

PROMOTING LEARNER SELF-DIRECTION WITH TASK-CENTERED LEARNING
ACTIVITIES IN A GENERAL EDUCATION BIOLOGY COURSE

by

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(Under the Direction of Dr. Lloyd P. Rieber)

ABSTRACT

There is currently a growing recognition of the importance of knowledge and skills that enable students to self-direct and self-regulate personal learning processes. This type of knowledge and skill has received recent attention in higher educational contexts. Despite this attention, it is not widely known how learner self-direction can best be fostered among students in formal education environments. One possible method involves centering learning on real-world tasks or problems. Conceptual connections have been made in the literature between learner self-direction and task-centered learning, yet little empirical research currently supports this connection. The purpose of this study was to investigate the effect of a task-centered approach in a large-enrollment general education biology course on learner self-direction and students' understanding of science concepts. This quasi-experimental study compared two course sections (control and treatment) on measures of learner self-direction and conceptual understanding. The treatment section incorporated learning tasks that required groups of students to work together to apply their science and biology knowledge while the control section incorporated note taking and other activities. Results from this study indicate that students in the control and treatment sections did not significantly differ from each other on the measure of

learner self-direction, nor did either section significantly change over time on this measure.

Additionally, students in the control and treatment groups did not significantly differ from each other on the measure of students' understanding of science concepts. Both sections increased to the same degree on this measure over the semester. In a task survey, students responded that they lacked intrinsic motivation and personal monitoring when doing the learning tasks. However students also reported that they felt the learning tasks were realistic and required the use of information literacy skills. Overall, results from this study suggest that students who learn in a task-centered approach do not increase in learner self-direction any more than students who do not learn in a task-centered approach. The results also suggest that students do not necessarily increase their conceptual understanding in a task-centered learning environment more than in another learning environment.

INDEX WORDS: Self-direction, Self-directed learning, Task-centered, Problem-centered
Self-regulated learning, Self-regulation

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CHAPTER I

INTRODUCTION

The concept of self-direction has captured the imagination of many practitioners and scholars over the past few decades (Merriam, Caffarella, & Baumgartner, 2007). This concept has been described in various ways by researchers and practitioners with terms such as self-directed learning (SDL), learner control, personal responsibility, learner self-direction, and self-direction in learning. Malcolm Knowles (1975) provided a fitting definition of the process of SDL:

“self-directed learning” describes a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes. (p. 18)

In the past, practitioners and scholars have viewed SDL as a kind of panacea for learning. Often, adults were viewed as universally highly self-directed during learning activities. In addition, those who initiate their own learning were hypothesized to learn more deeply and meaningfully than those who don’t initiate their own learning (Knowles, 1975, 1980). While these ideals make some sense initially, experience and further reflection indicate that SDL is not always the best solution, nor are all adults highly self-directing (Brockett, 1994). More recent adult learning theory acknowledges that learners (whether adult or not) will demonstrate various levels of learner self-direction depending on the learning situation (Candy, 1991; Knowles, 1980;

Knowles, Holton, & Swanson, 1998). Learners with more SDL experience and domain knowledge will likely be more ready to self-direct their own learning than those who lack this experience and knowledge (Candy, 1991; Grow, 1991). Consequently, one major focus of the SDL literature is on fostering learner self-direction. Learner self-direction is defined as the ability to self-direct and self-regulate one's own independent learning processes (see Brockett & Hiemstra, 1991; Candy, 1991). Learner self-direction refers to the skills learners need for SDL.

Fostering learner self-direction is an important aim for all educational institutions (Bolhuis, 2003; Guglielmino, 2008; Meichenbaum & Biemiller, 1998). Graduates will need self-directed and self-regulated learning (SRL) skills to help them remain productive in career, personal, and academic settings (Guglielmino, 2008; Zimmerman, 1994). Graduates now enter an economy characterized by high career mobility (U. S. Bureau of Labor Statistics, 2008) and abundant information (Lyman & Varian, 2003), making learner self-direction both more possible and more necessary than it has been in the past. Yet concerns have been raised nationally about the ability of higher education institutions to prepare students with the skills necessary to learn independently and keep up with career changes (The Secretary of Education's Commission on the Future of Higher Education, 2006; The Secretary's Commission on Achieving Necessary Skills, 1991).

At the same time, preliminary studies on the undergraduate experience in general and in engineering have specifically found no significant increase in SDL skills among students from the freshman to senior years (Litzinger, Wise, Lee, & Bjorklund, 2003; Preczewski, 1997). U.S. higher education institutions have been challenged to develop new and innovative pedagogies to support previously neglected skills such as student ability to learn independently (The Secretary of Education's Commission on the Future of Higher Education, 2006; The Secretary's

Commission on Achieving Necessary Skills, 1991). These types of outcomes have been advocated more particularly in science education by the National Science Education Standards of the National Research Council (1996). In this report, inquiry based activities that involve students in the process of science are advocated, and teachers are encouraged to foster learner self-direction by offering students the opportunity to take responsibility for personal learning, conduct self-assessments, and participate in the design of learning environments (see also Bransford & Donovan, 2005).

While fostering learner self-direction is essential, there is not wide agreement on how this is best accomplished. A variety of practices have been proposed and implemented with differing results, perhaps because writers do not agree on a universal definition of learner self-direction. A focused review of SDL theory, practice, and research in order to determine prescriptions for fostering learner self-direction in formal educational environments reveals four main principles: (a) match the level of self-directed learning required in learning activities to learner readiness; (b) progress from teacher to learner direction of learning over time; (c) support the acquisition of subject matter knowledge and learner self-direction together; and (d) have learners practice self-directed learning in the context of learning tasks (Bolhuis, 2003; Brockett & Hiemstra, 1991; Grow, 1991; Hammond & Collins, 1991; Houle, 1961; Knowles, 1975; Meichenbaum & Biemiller, 1998; Tough, 1979). These principles can be used to inform instructional design for fostering learner self-direction.

