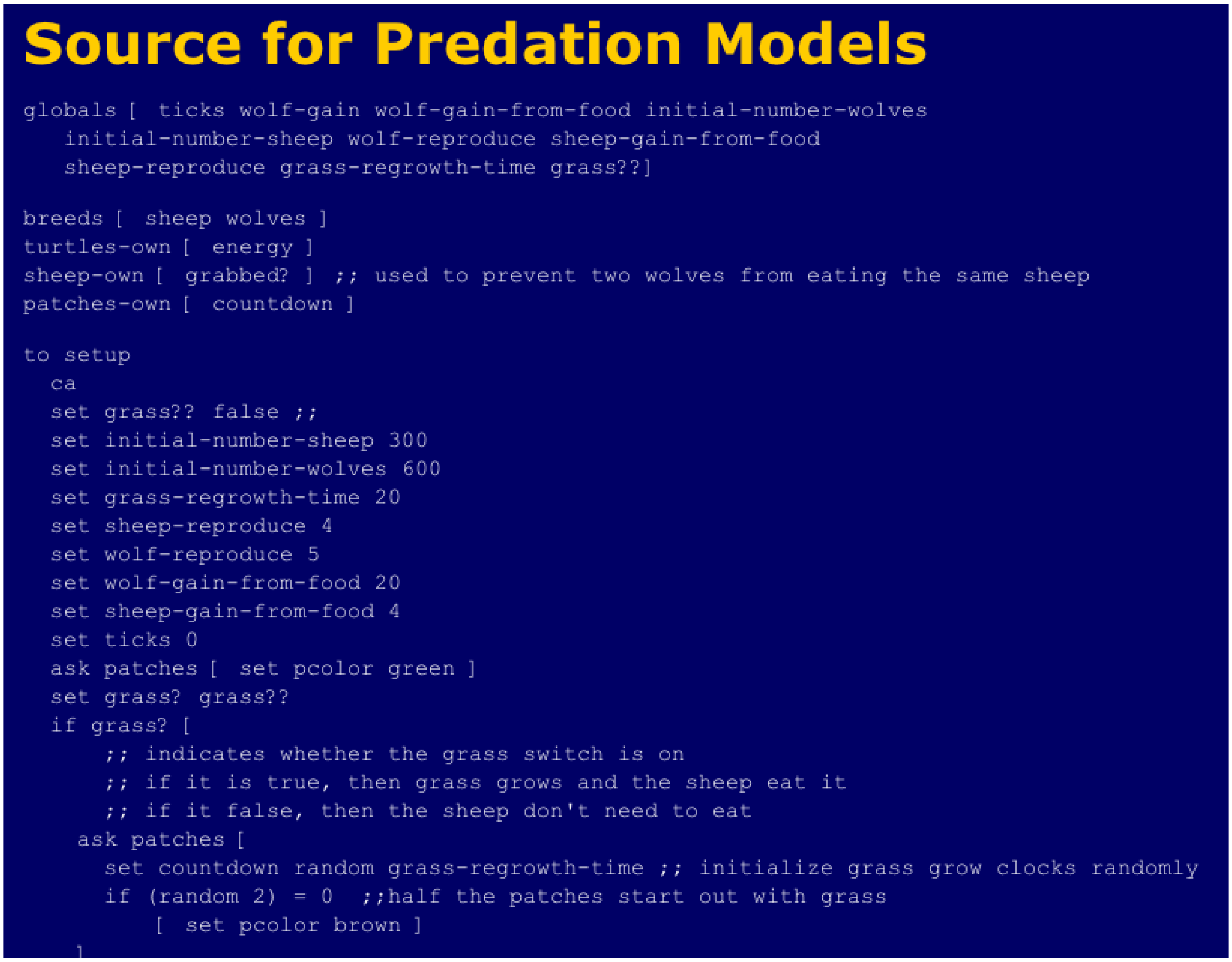
Other Resources

- About how these simulations work

See Your Models

- See people's Models

Figure 21: List of resources for Simulation activities



Source for Predation Models

```
globals [  ticks wolf-gain wolf-gain-from-food initial-number-wolves
   initial-number-sheep wolf-reproduce sheep-gain-from-food
   sheep-reproduce grass-regrowth-time grass??]

breeds [  sheep wolves ]
turtles-own [  energy ]
sheep-own [  grabbed? ] ;; used to prevent two wolves from eating the same sheep
patches-own [  countdown ]

to setup
  ca
  set grass?? false ;;
  set initial-number-sheep 300
  set initial-number-wolves 600
  set grass-regrowth-time 20
  set sheep-reproduce 4
  set wolf-reproduce 5
  set wolf-gain-from-food 20
  set sheep-gain-from-food 4
  set ticks 0
  ask patches [  set pcolor green ]
  set grass? grass??
  if grass? [
      ;; indicates whether the grass switch is on
      ;; if it is true, then grass grows and the sheep eat it
      ;; if it false, then the sheep don't need to eat
    ask patches [
      set countdown random grass-regrowth-time ;; initialize grass grow clocks randomly
      if (random 2) = 0  ;;half the patches start out with grass
          [  set pcolor brown ]
    ]
```

Figure 22: Viewing source code for challenge 1.

Experiment 1: Lo Grass - Lo Sheep - Hi Wolves

Lo Grass - Lo Sheep - Hi Wolves
Wolves are at the top of their food chain. They are predators.
Wolves eat sheep. Animals at the top of the food chain need to
reproduce slowly. If animals at the top of the food chain
reproduce too quickly, there will be too many of them. They
will eat their food supplies and die.

close window

Figure 23: Resource for challenge 1.

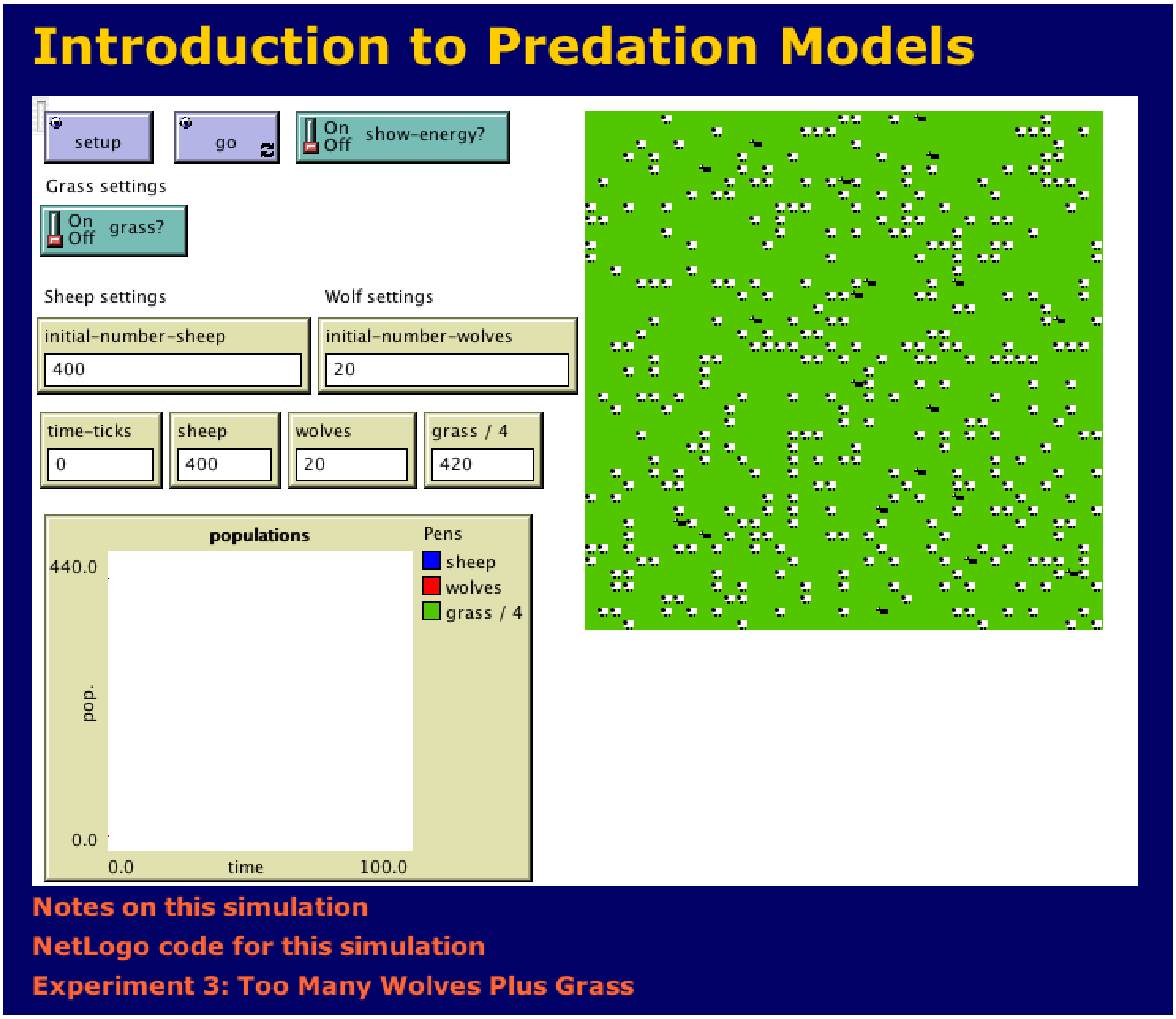


Figure 24: Initial view of program 2

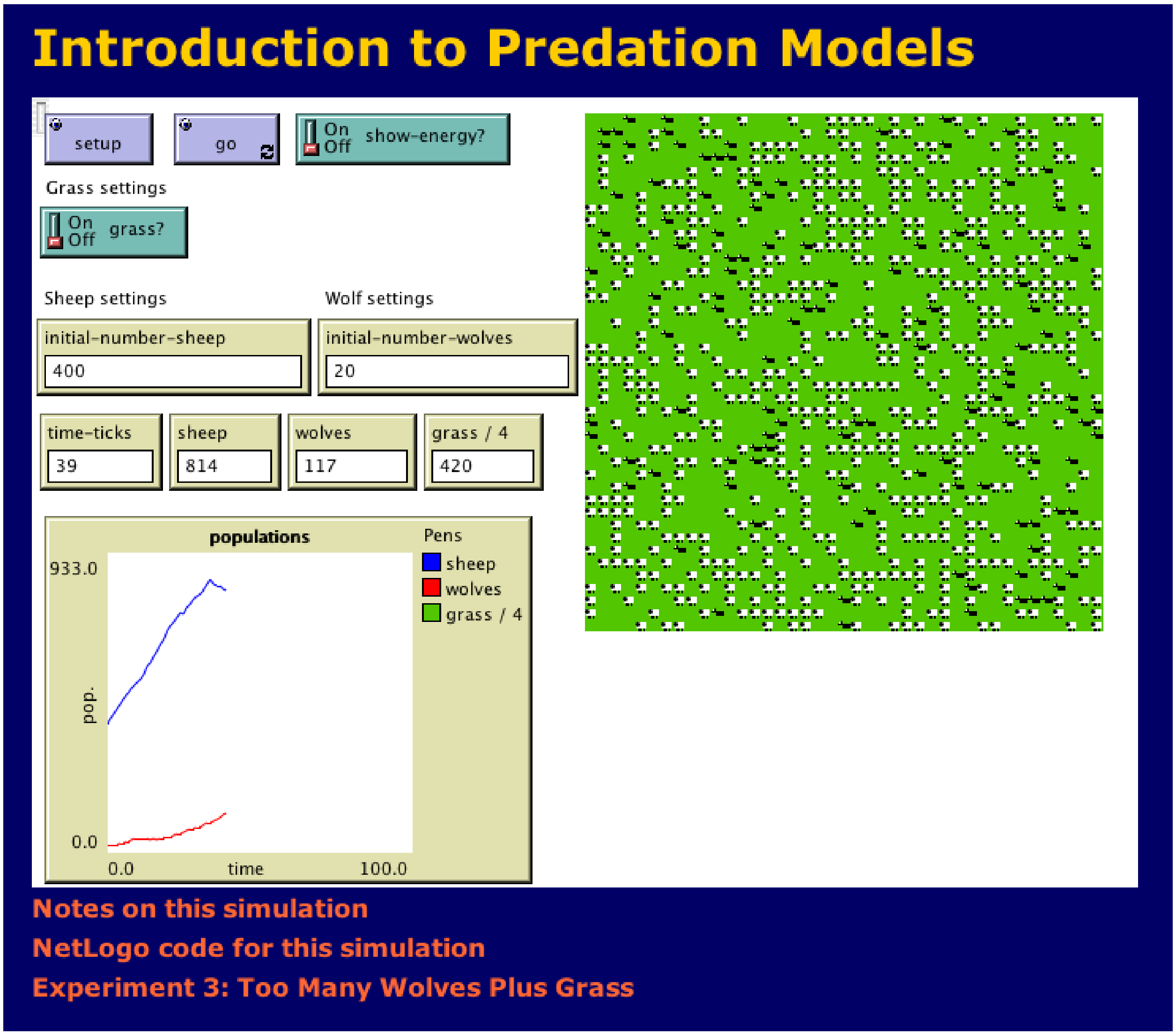


Figure 25: Program for challenge 2

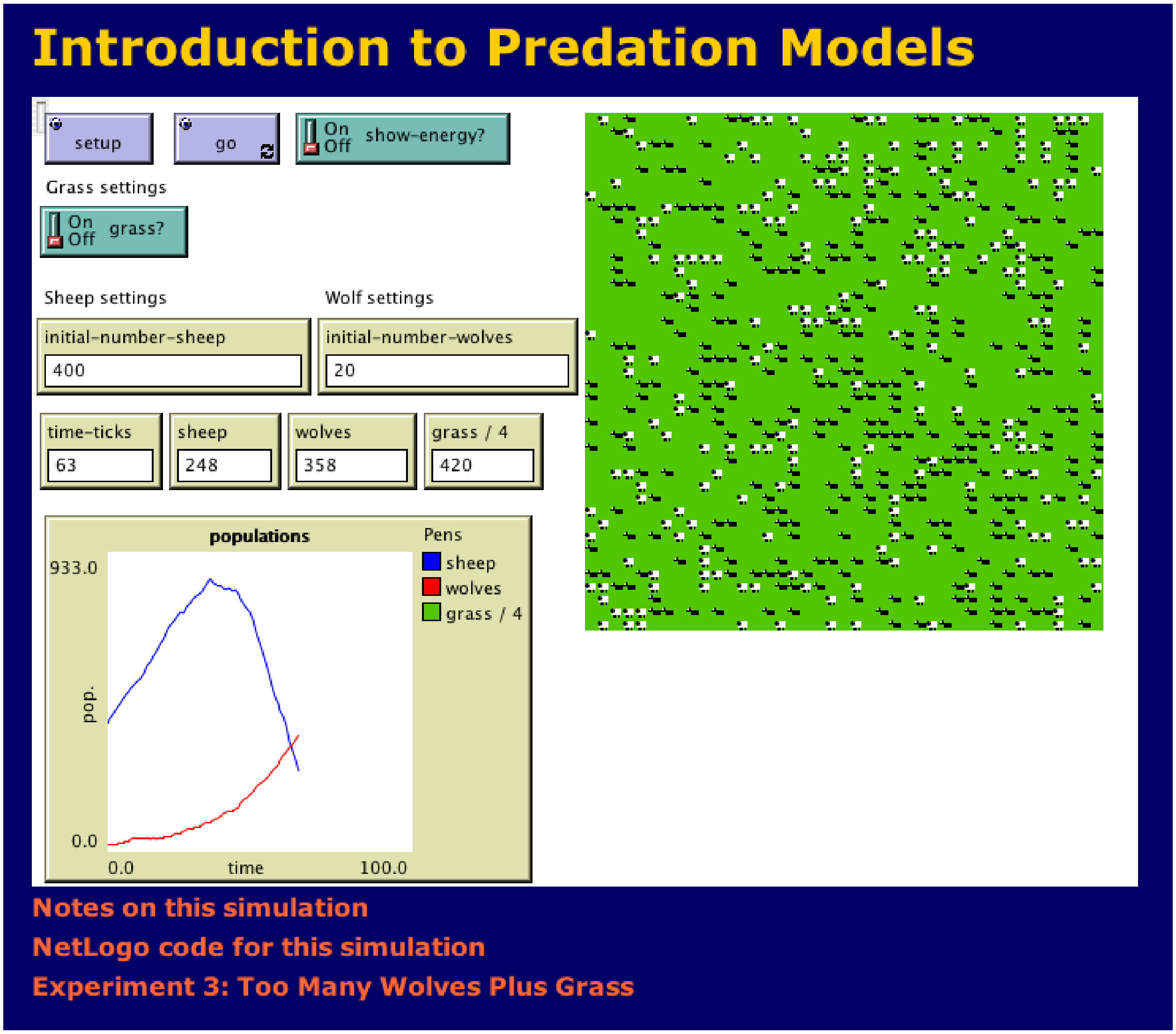


Figure 26: View 2 of program for challenge 2

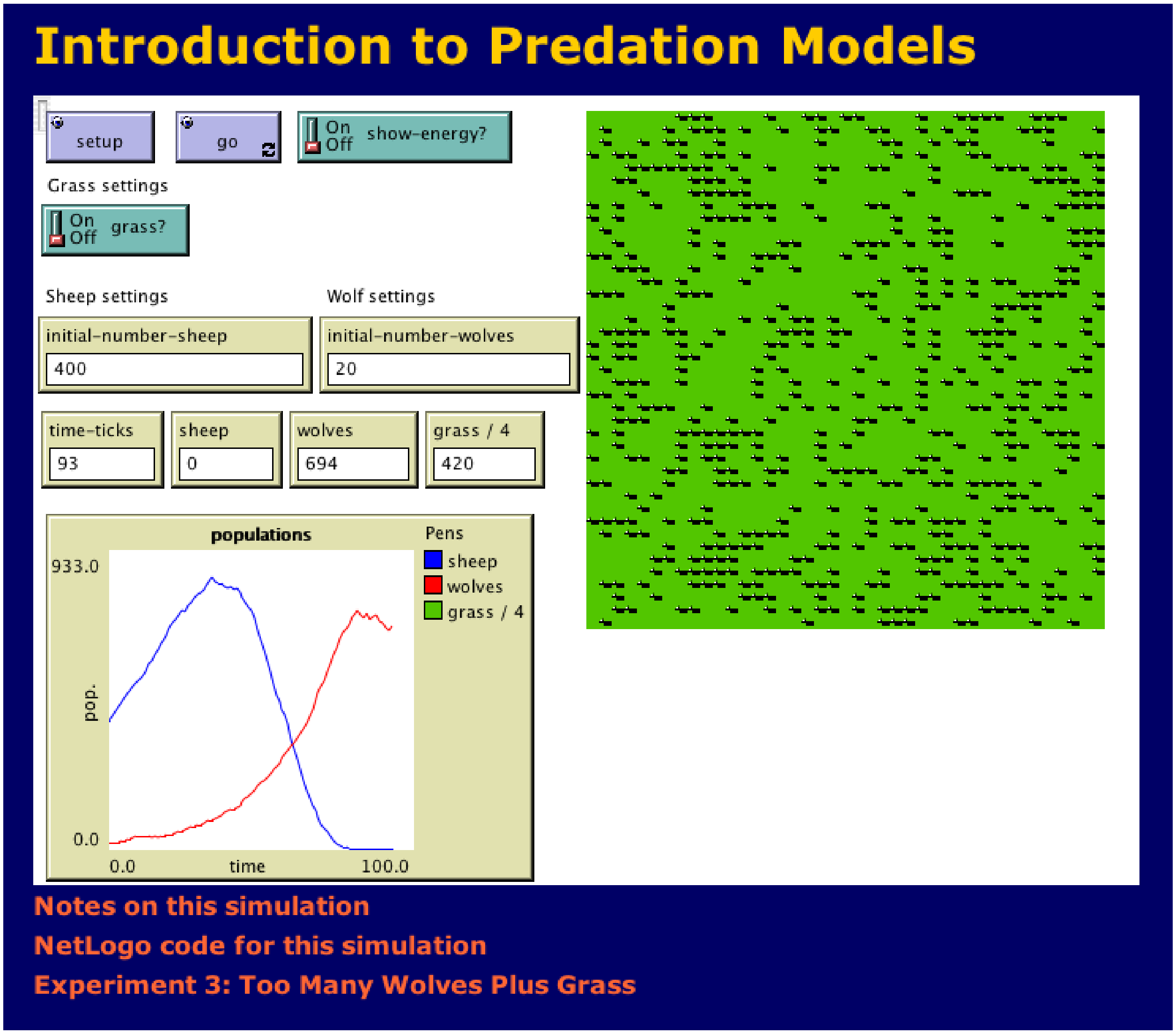


Figure 27: View 3 of program for challenge 2

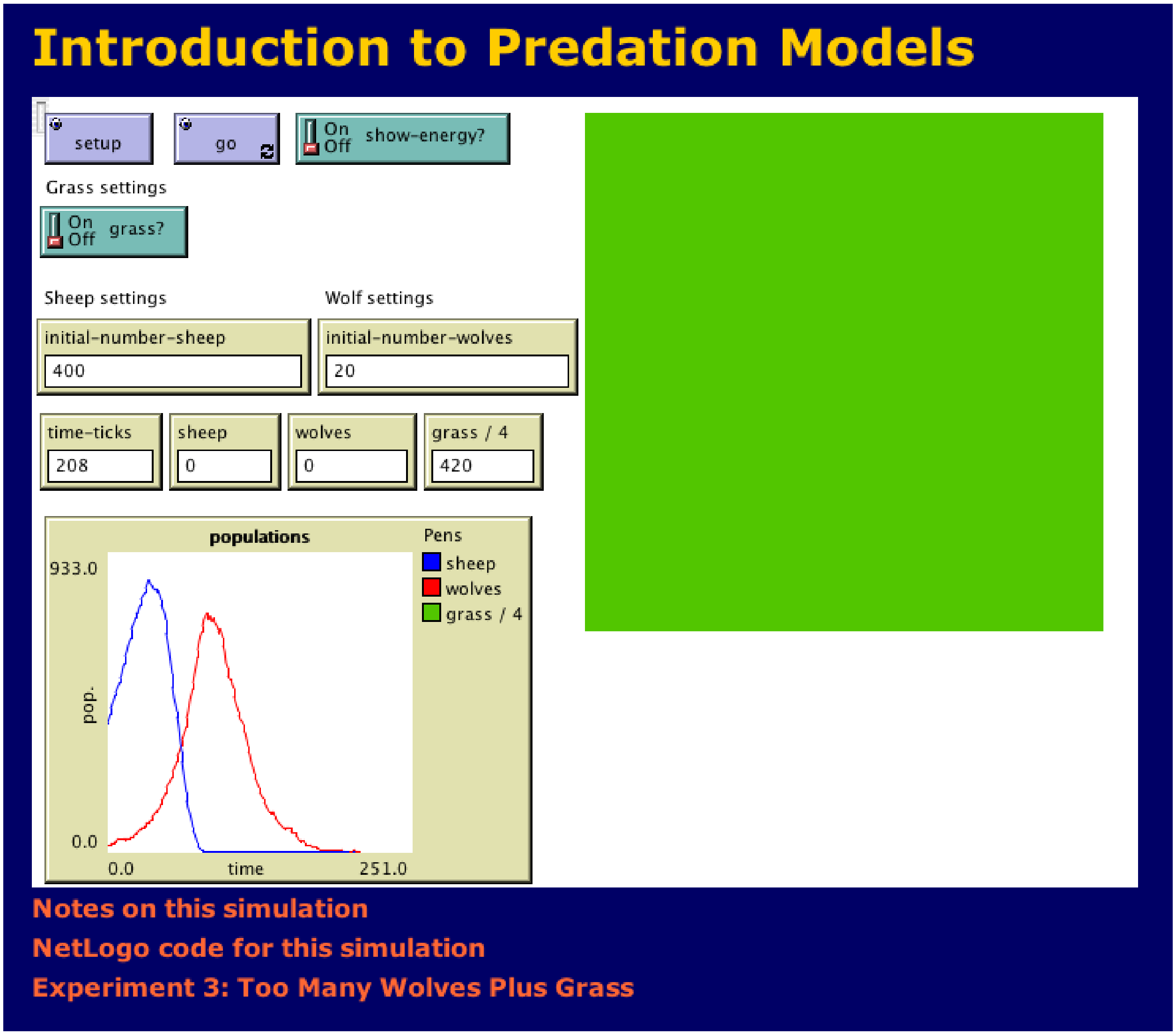
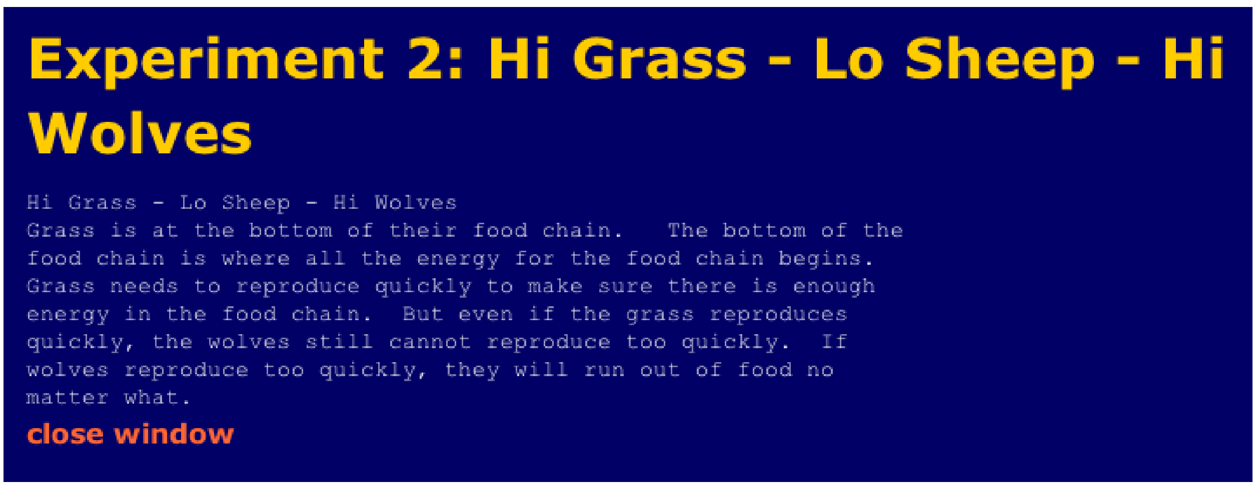


Figure 28: View 4 of program for challenge 2 (simulation finished)


Experiment 2: Hi Grass - Lo Sheep - Hi Wolves

Hi Grass - Lo Sheep - Hi Wolves
Grass is at the bottom of their food chain. The bottom of the food chain is where all the energy for the food chain begins. Grass needs to reproduce quickly to make sure there is enough energy in the food chain. But even if the grass reproduces quickly, the wolves still cannot reproduce too quickly. If wolves reproduce too quickly, they will run out of food no matter what.