While some or all of the above principles for fostering learner self-direction have been advocated by SDL experts and practitioners, they do not provide specific guidance for sequencing learning tasks, shifting responsibility for learning toward students and supporting

acquisition of subject matter knowledge and learner self-direction together. Prescriptions from the task-centered learning literature provide more specific guidelines on these matters.

As the name implies, task-centered learning emphasizes students completing tasks rather than studying topics (Merrill, 2007). In an age where information has proliferated and the time it takes to access this information has greatly decreased (Lyman & Varian, 2003), there is a need for more instructional strategies that aim for application and transfer rather than memorization of knowledge. Task-centered models have emerged as a way to holistically integrate learning objectives and support the transfer of learning (van Merriënboer & Kester, 2008; van Merriënboer & Kirschner, 2007; Merrill, Barclay, & van Schaak, 2008). Task-centered instructional strategies give learners opportunities to apply and transfer knowledge in learning tasks. Teaching and learning is centered on tasks that learners are likely to encounter in the future, rather than the topics of a discipline (Merrill, 2002a, 2007). Task-centered models provide specific guidelines for the sequencing of tasks, the fading of support given to learners, and other important aspects of learning and instruction.

There are connections between task-centered instructional strategies and SDL theory and research which may not be obvious at first glance but which become clearer upon further examination. The task-centered learning process is very similar to the SDL process as described in the SDL literature (e.g., Brockett & Hiemstra, 1991; Spear & Mocker, 1984; Tough, 1979), and several of the same activities are common in both approaches including: (a) selecting learning tasks appropriate to personal learning needs (preflection; van Merriënboer & Sluijsmans, 2009); (b) autonomously engaging in deliberate practice activities to achieve learning goals (Ericsson, 2006; Ericsson, Krampe, & Tesch-Römer, 1993); (c) finding, evaluating, and applying information to complete tasks and solve problems (Bolhuis, 2003;

Candy, 1991); (d) monitoring and adjusting learning activities as needed (Garrison, 1997); and (e) determining ways in which personal performance needs to be improved (reflection; Bolhuis, 2003; van Merriënboer & Sluijsmans, 2009).

Statement of the Problem

As previously mentioned, concerns have been raised on the national stage about the ability of higher education to foster learner self-direction (The Secretary of Education's Commission on the Future of Higher Education, 2006; The Secretary's Commission on Achieving Necessary Skills, 1991) because such skills will be needed in most work and life settings outside of school (Guglielmino, 2008). In addition, the National Research Council (1996) has specifically advocated fostering learner self-direction in science learning. At the same time, preliminary studies have been conducted in university settings which found no significant improvement in SDL skills among junior and senior college students (Litzinger et al., 2003; Preczewski, 1997).

It is not known how learner self-direction can best be fostered among students in formal education. A variety of reports and studies reflect the disagreement that researchers have with each other on definitions of the concepts of self-direction in learning (Brockett & Hiemstra, 1991; Candy, 1991; Merriam et al., 2007). In addition, much of the literature contains theoretical or practical advice for fostering learner self-direction without empirical backing that measures changes in learner self-direction (e.g., Grow, 1991; Hammond & Collins, 1991; Knowles, 1975). Other research is primarily exploratory in nature, correlating certain variables such as management levels, academic performance, and income, to SDL readiness (Durr, 1992; Guglielmino & Guglielmino, 2008, 2006; Hashim, 2008; Oliveira, Silva, Guglielmino, &

Guglielmino, 2010). In general, there is a paucity of research on the effects of differing instructional strategies and learning experiences on the ability of learners to self-direct and self-regulate their own independent learning processes (Merriam et al., 2007).

From a practical standpoint, there is also a need to provide college teachers with realistic guidance on how to foster learner self-direction and center learning on tasks that is backed by empirical research. The shift from teaching only for subject matter acquisition toward higher order skills such as learner self-direction is a formidable challenge for many teachers (Bolhuis, 2003). Guidance for this shift should come from realistic research settings and show connections between instructional design decisions and learner self-direction outcomes.

In addition, there is a need for more research on the effects of task-centered learning on learner self-direction and other learning variables. Preliminary findings from the literature have indicated that centering learning on problems can support SDL skills (Hung, Jonassen, & Liu, 2008), however, centering learning on problems or tasks with the use of fading support, modeling and task sequencing has not been extensively tested for its effect on the acquisition of SDL strategies or readiness. Nevertheless, conceptual and research connections have been made between the implementation of task-centered elements and SDL in the literature (see Kicken, Brand-Gruwel, van Merriënboer, & Slot, 2008b, 2009; van Merriënboer & Sluijsmans, 2009).

Purpose of the Study

The purpose of this study was to investigate the effect of a task-centered learning approach in a large-enrollment general education biology course (*Concepts in Biology*) on learner self-direction and students' understanding of science concepts. *Concepts in Biology* is offered each semester at a large public university in the southeast United States. Students usually

take *Concepts in Biology* in order to satisfy a general education science requirement. This course introduces students to basic science concepts from the field of Biology as well as scientific thinking and reasoning. The number of students in the *Concepts in Biology* course sections ranges from 130-350 students during the fall and spring semesters, with lower numbers during the summer. Students in this course are generally not biology majors and are taking the course because of general education science requirements. These students have varying levels of biology knowledge and widely varying levels of ability to take responsibility for their own learning. Ideas from task-centered learning and SDL influenced the *Concepts in Biology* treatment section redesign.