close window

Figure 29: Resource for challenge 2

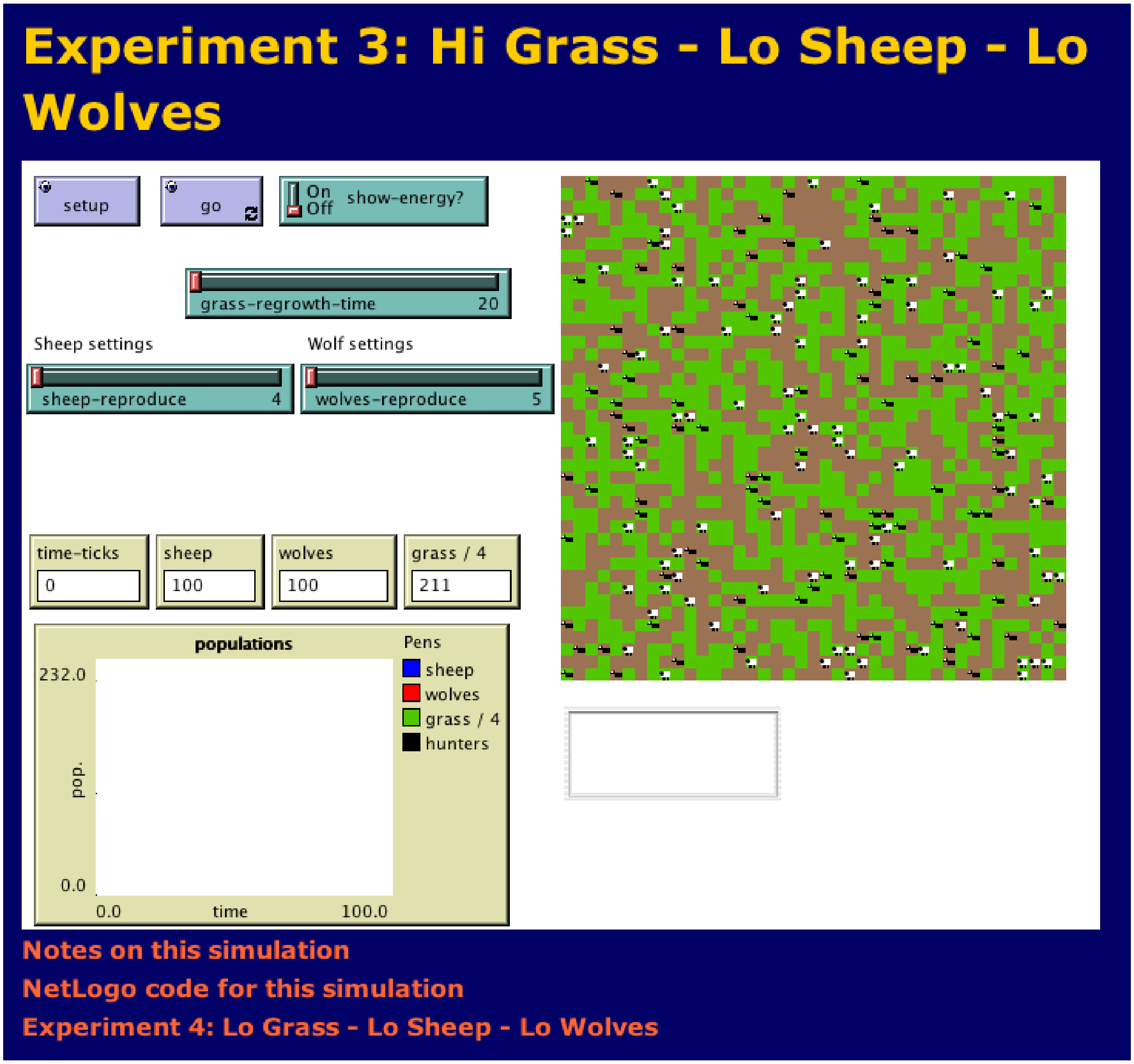


Figure 30: Program resource for challenge 3

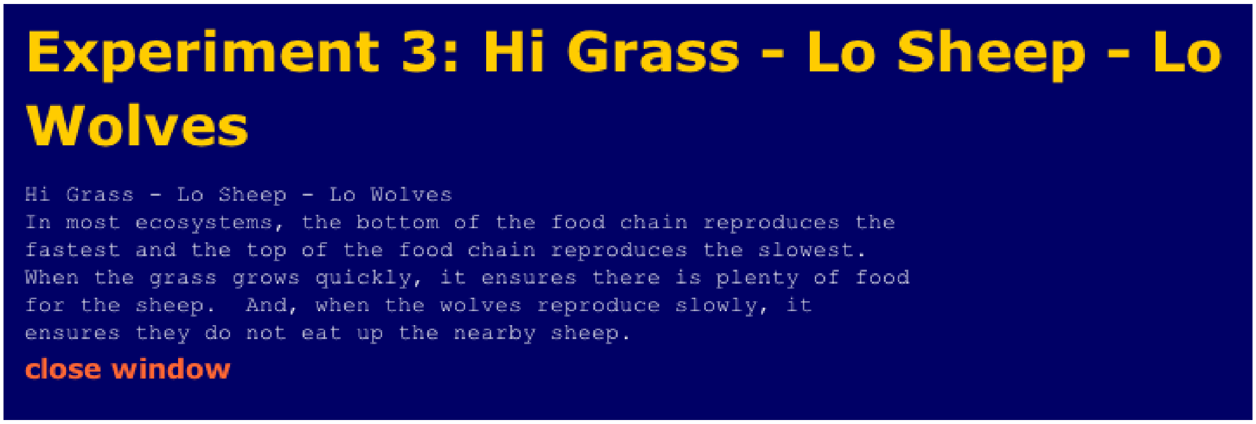


Figure 31: Content resource for challenge 3

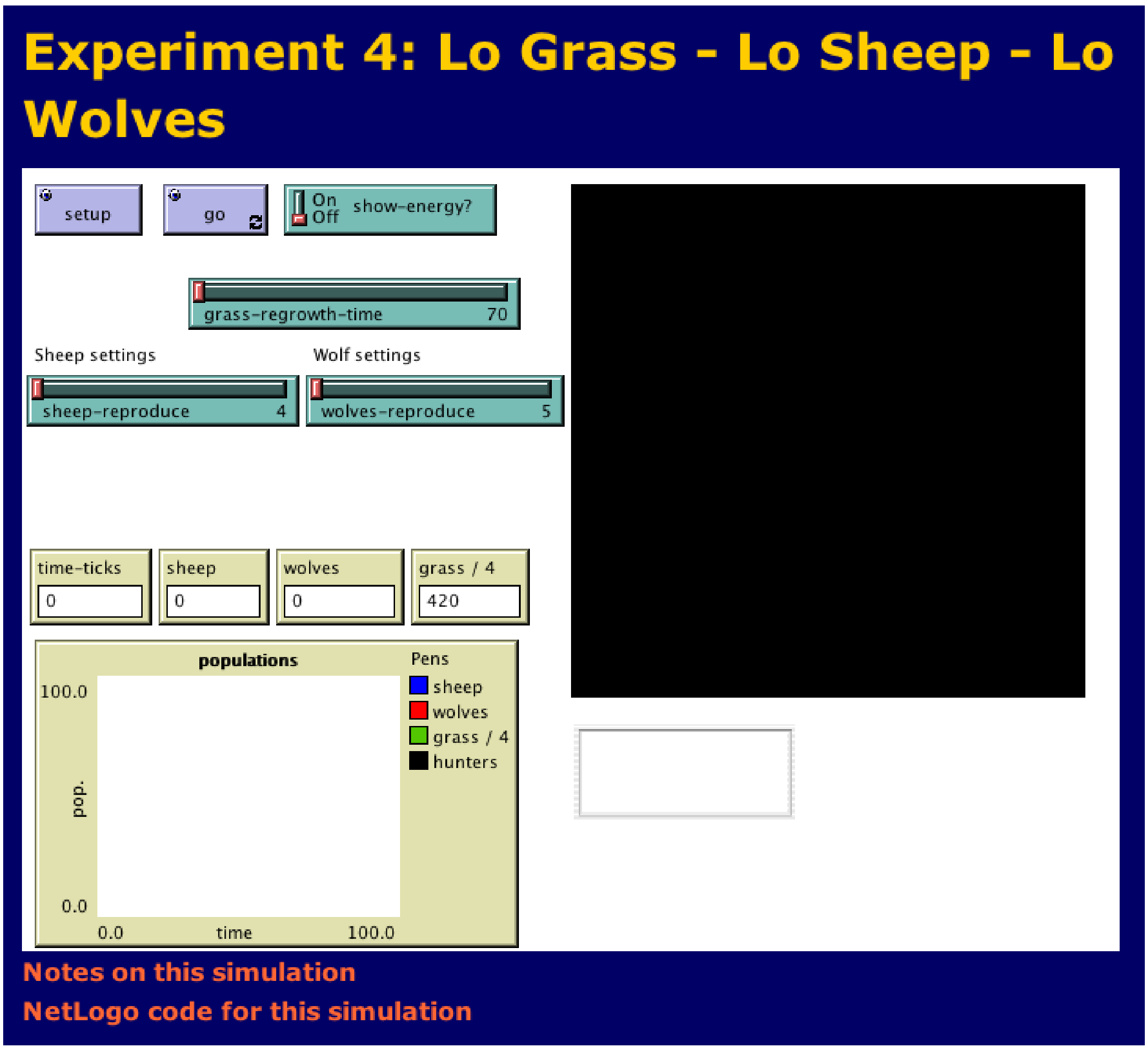


Figure 32: Program resource for challenge 4

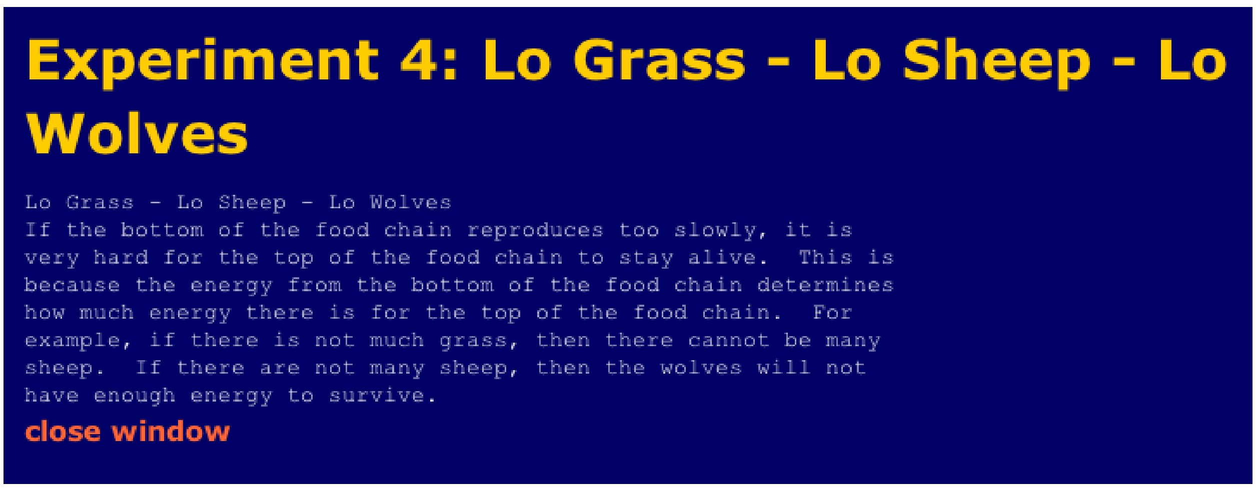


Figure 33: Contenet resource for challenge 4

5.2 Observation Activities

Figure 34: Activity List for Observation Activities

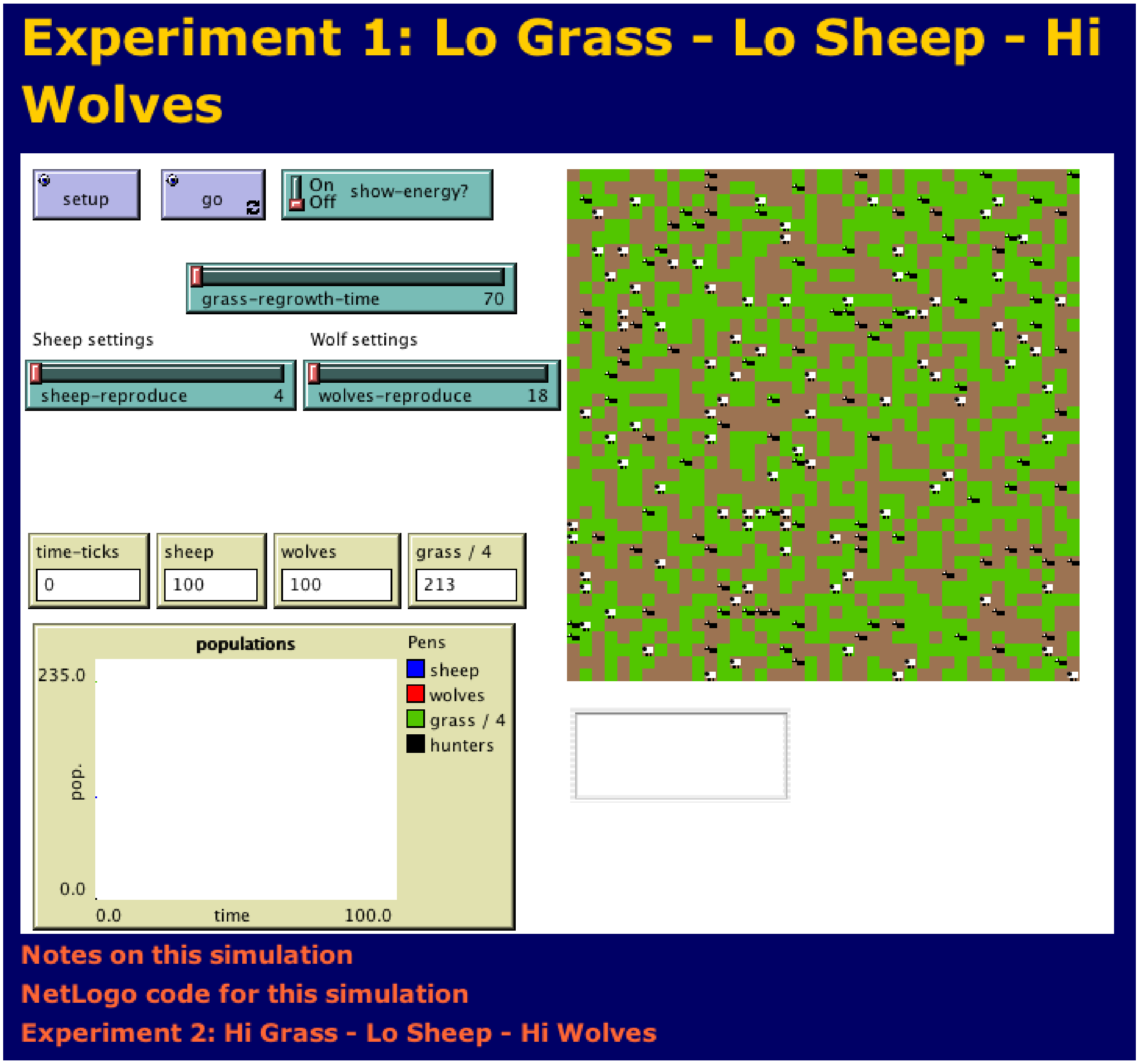


Figure 35: Program 1 Main Page

Figure 36: Program 1 Resource