In the treatment (task-centered) section of the *Concepts in Biology* course, groups of students completed learning tasks that were designed to help them apply subject matter knowledge to meaningful activities. The tasks were based on what non-biology majors are expected to do outside of school with their science knowledge. Example tasks include the creation of an information card on sustainable and non-sustainable fish and building an information document explaining why a certain food is unhealthy. In the learning process, students were: (a) introduced to the learning task; (b) taught biology concepts relevant to the task; (c) shown how biology concepts can be used to complete the task; (d) directed to complete the task; and (e) assessed on their task performance. This process repeated for each task. Student groups were also given the choice of which tasks to complete during the semester.

Conceptual and research connections have been made between learner self-direction and task-centered learning (Kicken et al., 2009; van Merriënboer & Sluijsmans, 2009). In the current study it was expected that students would practice some SDL skills as they completed learning tasks (see figure 1). For instance, in *Concepts in Biology*, students selected learning tasks, found,

evaluated and applied information to complete these tasks, and monitored and adjusted their group/personal performance.

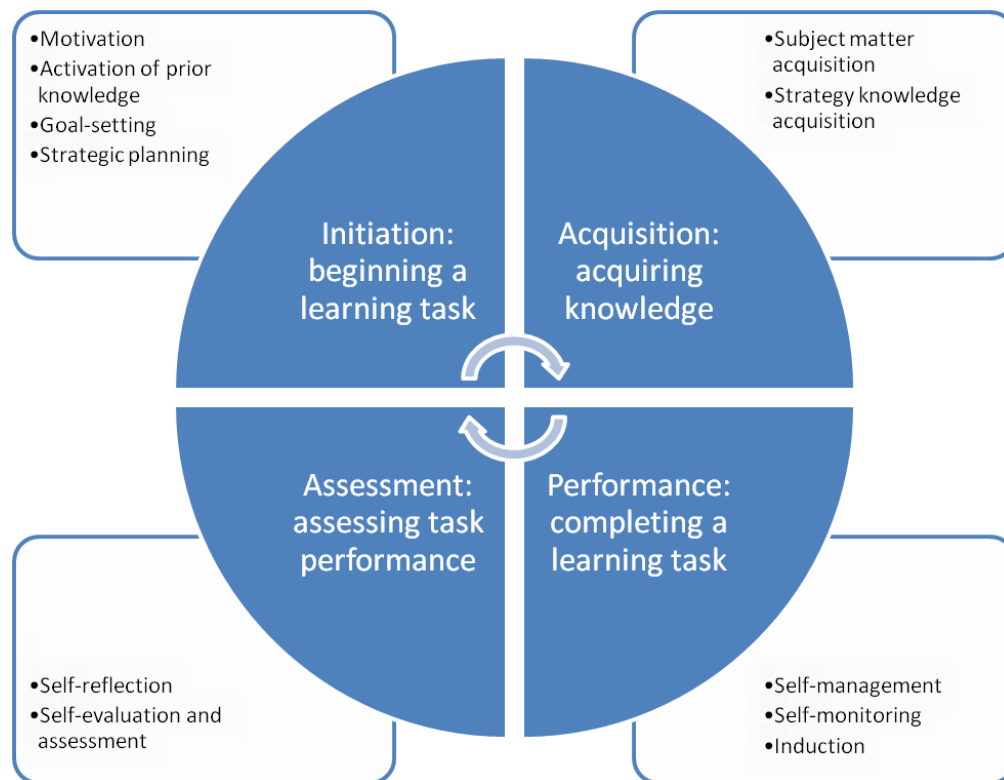


Figure 1. Student processes related to learning tasks within the *Concepts in Biology* treatment section. In each task, students initiated a learning task, acquired knowledge relevant to the task, performed the task and assessed task performance. Hypothesized student skills important for self-direction are given in the outer boxes.

Research Questions, Hypotheses, and Measures

This study has two main research questions about learner self-direction and task-centered learning, and one sub-question:

1. What is the effect of an undergraduate science course designed with a task-centered approach on learner self-direction?

- a. What are participant perceptions of their own self-direction and engagement in task activities during the course?
2. What is the effect of an undergraduate science course designed with a task-centered approach on students' understanding of science concepts?

In order to determine the effect of the redesigned *Concepts in Biology* course, a comparison was made between the *Concepts in Biology* treatment section designed with task-centered activities and a control section taught by the same instructor that did not provide learning tasks to students. Two main hypotheses were formulated based on these questions along with appropriate analysis methods (see also table 1):

Hypothesis 1.1: Participants in the treatment *Concepts in Biology* section will show a higher improvement in learner self-direction than participants in the control *Concepts in Biology* section, as demonstrated by their pre- and post-learner self-direction scores on the personal responsibility orientation self-directed learning scale (PRO-SDLS; Stockdale & Brockett, 2011).

Analysis 1.0: A statistical comparison was made between pre- and post- differences among students in the control and treatment groups. In addition, a task survey was used to help explain why learner self-direction changes did or did not occur and a working memory test was implemented to help explain some of the variance in PRO-SDLS scores. Design team observations were also used to describe the control and treatment sections.

Hypothesis 2.1: Participants in the treatment *Concepts in Biology* section will show a higher improvement in students' understanding of science concepts than participants in the control *Concepts in Biology* section as demonstrated by their scores on a science concepts test (QPS).

Analysis 2.0: A statistical comparison was made between pre- and post- differences among students in the control and treatment groups. Design team observations were also used to describe the control and treatment sections.