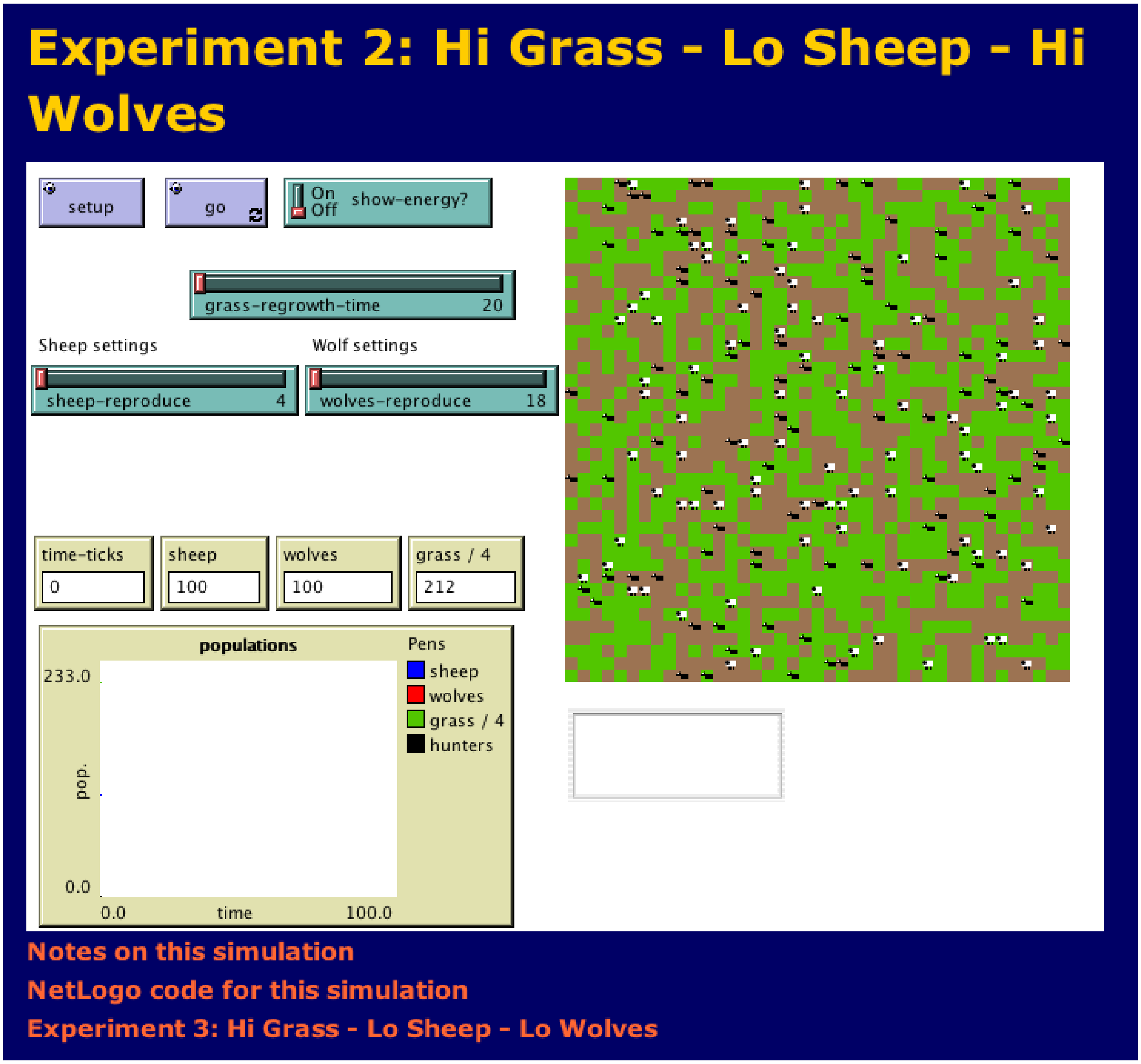
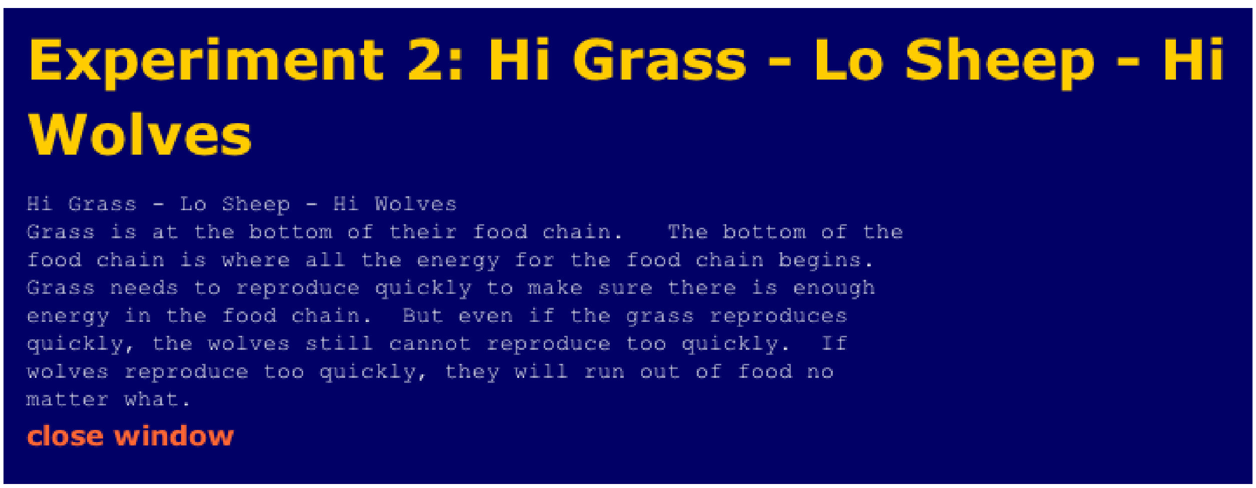


Figure 37: Program 2 Main Page


Experiment 2: Hi Grass - Lo Sheep - Hi Wolves

Hi Grass - Lo Sheep - Hi Wolves
Grass is at the bottom of their food chain. The bottom of the food chain is where all the energy for the food chain begins. Grass needs to reproduce quickly to make sure there is enough energy in the food chain. But even if the grass reproduces quickly, the wolves still cannot reproduce too quickly. If wolves reproduce too quickly, they will run out of food no matter what.