Table 1

Hypotheses, methods and analyses for the research questions in this study

Research Question	Hypothesis	Method	Data Analysis
What is the effect of an undergraduate science course designed with a task-centered approach on learner self-direction?	Participants in the treatment section will show a higher improvement in learner self-direction than participants in the control section	PRO-SDLS instrument, working memory test, design team observations	Comparison between pre- and post- differences among students in control and treatment groups, working memory as covariate, analysis of survey responses
What is the effect of an undergraduate science course designed with a task-centered approach on students' understanding of science concepts?	Participants in the treatment section will show a higher improvement in students' understanding of science concepts than participants in the control section	QPS instrument, design team observations	Comparison between pre- and post- differences among students in control and treatment groups

Rationale and Significance

Education has the potential to prepare graduates with the skills needed to keep up with career and life changes through SDL (Guglielmino, 2008). Current conditions make it both necessary and possible to self-direct one's own learning as changes in technology and society occur (Guglielmino, 2008; Knowles et al., 1998). However, student knowledge of key domain concepts cannot be neglected as this knowledge is important for learner self-direction (Bolhuis,

2003; Candy, 1991; Garrison, 1997). This study attempts to link learner self-direction to learning environment characteristics within a practical research setting. Findings can inform practice within the specific classroom of the study, and also seek to provide practical guidelines for designing learning environments that center learning on tasks rather than topics and are designed to foster learner self-direction.

Limitations

In this study it was not possible to randomly assign students to differing conditions; students enrolled in sections themselves. This study measured learner self-direction through the use of the PRO-SDLS (Stockdale & Brockett, 2011), a questionnaire that participants filled out themselves. The assumption with the use of a questionnaire is that students are responding honestly and accurately to the instrument; however a limitation is that they may respond in any way they wish. Another assumption is that the QPS actually measured the conceptual understanding it intended to measure, and students thoughtfully tried to use their science knowledge to respond to it. Due to the length of the study, changes manifest in the instruments from pre- to post- tests may have been affected by nuisance variables such as history and maturation (Campbell & Stanley, 1963), rather than the *Concepts in Biology* course experience. The use of control and treatment sections for this study was designed to reduce the likelihood of these nuisance variables; however this is still a limitation in this study.

The generalizability of this study is limited to situations similar to the original research setting, which involves undergraduate students enrolled at a large public university in the southeast United States. Differences between the original research study and replication study settings and practices may arise, making different measurement outcomes possible.

Another limitation with this study stems from its dynamic nature. Since the *Concepts in Biology* course is an actual college course, negotiations occurred during the semester that may have had effects on how the learning took place in the course. The design team observations were used to report on the final course design as it actually turned out and briefly explain important design decisions to help mitigate this issue.

Summary

Scholars and practitioners have conceptualized self-direction in learning in many different ways. One focus of this literature has been on fostering learner self-direction, or the ability to self-direct and self-regulate one's own independent learning processes (see Brockett & Hiemstra, 1991; Candy, 1991). Skills for SDL and SRL are becoming increasingly important because of changes in society, including career mobility and information proliferation (Guglielmino, 2008). Institutions of higher education and science teaching in the United States and elsewhere urgently need to foster learner self-direction, yet there is no general agreement on how to best accomplish this (National Committee on Science Education Standards and Assessment, 1996; The Secretary of Education's Commission on the Future of Higher Education, 2006; The Secretary's Commission on Achieving Necessary Skills, 1991). A review of the literature in self-direction and task-centered learning provides guidelines for fostering learner self-direction. There is a need to investigate the effects of learning environments on learner self-direction, including task-centered learning. Teachers are also in need of practical and empirical guidelines for centering learning on tasks and fostering learner self-direction.

The current study was designed to determine the effect of a redesigned large-enrollment biology course on students' understanding of science concepts and self-direction. The course

redesign is based on ideas from the self-directed and task-centered learning literature. This study used control and treatment conditions for comparison on learning performance (using the QPS) and learner self-direction (using the PRO-SDLS). This study contributes to our understanding of the effects of learning environments on learner self-direction and provides practical guidelines for fostering learner self-direction.

CHAPTER II

REVIEW OF THE LITERATURE

The purpose of this study was to investigate the effect of a task-centered approach in a large-enrollment general education biology course (*Concepts in Biology*) on learner self-direction and students' understanding of science concepts. The treatment *Concepts in Biology* course section was redesigned to feature learning tasks that require students to self-direct some aspects of their learning and performance. The study was influenced by the self-directed learning (SDL) and task-centered learning literature, thus, two main areas of review are featured, SDL and task-centered learning.

Search tools used to complete this literature review include the ERIC database of journal articles, Google scholar, and World Wide Web search engine databases. In addition, the GALILEO and GIL databases available from the University of Georgia Library system have been used. Where appropriate, bibliographies of books and articles were used to find additional resources. Search terms included the following: self-directed learning, learner self-direction, self-direction, self-directed learning skills, self-regulated learning (SRL), self-regulation, task-centered, whole-task, first principles of instruction, and related terms.

Because the broad concept of self-direction in learning is viewed in different ways by different people, this chapter provides an overview of the different definitions emerging from this concept. Next, the definition of learner self-direction is given along with an explanation why fostering learner self-direction in higher education (the setting for the current study) is important.

A review of studies designed to foster learner self-direction is then presented. Finally, these studies, along with SDL and SRL research and theory are synthesized for four main prescriptive principles for fostering learner self-direction in education.