close window

Figure 38: Program 2 Resource

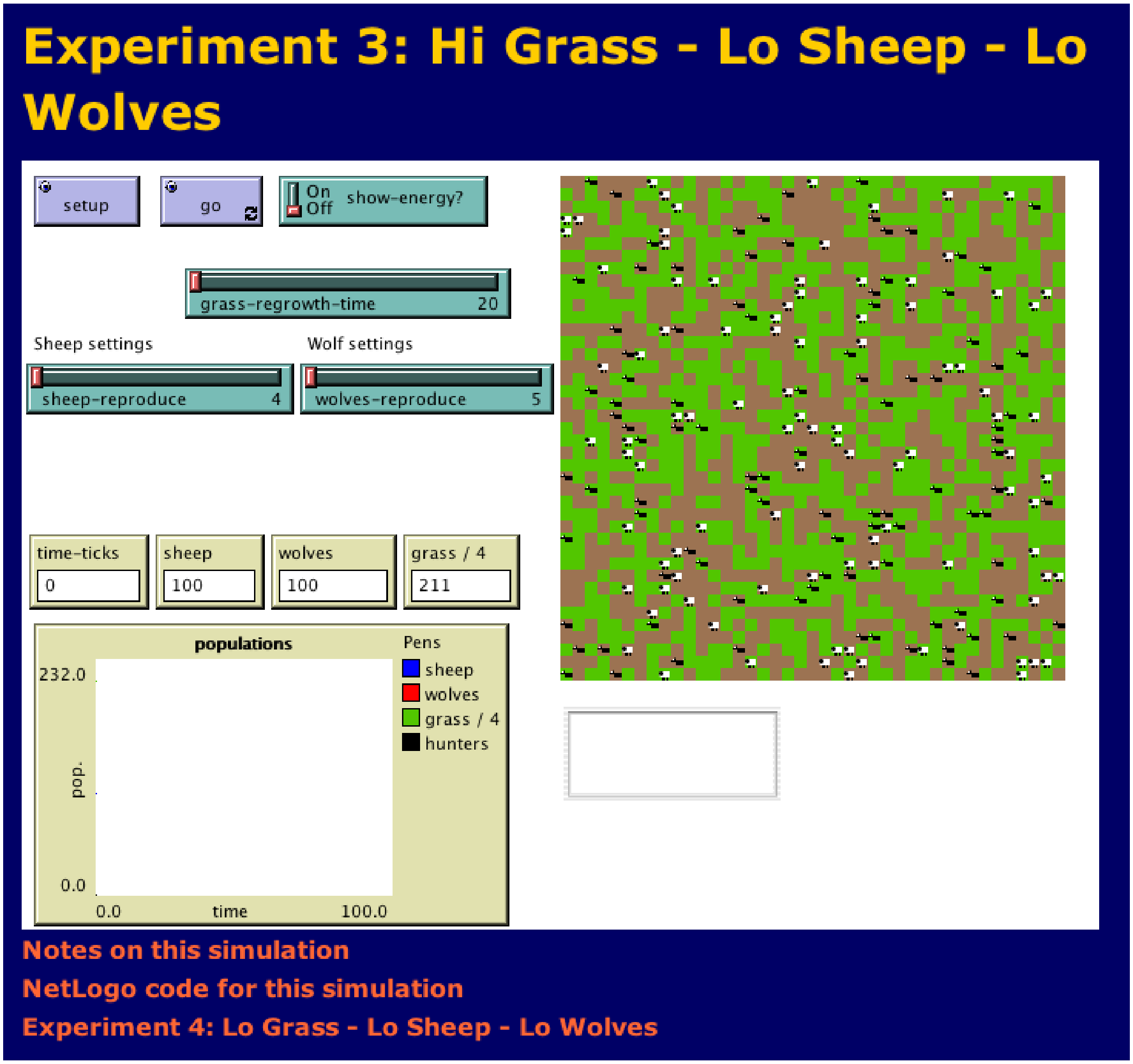


Figure 39: Program 3 Main Page

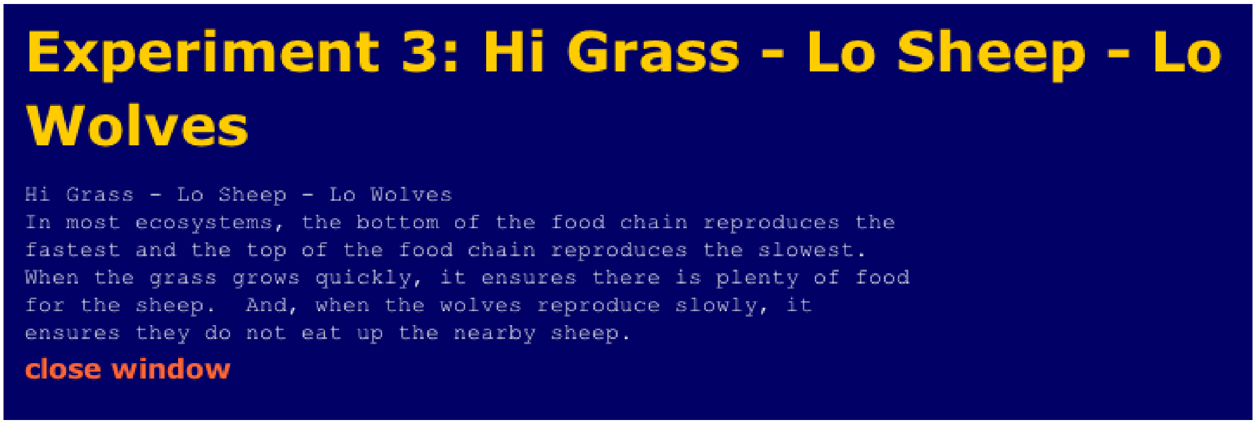


Figure 40: Program 3 Resource

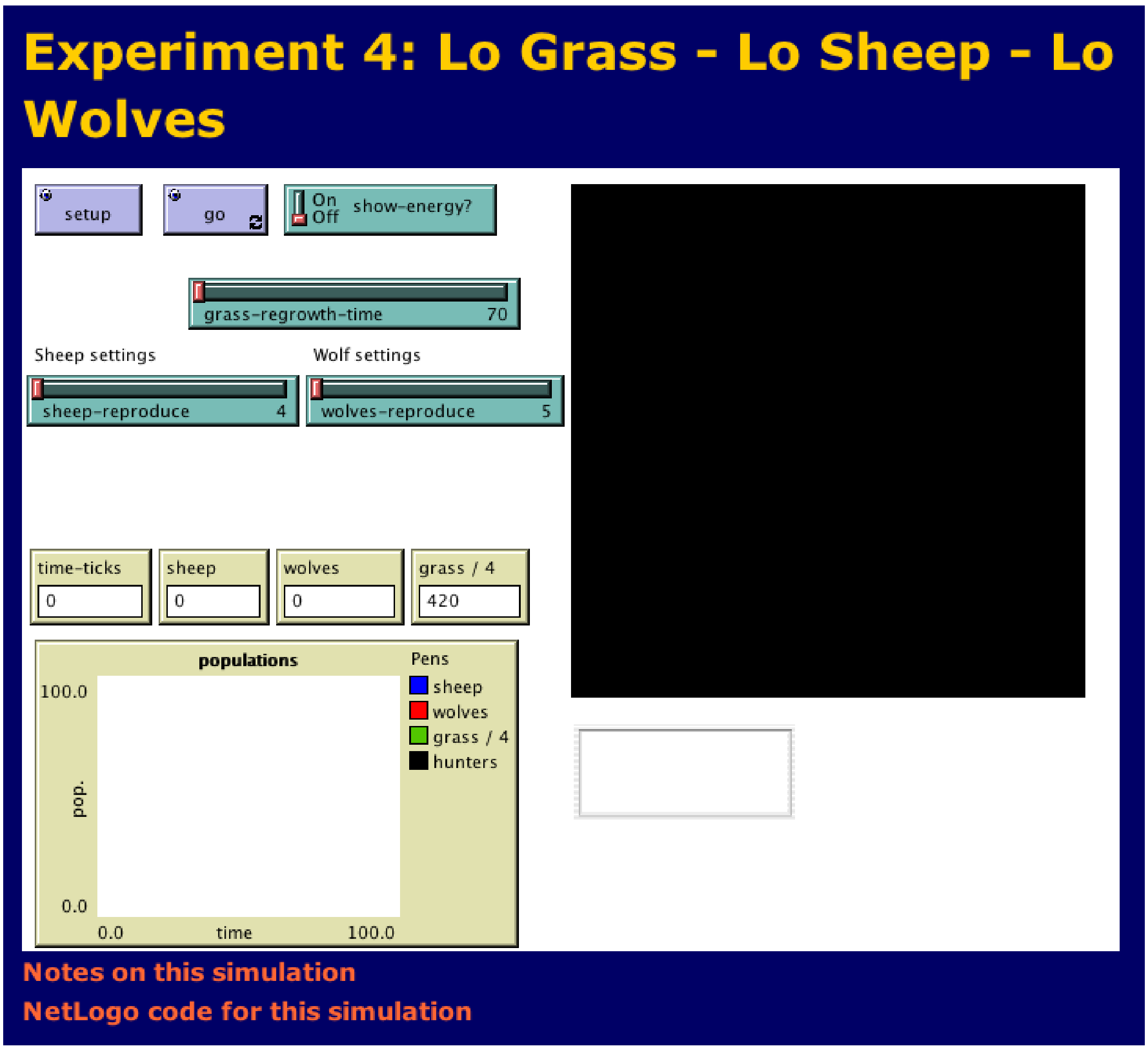


Figure 41: Program 4 Main Page

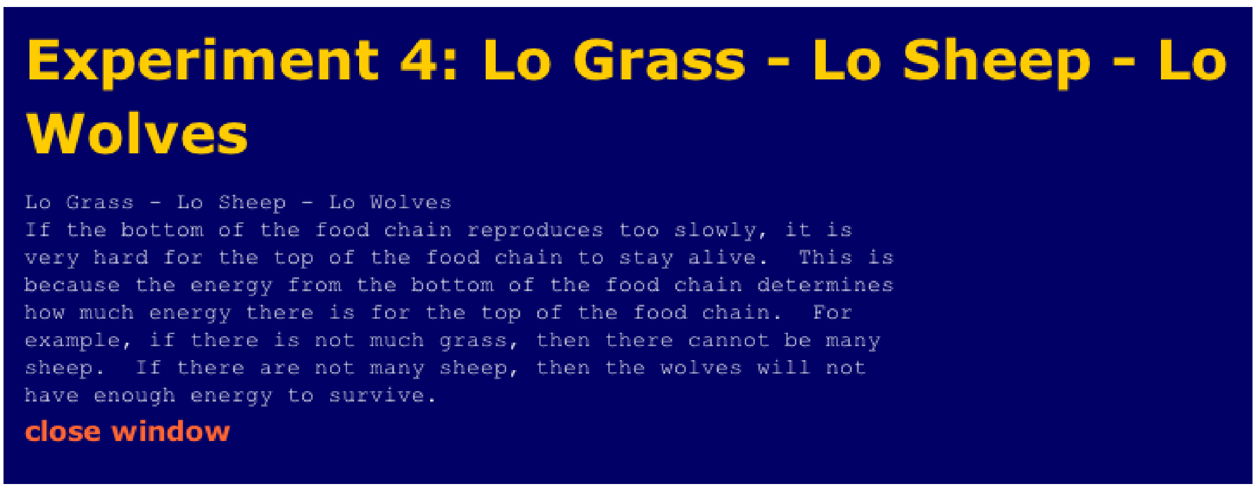
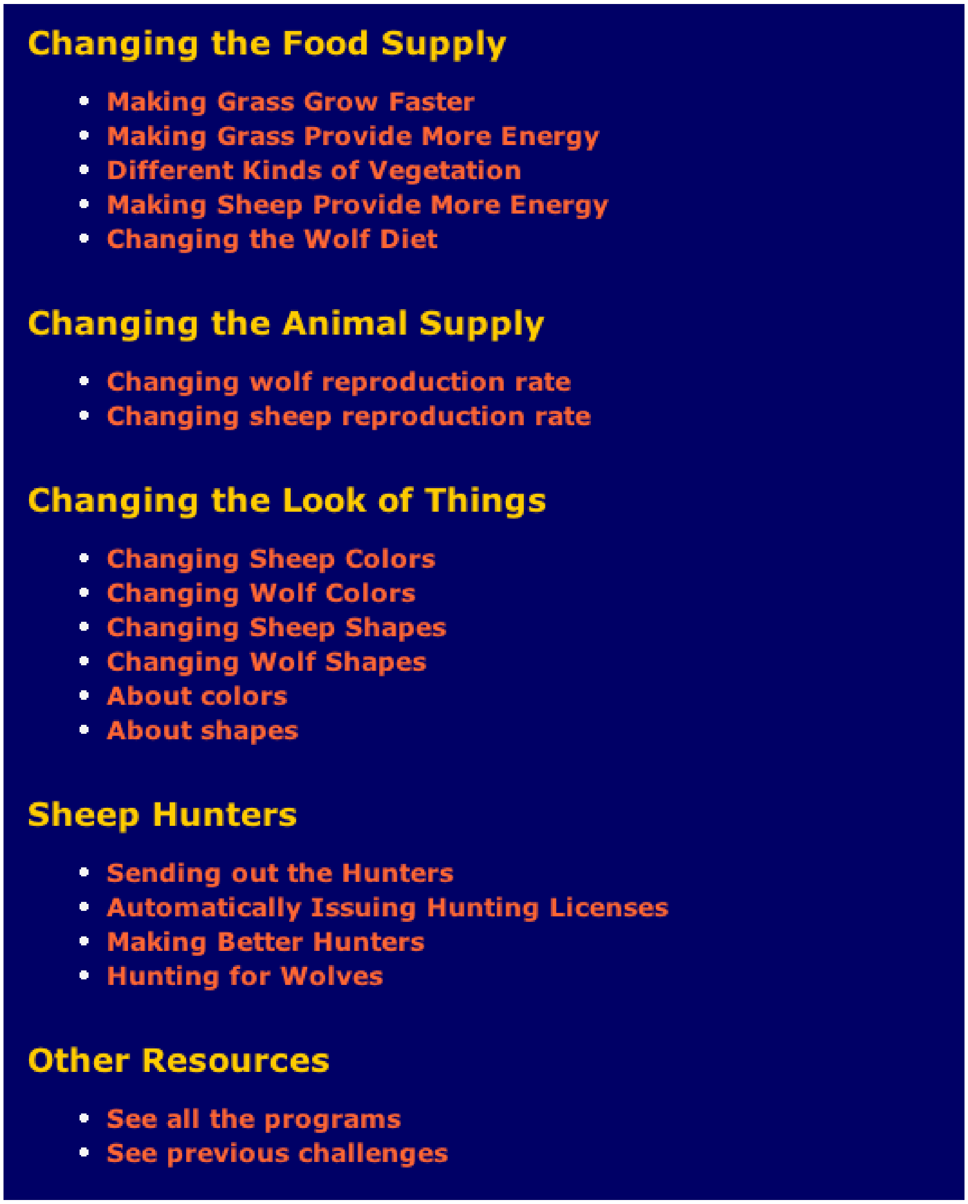


Figure 42: Program 4 Resource



Changing the Food Supply

- Making Grass Grow Faster
- Making Grass Provide More Energy
- Different Kinds of Vegetation
- Making Sheep Provide More Energy
- Changing the Wolf Diet

Changing the Animal Supply

- Changing wolf reproduction rate
- Changing sheep reproduction rate

Changing the Look of Things

- Changing Sheep Colors
- Changing Wolf Colors
- Changing Sheep Shapes
- Changing Wolf Shapes
- About colors
- About shapes

Sheep Hunters

- Sending out the Hunters
- Automatically Issuing Hunting Licenses
- Making Better Hunters
- Hunting for Wolves

Other Resources

- See all the programs
- See previous challenges

Figure 43: List of resources for changing programs

Making Grass Grow Faster (grass-regrowth-time)

If your sheep need more food, you might try making the grass grow faster. In the real world, you might do this by planting some food for your sheep. In this simulation, **change the `grass-regrowth-time` to a lower number** (in the `setup` procedure). You might want to make it a slider (0 to 50 would be good) to make it easier to change.

```
to setup
  . . . . (stuff deleted, don't change that now) . . . .
  ;; THIS NEXT LINE IS CHANGED
  grass-regrowth-time 20  ; how long it takes grass to re-grow
  ;; END OF CHANGES
  . . . . (stuff deleted, don't change that now) . . . .
end
```

close window

Figure 44: Resource for changing the speed grass grows

Making Grass Provide More Energy (sheep-gain-from-food)

If your sheep need more food, you might try making the grass more nutritious. In the real world, you might do this by planting some other food (like corn) for your sheep. In this simulation, **change the `sheep-gain-from-food` to a higher number** (in the `setup` procedure). You might want to make it a slider (like 0 to 20) to make it easier to change.

close window

Figure 45: Resource for making changing amount of energy grass provides

Different Kinds of Vegetation (Weeds)

You might try introducing weeds (or a super-nutritious plant) to see what effect that has on your sheep. To allow the weeds to grow set `weeds?` to true in procedure `setup`:

```
to setup
  . . . . (stuff deleted, don't change that now) . . . .
  ;; THIS NEXT LINE IS CHANGED
  set weeds? true
  ;; END OF CHANGES
  . . . . (stuff deleted, don't change that now) . . . .
end
```

This will make the weeds grow, but the sheep won't eat them unless you change the `be-a-sheep` procedure so that they also `eat-weeds`.

```
to be-a-sheep
    move
    if grass? [
      set energy energy - 1  ;; deduct energy for sheep only if grass? switch is on
      eat-grass
      eat-weeds  ;; THIS LINE IS CHANGED
   ]
    reproduce-sheep
    death
end
```

close window

Figure 46: Resource for adding weeds

Making Sheep Provide More Energy (wolves-gain-from-food)

If your wolves need more food, you might try making the sheep more nutritious. In the real world this happens when an animal's prey changes (like eating sheep rather than rabbits, for instance) or gains access to more food so that they are larger. In this simulation, **change the `wolves-gain-from-food` to a higher (or lower) number** (in the `setup` procedure. You might want to make it a slider (like 0 to 20) to make it easier to change.