A review of task-centered learning is also given in this chapter. Task-centered learning is learning that is centered on tasks learners perform rather than the topics of a discipline (van Merriënboer & Kirschner, 2007; Merrill, 2007). In this chapter a synthesis of task-centered models is presented in order to explain the elements of a task-centered learning approach. First principles of instruction (Merrill, 2002a) and four-component instructional design (van Merriënboer & Kirschner, 2007) are outlined as examples of task-centered models. A review of the literature on task-centered implementations is also provided, showing effects on student satisfaction, learning performance and learner self-direction.

Also in this chapter, a connection is made between learner self-direction and task-centered learning. These two concepts are connected based on Brockett and Hiemstra's (2010) PRO model conceptualization of SDL, including the SDL process, personal skills and abilities and the learning context. Finally, suggestions for future research on task-centered learning and learner self-direction are offered.

Self-Directed Learning

SDL theory and research is largely based on studies of adults' independent learning projects (Merriam et al., 2007). Such studies describe adults' learning activities, preferences and abilities (e.g., Houle, 1961; Tough, 1979). Much of what we know in adult learning theory has been heavily influenced by early studies of SDL (Merriam, 2001). The research and theory of

SDL show a variety of different viewpoints about this concept (Merriam, 2001; Merriam et al., 2007).

The broad concept of self-direction in learning has been conceptualized in different ways (see Table 2) including self-directed learning, learner control, personal responsibility, learner self-direction and self-direction in learning. *Self-directed learning* refers to the process in which learners take primary responsibility for their own learning (Candy, 1991; Knowles, 1975; Merriam et al., 2007). SDL as a process has been studied both inside and outside formal educational settings (Candy, 1991; Merriam et al., 2007). Research on this element of self-direction has mainly focused on the activities learners carry out to learn independently (Houle, 1961; Merriam et al., 2007; Tough, 1979). A variety of models that describe the processes learners undergo for SDL have been proposed, ranging from linear to haphazard (Merriam et al., 2007). Some research has also centered on elements external to and supportive of the learner such as evaluation activities, learning resources, needs assessment, and teacher roles (Brockett & Hiemstra, 1991).

Learner control is a way of organizing instruction or instructional materials in a formal educational setting so as to give learners some degree of control over the learning situation (Candy, 1991; Williams, 1993). Allowing learners a degree of control over the learning situation is essential to giving learners practice at being self-directed in their learning (Bolhuis, 1996, 2003; Zimmerman, 1994). Most of the research on learner control has attempted to determine what types (sequence, scope, pacing, etc.) and amounts of learner control are best for learning outcomes and motivation (Niemic, Sikorski, & Walberg, 1996; Williams, 1993). Although taken together, much of the learner control literature has been inconclusive (Reeves, 1993). However, learner control still remains an area of serious inquiry, particularly in computer-based

instruction (eg. Eom & Reiser, 2000; Kopcha & Sullivan, 2008; Scheiter & Gerjets, 2007; Schmidt & Ford, 2003).

Table 2

Conceptualizations of the concept of self-direction

SDL element	Definition	Research focus
Self-directed learning	A process of learning in which learners take responsibility for personal learning	Effect of elements external to the learner on performance and the process learners undergo to learn independently
Learner control	Giving students some control over learning situations in formal educational settings	Type and amount of control to give students and the effect on performance and motivation
Learner autonomy	The capacity and willingness to take control of one's own learning	Ability of learners to take control of a learning situation, personal attributes tied to learner self-direction and how to increase learner self-direction
Learner self-direction	The ability to self-direct and self-regulate one's own independent learning processes	Skills needed to self-direct learning and methods to increase these skills
Self-direction in learning	The combination of both learner self-direction and the self-directed learning process in a learning situation	Both personal skills and attributes of learners and elements of learning external to the learner as well as the degree of fit between the two

Note. The concept of self-direction has been conceptualized in many different ways in the literature (Brockett & Hiemstra, 1991; Candy, 1991; Houle, 1961; Meichenbaum & Biemiller, 1998; Merriam et al., 2007; Tough, 1979; Williams, 1993).

Learner autonomy refers to a personal capacity and willingness to take control of one's own learning including making appropriate learner choices and carrying out learning tasks independently (Brockett & Hiemstra, 1991; Candy, 1991). Based on this definition, a combination of personal characteristics and skills are needed for a learner to be able to self-direct

learning. *Learner self-direction* is comprised of the skills and subject matter knowledge that one needs in order to successfully self-direct and self-regulate learning. Learner self-direction for a particular learner can be seen as sitting on a continuum between high learner self-direction (i.e., possessing a high level of skill and subject matter knowledge for SDL in a particular domain) and low learner self-direction (i.e., possessing a low level of skill and subject matter knowledge for SDL in a particular domain; Brockett & Hiemstra, 1991; Candy, 1991).

Self-direction in learning integrates both learner self-direction and the SDL process into a single learning situation (Brockett & Hiemstra, 1991; Meichenbaum & Biemiller, 1998). Any given learning situation sits on a continuum from low to high SDL required of learners. A given learner will also sit on a continuum from low to high self-direction. A match between learner self-direction and required SDL activity indicates a situation in which optimal learning may occur (Brockett & Hiemstra, 1991; Grow, 1991). Research focused on self-direction in learning has examined personal attributes and skills of learners that allow them to be self-directed as well as activities requiring the learner to engage in SDL (Brockett & Hiemstra, 1991; Candy, 1991).

One major focus in the SDL literature is how to increase learner self-direction (Merriam et al., 2007). There are many reasons for efforts to increase the ability of students to self-direct and self-regulate their own learning. Such efforts have been proposed, developed, and implemented to help learners increase their ability to self-direct and self-regulate personal learning processes (Bolhuis, 2003; Candy, 1991; Grow, 1991; Merriam et al., 2007).

Differences and Similarities Between Self-Directed and Self-regulated Learning

The terms *self-directed learning* and *self-regulated learning* have often been used interchangeably in the literature and these concepts have many similarities (Loyens, Magda, &

Rikers, 2008; Zimmerman & Lebeau, 2000). Both SDL and SRL involve learners who set goals, implement learning plans, self-evaluate, and make use of metacognition, motivation and domain knowledge (Loyens et al., 2008). SDL, however, generally encompasses both design features of a learning environment and learner characteristics, whereas SRL is sometimes described in the literature as no more than a student characteristic employed in formal learning environments (see table 3; Loyens et al., 2008; Pilling-Cormick & Garrison, 2007).

Table 3

A comparison of self-regulated and self-directed learning

Aspects	Self-Regulated Learning	Self-Directed Learning
Audience	Elementary and higher education	Adult learning and higher education
Study settings	Primarily formal education	Formal, non-formal and informal learning
Learning tasks	Academic (homework, writing, readings etc.) and professional practice-based	Professional practice-based
Learner activities	Setting goals, learning (forethought, performance, self-reflection), and evaluation	Choosing what to learn, self-initiation, learning, performance, and assessment
Learner characteristics	Metacognition, motivation, and domain knowledge	Assumptions about adult learning
Design implications	(not always implied) Student control, guidance and support	Student control, center learning on tasks

Note. For differences between SDL and SRL, see audience, study settings, and learning tasks (Loyens et al., 2008; Pilling-Cormick & Garrison, 2007; Zimmerman & Lebeau, 2000).

Literature from both SDL and SRL is relevant to efforts to foster learner self-direction because both have implications for the design of instruction. SRL skills are those skills necessary for direction of personal learning within educational settings whereas SDL skills are skills necessary for direction of personal learning outside of educational settings. Descriptions of SDL skills usually encompass SRL skills and abilities in the literature (Loyens et al., 2008).

Learner Self-Direction in Higher Education

Learner self-direction is one of the most important skills that higher education can foster among students (Bolhuis, 2003; Guglielmino, 2008; Meichenbaum & Biemiller, 1998). The need for learner self-direction has become urgent in recent times because of increased career change frequency (U. S. Bureau of Labor Statistics, 2008) and differences between the information and skills taught in school and those used in outside-of-school contexts (Brown, Collins, & Duguid, 1989; Lave, de la Rocha, Faust, Murtaugh, & Migalski, 1982).

The career climate is currently different for those entering the market than it has been in the past (Brown, 2000; Neal, 1999). Graduates can no longer count on the same job for a career or on using a similar set of skills for each work situation. In most careers some SDL will likely be needed to keep up with career changes (Guglielmino, 2008). Career mobility data give support for the assumption that education should produce graduates who are able to independently direct their own learning. During the first eight years of work, men change their career or job an average of 4.8 times and women change their career or job an average of 4.3 times (Light, 2005; U. S. Bureau of Labor Statistics, 2008). Those with a college degree change careers at a rate higher than those without (U. S. Bureau of Labor Statistics, 2008). These statistics indicate that a past ideal of job stability has been supplanted with job flexibility and

adaptability as workers frequently change jobs because of layoffs, firings, and other economic reasons (Brown, 2000; Neal, 1999). Job security can no longer be tied to longevity within an organization – rather it has increasingly been associated with an individual’s resilience and career management skills (Brown, 2000). Skills needed in today’s changing workplace include a capacity to adapt to change and independently increase one’s own skills (Brown, 2000; Sterns & Dorsett, 1994).

Even if one were to assume that graduates would be working in a relatively stable career, there is also long-standing evidence that differences exist between learning in school and task performance outside of school that may inhibit the transfer of personal learning skills to post-school settings (Lave et al., 1982; Resnick, 1987). Based on studies of learning experiences in what she terms “practical settings,” Resnick (1987) outlines several key dimensions upon which learning out of school differs from learning in school and suggests that more effective career preparation is needed than is currently supported in schools. Also, curriculum designers and teachers in education may still rely upon instructional design that tends to compartmentalize learning domains, fragment learning objectives and sequence learning activities in ways that inhibit transfer of learning to out-of-school settings (van Merriënboer & Kirschner, 2007).

Because career mobility rates have increased and because tasks in school may be different than tasks outside of school, concerns have been raised in the United States about the ability of higher education to provide adequate career and life preparation. As early as 1991, the United States Department of Labor indicated that the types of skills typically learned in education and those needed for success outside of education were quite different (The Secretary’s Commission on Achieving Necessary Skills, 1991). This report indicates that, among other things, higher education should foster previously neglected skills, including finding,

evaluating and applying information appropriately, learning independently and solving problems. A more recent report commissioned by the U.S. Department of Education further declares that employers are not satisfied with recent graduates' critical thinking, writing, and problem-solving skills (The Secretary of Education's Commission on the Future of Higher Education, 2006). This report suggests that many institutions of higher education have not taken full advantage of methods of teaching that could prepare students for lifelong learning demands. U.S. higher education institutions have been challenged to develop new pedagogies, curricula, and technologies to improve learning (The Secretary of Education's Commission on the Future of Higher Education, 2006).

Within science learning, inquiry based activities that allow students to be involved in the process of science have been advocated (Bransford & Donovan, 2005). In addition, teachers are encouraged to foster learner self-direction by offering students the opportunity to take responsibility for personal learning, conduct self-assessments, and participate in the design of learning environments (National Committee on Science Education Standards and Assessment, 1996).

There appears to be an urgent need to foster adequate career performance and higher order skills such as learner self-direction in higher education. Approaches that aim to foster higher order learning should go beyond basic skills assessment and incorporate assessment methodologies that measure higher-order outcomes such as improvements in student understanding of complex subject matter and improvement in student learning processes (Spector, 2003).