close window

Figure 47: Resource for changing the amount of energy sheep provide

Changing the Wolf Diet

Perhaps you want your wolves to be able to eat grass as well as sheep. In the `be-a-wolf` procedure, un-comment the `eat-grass` procedure to let them eat grass as well.

```
to be-a-wolf
    move
    set energy energy - 1  ;; wolves lose energy as they move
    catch-sheep
    ; eat-weeds
    eat-grass ; THIS LINE IS CHANGED
    reproduce-wolves
    death
end
```

close window

Figure 48: Resource for allowing wolves to eat grass

Changing Wolf Birth Rates

Different animals have different birth rates. If you would like your wolves to have a different birth rate (a chance to have offspring at each time through the `go` procedure), then **change the `wolf-reproduce` variable (in `setup`)** or make it into a slider (0-20 would be a good range).

```
to setup
  . . . . (stuff deleted, don't change that now) . . . .
  set wolf-reproduce 5
  . . . . (stuff deleted, don't change that now) . . . .
end
```

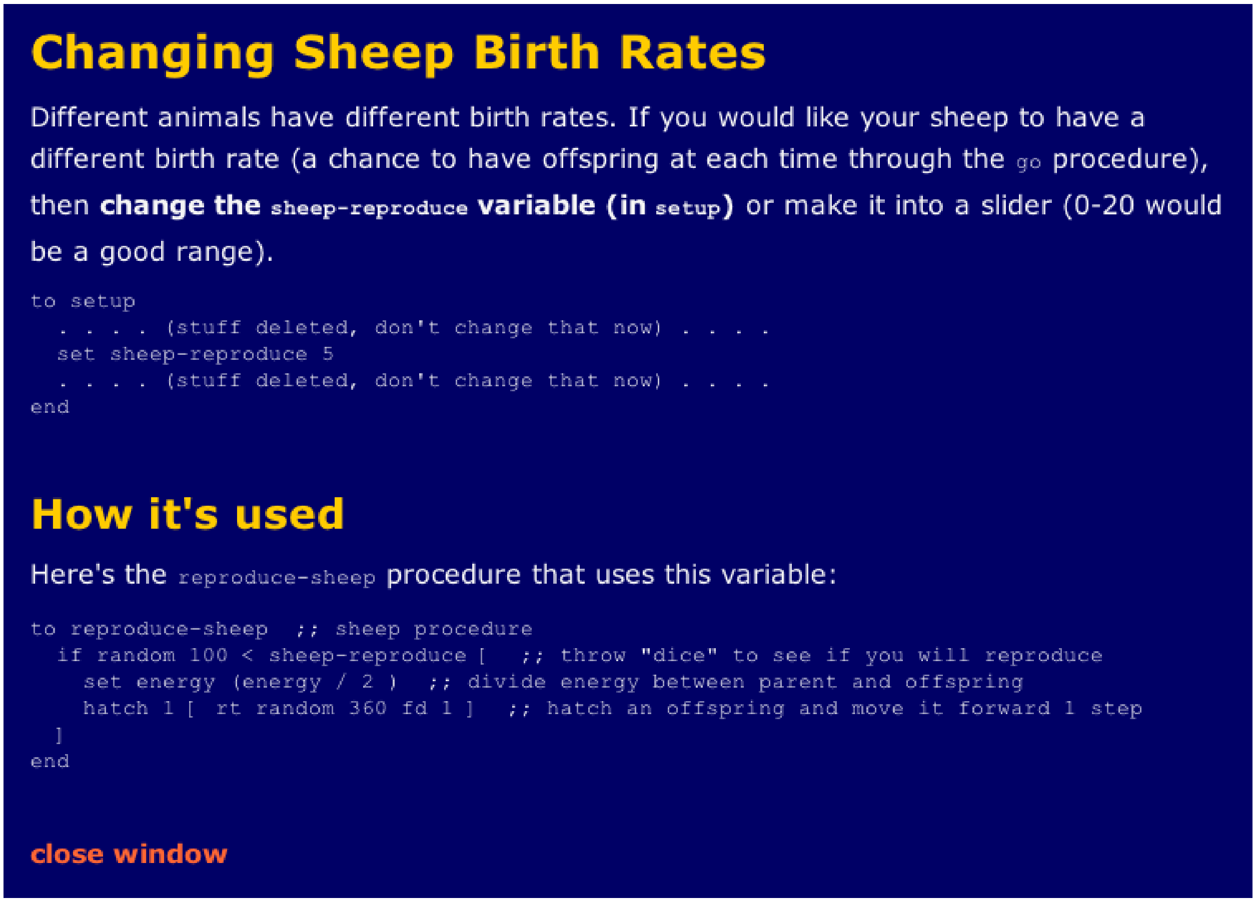
How it's used

Here's the `reproduce-wolves` procedure that uses this variable:

```
to reproduce-wolves  ;; wolf procedure
  if random 100 < wolf-reproduce [  ;; throw "dice" to see if you will reproduce
    set energy (energy / 2 )  ;; divide energy between parent and offspring
    hatch 1 [ rt random 360 fd 1 ]  ;; hatch an offspring and move it forward 1 step
  ]
end
```

close window

Figure 49: Resource for changing wolve reproduction rate



Changing Sheep Birth Rates

Different animals have different birth rates. If you would like your sheep to have a different birth rate (a chance to have offspring at each time through the `go` procedure), then **change the `sheep-reproduce` variable (in `setup`)** or make it into a slider (0-20 would be a good range).

```
to setup
  . . . . (stuff deleted, don't change that now) . . . .
  set sheep-reproduce 5
  . . . . (stuff deleted, don't change that now) . . . .
end
```

How it's used

Here's the `reproduce-sheep` procedure that uses this variable:

```
to reproduce-sheep  ;; sheep procedure
  if random 100 < sheep-reproduce [   ;; throw "dice" to see if you will reproduce
    set energy (energy / 2 )   ;; divide energy between parent and offspring
    hatch 1 [  rt random 360 fd 1 ]   ;; hatch an offspring and move it forward 1 step
  ]
end
```

close window

Figure 50: Resource for changing the sheep reproduction rate

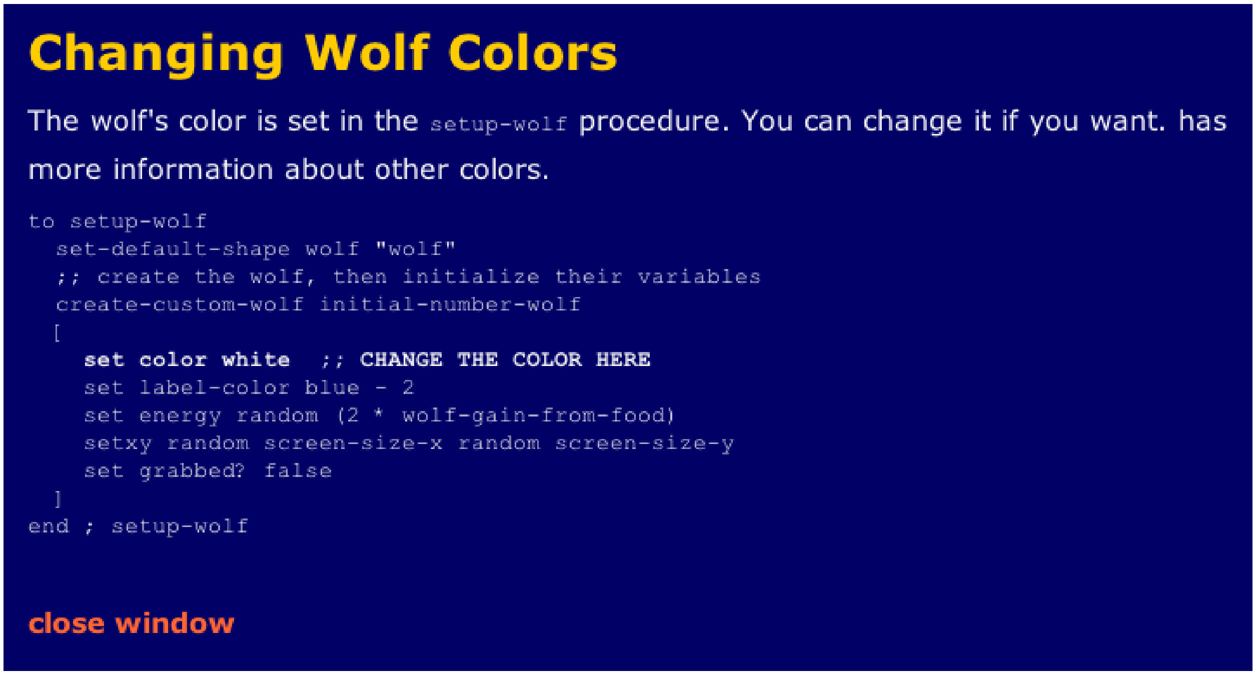
Changing Sheep Colors

The sheep's color is set in the `setup-sheep` procedure. You can change it if you want. has more information about other colors.

```
to setup-sheep
  set-default-shape sheep "sheep"
  ;; create the sheep, then initialize their variables
  create-custom-sheep initial-number-sheep
  [
    set color white   ;; CHANGE THE COLOR HERE
    set label-color blue - 2
    set energy random (2 * sheep-gain-from-food)
    setxy random screen-size-x random screen-size-y
    set grabbed? false
  ]
end ; setup-sheep
```

close window

Figure 51: Resource for changing colors of sheep



Changing Wolf Colors

The wolf's color is set in the `setup-wolf` procedure. You can change it if you want. has more information about other colors.

```
to setup-wolf
  set-default-shape wolf "wolf"
  ;; create the wolf, then initialize their variables
  create-custom-wolf initial-number-wolf
  [
    set color white  ;; CHANGE THE COLOR HERE
    set label-color blue - 2
    set energy random (2 * wolf-gain-from-food)
    setxy random screen-size-x random screen-size-y
    set grabbed? false
  ]
end ; setup-wolf
```

close window

Figure 52: Resource for changing the colors of wolves

Changing Sheep Shapes

The sheep's shape is set in the `setup-sheep` procedure. You can change it if you want. **this link** has more information about creating other shapes.

```
to setup-sheep
  set-default-shape sheep "sheep" ;; CHANGE SHAPE HERE
  ;; create the sheep, then initialize their variables
  create-custom-sheep initial-number-sheep
  [
    set color white
    set label-color blue - 2
    set energy random (2 * sheep-gain-from-food)
    setxy random screen-size-x random screen-size-y
    set grabbed? false
  ]
end ; setup-sheep
```

close window

Figure 53: Resource for changing the shape of the sheep

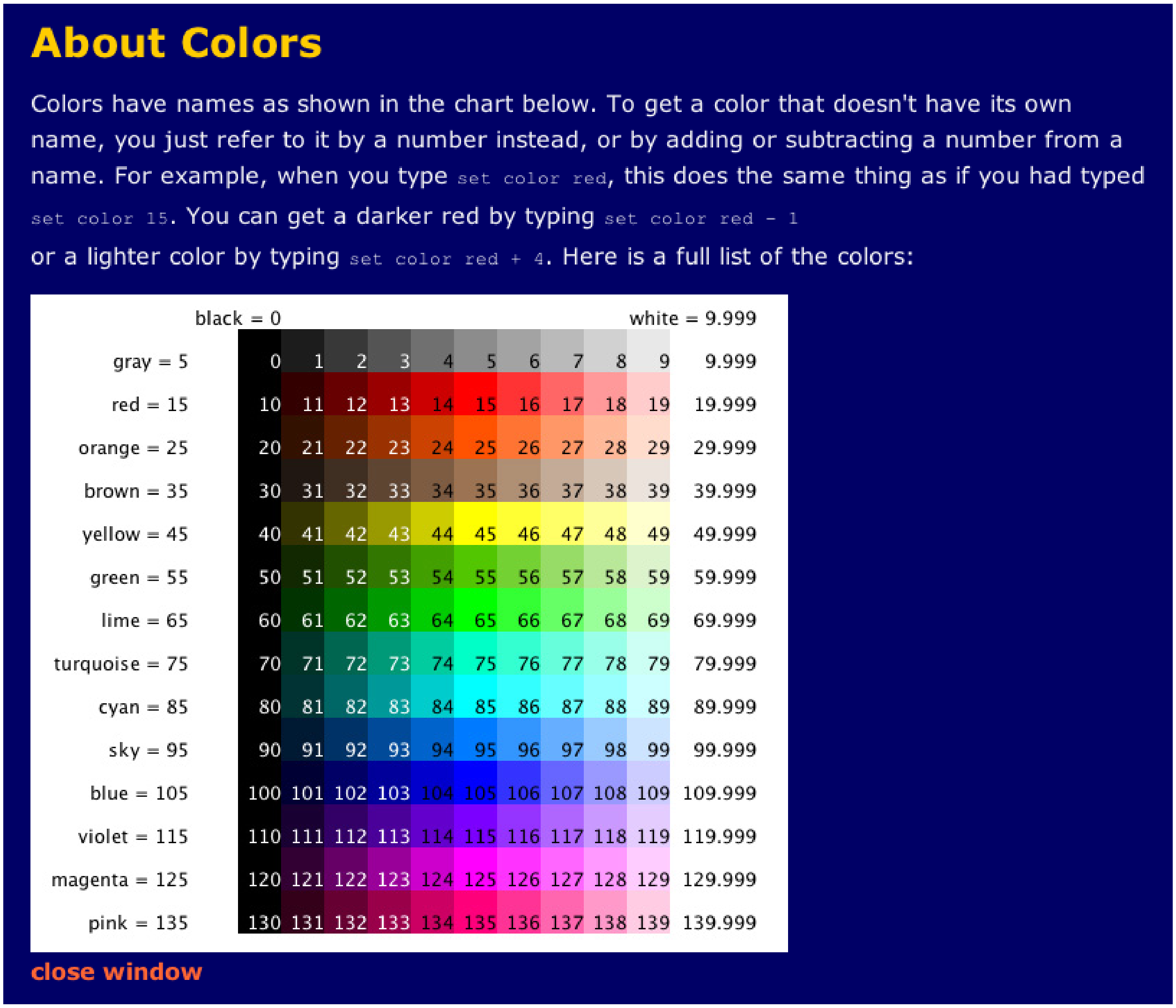
Changing Wolf Shapes

The wolves' shape is set in the `setup-wolf` procedure. You can change it if you want. **this link** has more information about creating other shapes.

```
to setup-wolf
  set-default-shape wolf "wolf" ; CHANGE SHAPE HERE
  ;; create the wolf, then initialize their variables
  create-custom-wolf initial-number-wolf
  [
    set color white
    set label-color blue - 2
    set energy random (2 * wolf-gain-from-food)
    setxy random screen-size-x random screen-size-y
    set grabbed? false
  ]
end ; setup-wolf
```