Some institutions of higher education have begun to take notice of the need to foster higher-order skills such as learner self-direction among students (Guglielmino, 2008). Studies

have linked SDL skills to several desirable characteristics such as high academic performance, high job performance, entrepreneurial success and high management levels (Oliveira et al., 2010; Hashim, 2008; Durr, 1992; Guglielmino, Guglielmino, & Long, 1987; Guglielmino & Klatt, 1994). Fostering SDL skills may provide a way to prepare students to adapt to career and life changes, but fostering learner self-direction involves more than simply providing a minimal level of guidance to students as such an approach may be detrimental to student acquisition of knowledge in long term memory (Kirschner, Sweller, & Clark, 2006). Prior research findings indicate the importance of guidance and support to foster more effective learning, however, there may also be a need for balance between personal student experience and teacher guidance to allow self-direction to occur within formal educational settings (Rieber & Noah, 2008). Thus questions still remain as to how much support and guidance is optimal to balance these needs.

There is a need to provide realistic guidance on how to foster learner self-direction and center learning on tasks that is supported by empirical research. The shift from teaching only for subject matter acquisition toward higher order skills such as learner self-direction is a formidable challenge for many teachers (Bolhuis, 2003). Guidance for this shift should come from realistic research settings and show connections between instructional design decisions and learner self-direction outcomes.

Review of Instructional Strategies to Foster Learner Self-Direction

Both SDL and SRL theories have led to the adoption of instructional strategies in education to foster learner self-direction. This review of instructional strategies is limited to studies that have empirical measurements of SRL and/or SDL strategies and readiness, and are implemented in educational settings. Three main areas of studies are presented, studies in which

students are given some control over the learning situation, studies in which a specific type of guidance or support is given to students, and studies in which learning is centered on tasks or problems to support learner self-direction.

Student Control

Many implementations aimed at fostering learner self-direction involve student control over the learning situation. In sixth grade classrooms in Israel, Eshel and Kohavi (2003) researched the effect on self-regulation of treatments in which varying levels of student control were offered. This study was exploratory in nature, examining correlations between variables identified through several different questionnaires and relying upon the assumption that students reported accurately. Findings indicate that students tend to exhibit self-regulatory behaviors in classrooms in which they also perceive a high amount of student control over the learning process. The authors suggest creating a classroom environment characterized by high student control.

This high amount of student control also showed self-direction outcomes in a problem-based learning environment. Arts, Gijssels and Segers (2002) modified a problem-based learning environment in business studies to increase the authenticity of cases, allow students to control aspects of learning tasks, and have students work in business practice teams. Findings from this quasi-experiment indicated that students in the modified problem-based learning (treatment) condition showed superior cognitive outcomes in the form of performance on a SRL problem to those in the control (regular problem-based learning) condition. Although it is not known which of the many factors in the study specifically led to the increased SRL outcomes, this study suggests that providing students with some control of their learning within a problem-based learning environment may enhance SRL skills.

Two qualitative studies investigated student and teacher perceptions of student autonomy within environments that allowed students to make choices about what to learn and what resources to use. Cotterall and Murray (2009) provided SDL opportunities to students in a language learning class by allowing students to decide what to learn and to choose which resources to use for learning. The authors conclude that these elements of the course structure, along with subject matter acquisition, contributed to student's metacognition and ability to plan, monitor and evaluate learning. Luke (2006) also observed increased learner autonomy among students in a language course that allowed students to choose their own inquiry-based learning activities. The author concluded that learner autonomy was enhanced by a choice of learning activities. Causality cannot be inferred from either study because of a lack of control-treatment comparisons.

Another study investigated the effects of information seeking (another form of student resource choice) on student readiness for SDL. Gabrielle, Guglielmino and Guglielmino (2006) tested whether requiring students to seek out their own information beyond that required for the course would increase student readiness for SDL (as measured by the self-directed learning readiness scale; Guglielmino, 1977). This study reported a statistically significant increase in SDL readiness scores for students in the treatment group (required to seek extra information), while the control group (not required to seek extra information) showed no such increase over the time of one semester. The treatment group also showed significantly better learning performance than the control group. Because the study lasted for a semester, it is difficult to fully attribute student's increase in SDL readiness to only the course in question and not nuisance variables related to history or maturation (Campbell & Stanley, 1963), but the use of a pre-

measurement strengthens the findings by comparing pre- and post-SDL readiness scores during the semester.

Based on these studies featuring different types of student control, learning experiences that allow students a level of control over the learning situation may help enhance learner self-direction. In these studies, students were allowed to control group meeting experiences, the sequencing of information, resources to learn from, and even what topics to learn about. When learning and self-direction were measured together, learning was significantly better in conditions allowing increased student control of the learning situation than in conditions that did not offer increased student control. These findings should be interpreted with caution, however. Clark (1982) indicated that higher ability students benefit from learning environments that provide more student control over learning processes, while lower ability students benefit most from learning environments characterized by low student control. His analysis revealed that students generally choose the learning environment that is not beneficial to them. Research is still needed to determine which aspects of the learning experience students should control and how much control should be given for the enhancement of learning and learner self-direction.