close window

Figure 54: Resource for changing the shape of the wolves



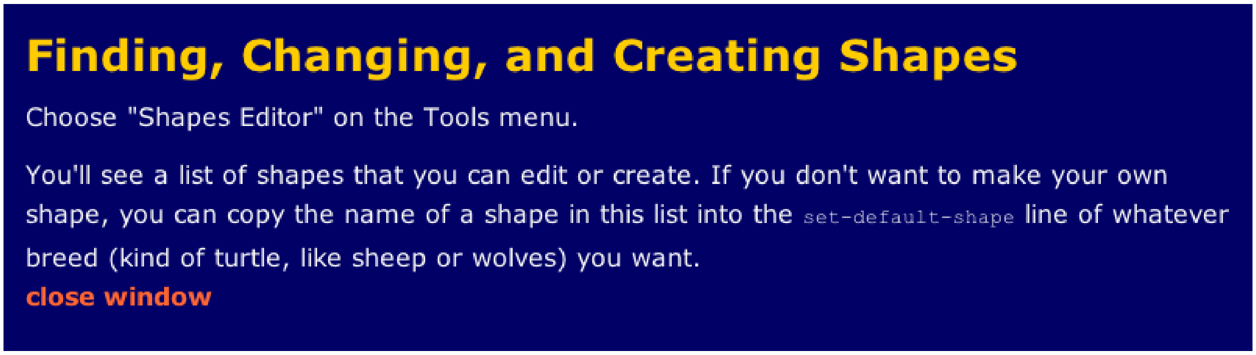
About Colors

Colors have names as shown in the chart below. To get a color that doesn't have its own name, you just refer to it by a number instead, or by adding or subtracting a number from a name. For example, when you type `set color red`, this does the same thing as if you had typed `set color 15`. You can get a darker red by typing `set color red - 1` or a lighter color by typing `set color red + 4`. Here is a full list of the colors:

	black = 0										white = 9.999
gray = 5	0	1	2	3	4	5	6	7	8	9	9.999
red = 15	10	11	12	13	14	15	16	17	18	19	19.999
orange = 25	20	21	22	23	24	25	26	27	28	29	29.999
brown = 35	30	31	32	33	34	35	36	37	38	39	39.999
yellow = 45	40	41	42	43	44	45	46	47	48	49	49.999
green = 55	50	51	52	53	54	55	56	57	58	59	59.999
lime = 65	60	61	62	63	64	65	66	67	68	69	69.999
turquoise = 75	70	71	72	73	74	75	76	77	78	79	79.999
cyan = 85	80	81	82	83	84	85	86	87	88	89	89.999
sky = 95	90	91	92	93	94	95	96	97	98	99	99.999
blue = 105	100	101	102	103	104	105	106	107	108	109	109.999
violet = 115	110	111	112	113	114	115	116	117	118	119	119.999
magenta = 125	120	121	122	123	124	125	126	127	128	129	129.999
pink = 135	130	131	132	133	134	135	136	137	138	139	139.999

close window

Figure 55: Resource for changing colors



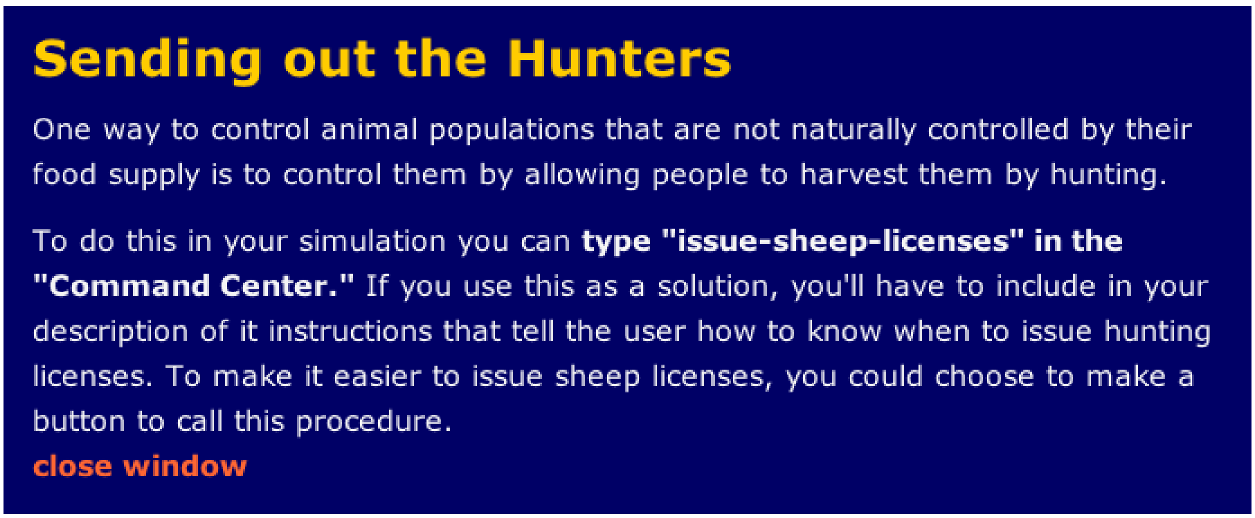
Finding, Changing, and Creating Shapes

Choose "Shapes Editor" on the Tools menu.

You'll see a list of shapes that you can edit or create. If you don't want to make your own shape, you can copy the name of a shape in this list into the `set-default-shape` line of whatever breed (kind of turtle, like sheep or wolves) you want.

close window

Figure 56: Resource for changing shapes



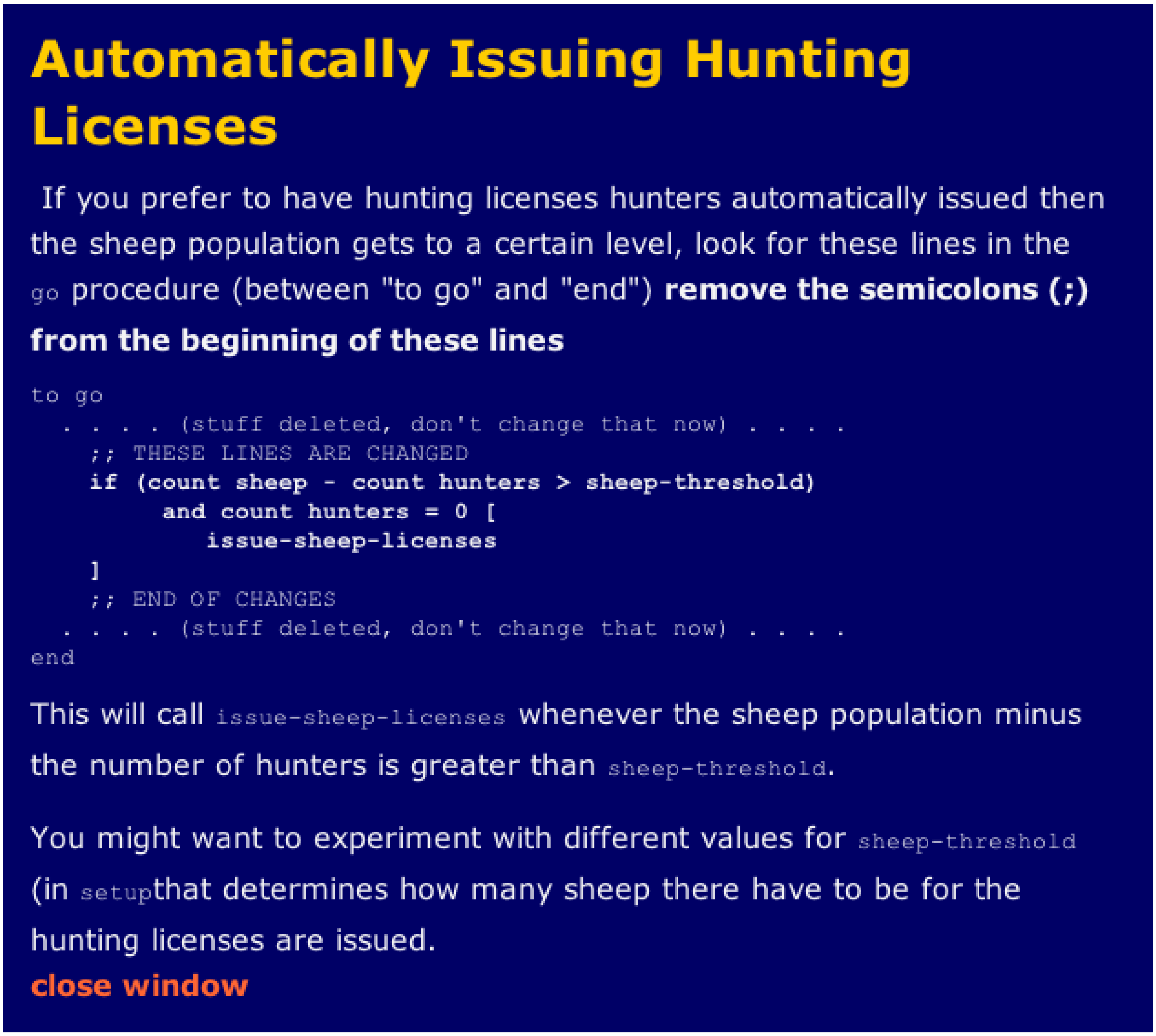
Sending out the Hunters

One way to control animal populations that are not naturally controlled by their food supply is to control them by allowing people to harvest them by hunting.

To do this in your simulation you can **type "issue-sheep-licenses" in the "Command Center."** If you use this as a solution, you'll have to include in your description of it instructions that tell the user how to know when to issue hunting licenses. To make it easier to issue sheep licenses, you could choose to make a button to call this procedure.

close window

Figure 57: Resource for creating hunters manually



Automatically Issuing Hunting Licenses

If you prefer to have hunting licenses hunters automatically issued then the sheep population gets to a certain level, look for these lines in the `go` procedure (between "to go" and "end") **remove the semicolons (;) from the beginning of these lines**

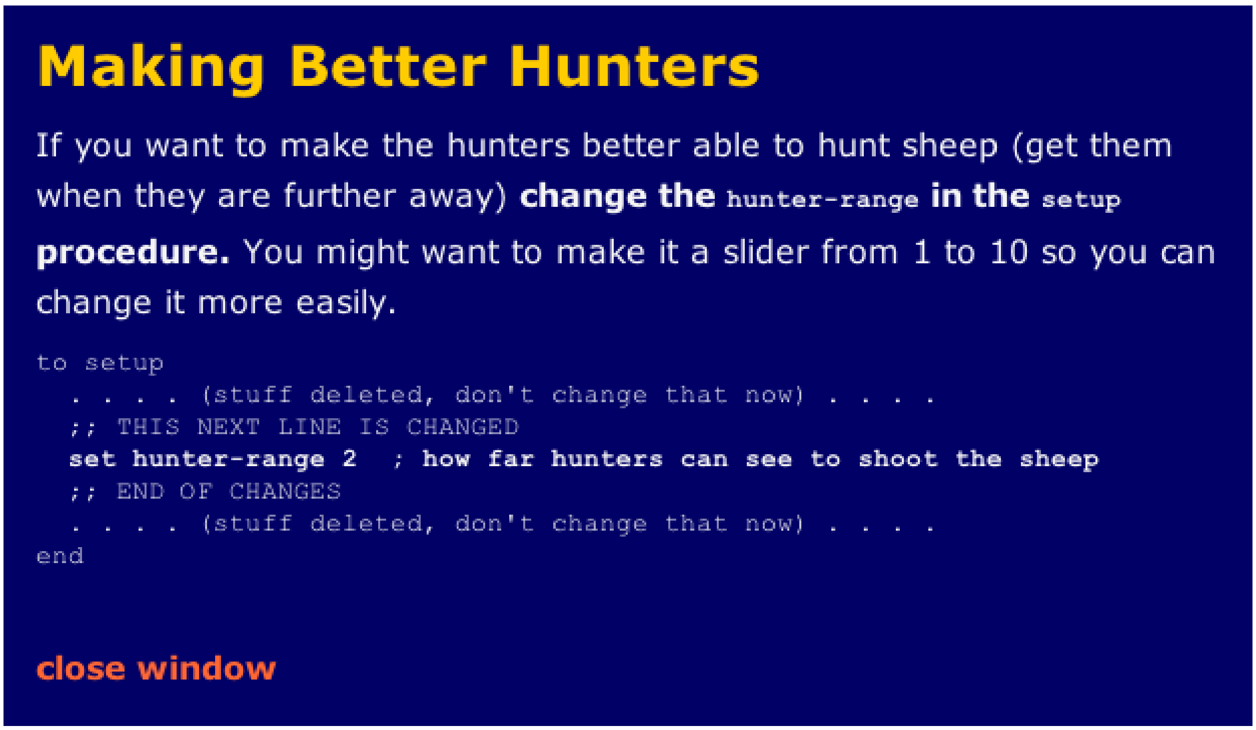
```
to go
  . . . . (stuff deleted, don't change that now) . . . .
    ;; THESE LINES ARE CHANGED
    if (count sheep - count hunters > sheep-threshold)
         and count hunters = 0 [
            issue-sheep-licenses
    ]
    ;; END OF CHANGES
  . . . . (stuff deleted, don't change that now) . . . .
end
```

This will call `issue-sheep-licenses` whenever the sheep population minus the number of hunters is greater than `sheep-threshold`.

You might want to experiment with different values for `sheep-threshold` (in `setup`that determines how many sheep there have to be for the hunting licenses are issued.

close window

Figure 58: Resource for creating hunters that appear when population increases



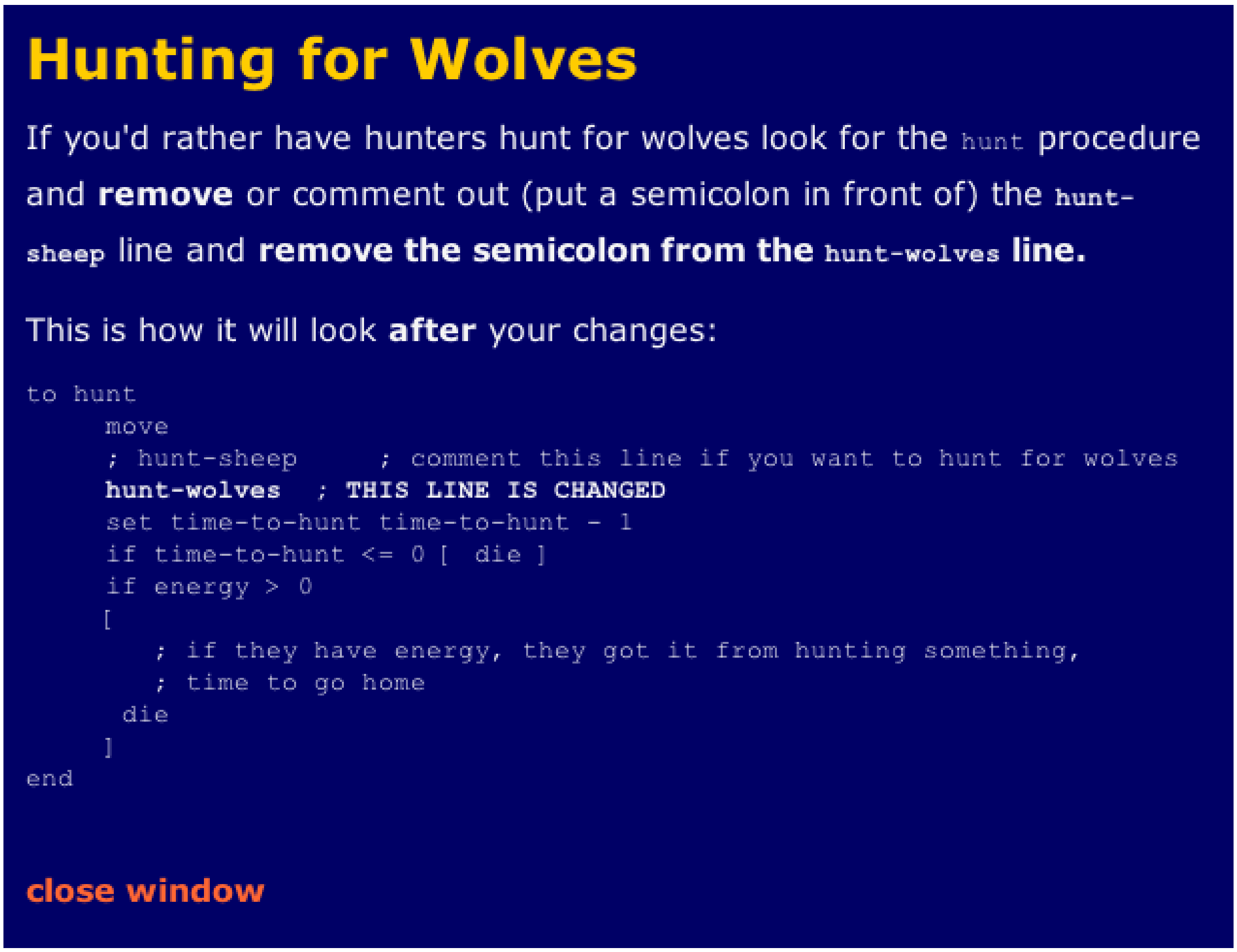
Making Better Hunters

If you want to make the hunters better able to hunt sheep (get them when they are further away) **change the `hunter-range` in the `setup` procedure.** You might want to make it a slider from 1 to 10 so you can change it more easily.

```
to setup
  . . . . (stuff deleted, don't change that now) . . . .
  ;; THIS NEXT LINE IS CHANGED
  set hunter-range 2  ; how far hunters can see to shoot the sheep
  ;; END OF CHANGES
  . . . . (stuff deleted, don't change that now) . . . .
end
```

close window

Figure 59: Resource for making hunters better shots



Hunting for Wolves

If you'd rather have hunters hunt for wolves look for the `hunt` procedure and **remove** or comment out (put a semicolon in front of) the **`hunt-sheep`** line and **remove the semicolon from the `hunt-wolves` line.**

This is how it will look **after** your changes:

```
to hunt
     move
     ; hunt-sheep     ; comment this line if you want to hunt for wolves
     hunt-wolves  ; THIS LINE IS CHANGED
     set time-to-hunt time-to-hunt - 1
     if time-to-hunt <= 0 [  die ]
     if energy > 0
     [
        ; if they have energy, they got it from hunting something,
        ; time to go home
      die
     ]
end
```

close window

Figure 60: Resource for having hunters also hunt for wolves

APPENDIX F

SOFTWARE AND RESEARCH TOOLS

6.1 Periodic Polling Tools (Engagement Sampling)

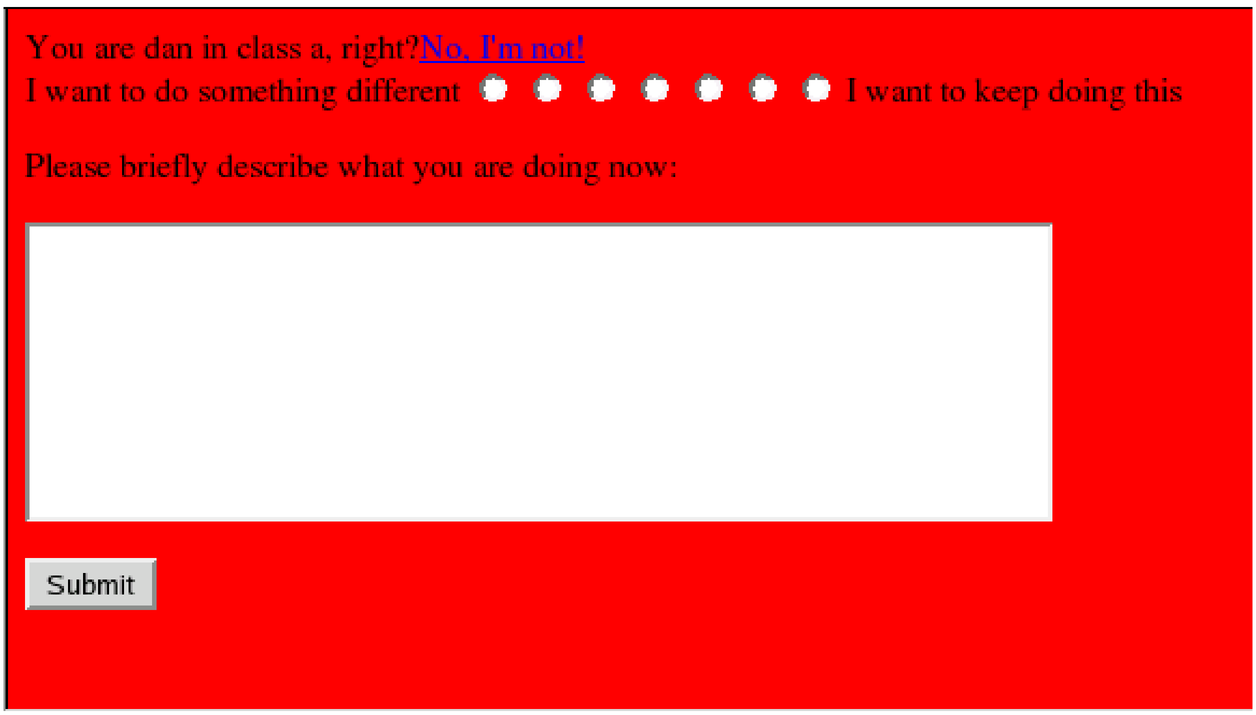


Figure 61: Student Engagement Survey Tool

6.2 NetLogo Program Viewer

6.3 Resource Use Tracker

6.4 Other Issues

- screen resolution
- browser issues
- out of control simulations crash computer

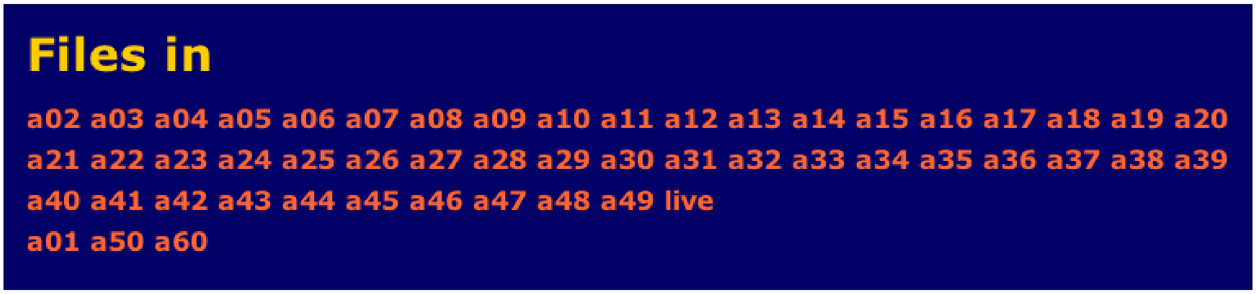


Figure 62: NetLogo Directory Browser

- used MP3 audio recorder

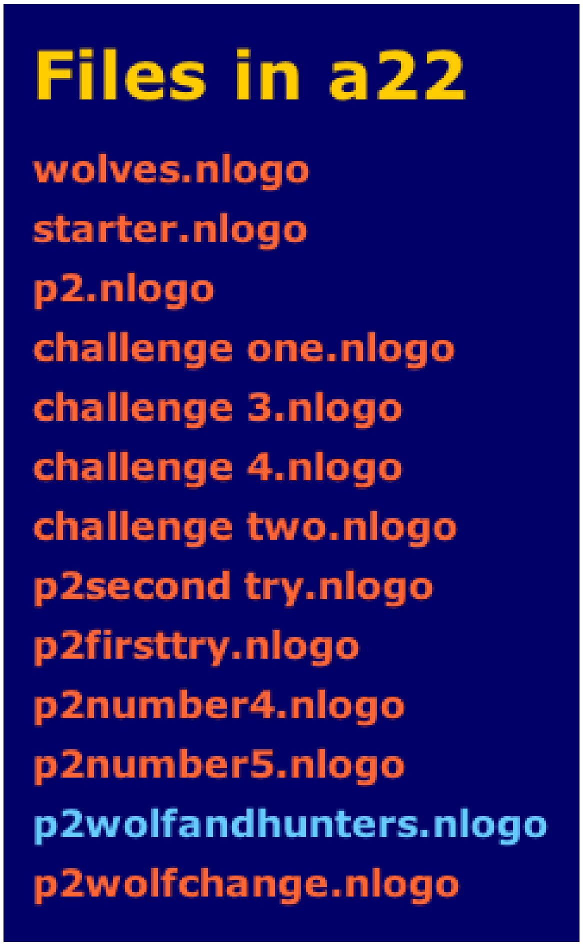


Figure 63: NetLogo Program Browser

```
p2wolfandhunters.nlogo

globals [  ticks
    sheep-threshold
    hunter-limit
    hunter-range
    sheep-reproduce
    sheep-bagged
    wolves-bagged
    wolf-reproduce
    wolf-gain-from-food
    sheep-gain-from-food
    grass-regrowth-time
    weed-regrowth-time
    weed-energy
    weed-color
    grass-color
    weeds?
]
breeds [  sheep wolves hunters]
turtles-own [  energy grabbed? ]
patches-own [  countdown ]
hunters-own [  time-to-hunt ]

to setup
  ca
  set wolf-gain-from-food 20
  set sheep-gain-from-food 4
  ;; set hunter variables (need to be globals or sliders)
  set sheep-threshold 150; how many sheep there are before hunting
                    ; licenses are issued
  set hunter-limit 75        ; how many hunting licenses are issued
  set hunter-range 1         ; how far hunters can see to shoot the sheep
  ;; end of hunter variables
```

Figure 64: Viewing NetLogo Program Code

Figure 65: Managing Trackable Resources

Figure 66: Managing Trackable Resources (Expanded View)

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