Guidance and Support for Self-Direction

Many studies documenting an increase in SRL and SDL skills investigated the effect of differing types of guidance and support. This guidance and support might show students how to carry out such learning strategies as detecting and responding to feedback, motivating one's self to initiate and complete tasks, set learning goals, evaluate learning outcomes and more. Findings from learning strategies research indicate that students often do not understand when to use a learning strategy, and efforts to increase student understanding about learning strategy use have shown improvement in self-direction (Borkowski, Levers, & Gruenfelder, 1976; Ghatala,

Levin, Pressley, & Goodwin, 1986). In addition, studies have suggested that determining the type and amount of guidance to give to students is a situated activity involving trade-offs between the need for certain instructional objectives to be met and the need for students to direct aspects of their own learning (Rieber & Noah, 2008; Rieber & Parmley, 1995).

While investigating the effects of guidance for learning task selection and planning, Kicken, Brand-Gruwel, van Merriënboer and Slot (2009) found that students receiving specific advice on the use of a portfolio designed to guide students' SDL activities selected more effective learning tasks and completed more assignments than those who only received learning feedback. This study was limited in that participants did not make extensive use of the portfolio and only had limited learning tasks to choose from, yet findings suggest that guidance and advice on planning learning tasks enhances learning and SDL skills.

Similar findings resulted from another study in which students were taught self-regulatory skills. Glaser and Brunstein (2007) compared writing skill outcomes between students who were taught SRL skills along with writing strategies (treatment) and students who were taught writing strategies alone (control). The SRL skills taught included strategic planning, self-monitoring, self-assessment and goal setting. Students in the treatment group showed superior writing and recall skills compared to the control group. Students in the treatment group also showed superior maintenance of writing skills over time. This study used pre-, post- and maintenance tests to support its findings.

Studies have focused on helping students with self-regulation during learning tasks with positive results on learner self-direction, one with the use of a facilitator and the others with the use of technology. Azevedo et al. (2008) investigated the effect of external facilitation on knowledge, mental model progress and SRL in a hypermedia learning environment. They found

that the presence of a facilitator who helped students activate their prior knowledge, plan time, monitor progress and use learning strategies helped students to learn better than students without a facilitator. However, students from both conditions exhibited learner self-direction behaviors including planning, monitoring, and the use of learning strategies. Kramarski and Michalsky (2009) also investigated the effect of the use of e-learning technology and learner self-direction support. They supported students' metacognitive self-questioning and investigated the effect on self-regulatory skills. Findings from both studies imply that an environment that provides regulatory support to students in the form of self-questioning and monitoring help may enhance learning and learner self-direction. In addition, Robertson (2011) investigated student blog postings about SDL aspects such as goal setting, learning evaluation, planning, predicting outcomes and identifying learning gaps. Her qualitative analysis revealed that about 96% of students and 50% of blog posts contained excerpts that exemplified one of these aspects of SDL.

Researchers stress the important role that feedback plays in SRL and SDL and offer strategies for helping students to take advantage of learning feedback (Butler & Winne, 1995). For example, Cleary and Zimmerman (2004) implemented the self-regulation empowerment program for middle school students in which students were taught to detect and appropriately respond to instructor feedback. The goal was to improve SRL skills and academic performance as a result. Implementations of this program have shown positive results on learning and learner self-direction. More recently, students in medical clinical internship positions were given explicit written and verbal feedback on their work (Embo, Driessen, Valcke, & Van der Vleuten, 2010). Student perceptions indicated that this feedback – along with assessment checklists of specific clinical duties – effectively supported their own SDL within this clinical environment.

In addition to detecting and responding to feedback, studies show the importance of building on prior knowledge for the development of SRL and SDL skills. Guterman (2003) tested whether metacognitive awareness training, which activated student's prior knowledge, would improve student reading comprehension. Findings indicated that fourth grade students' comprehension and use of metacognitive strategies were increased in the treatment condition, however the control condition was a "no instruction" condition, allowing one to question whether the effects resulted from the activation of prior knowledge or the presence of instruction. Similar to findings from Guterman (2003), Gaultney and Hack-Weiner (1993) observed that fourth- and fifth-grade students who were poor readers yet experts at baseball transferred the use of reading strategies more effectively when their prior knowledge of baseball was explicitly activated within strategy instruction. Thus the successful use and transfer of self-direction may be affected by the activation of learner prior knowledge.

Studies on the use of learner guidance for self-direction indicate that learner self-direction may be enhanced through instruction that teaches when and why to use learning strategies, provides advice on planning learning activities, supports students with self-questioning guidance, helps students detect and appropriately respond to feedback, provides modeling, and activates prior knowledge. However, research is still needed to determine which aspects and types of support and guidance are most effective at enhancing learner self-direction.

Centering Learning on Tasks and Problems

Mayer (1998) called attention to the importance of self-regulatory strategies in problem-solving, and Winne (1997) suggested that self-regulation is a part of goal-directed behavior and that students tend to learn self-regulatory skills while solving problems. Several research studies

have tested inquiry-based and problem-solving activities to determine effects on SRL and SDL skills.

Some studies have compared learning that is centered on problems to other learning environments. For instance, Blumberg and Michael (1992) implemented a partially teacher-directed and partially problem-based curriculum and observed increases in students' SDL activities as measured by self-reports, program evaluations and library circulation data. This study made use of a comparison class and found significantly higher student SDL activities in the problem-based class than those in the control (lecture-based) class. As mentioned previously, Arts, Gijssels and Segers (2002) implemented a problem-based learning environment with increased student control, task-authenticity and group work. Students in the enhanced problem-based learning condition outperformed students in the problem-based learning condition on a case study problem that required some learner self-direction for its completion.

Sungur and Tekkaya (2006) also compared problem-based learning to “traditional” (lecture-based) instruction to determine resultant student SRL skills (as measured by the motivated strategies for learning questionnaire or MSLQ; Pintrich, Smith, Garcia, & McKeachie, 1993). Findings indicated that students in the problem-based learning condition increased scores on the MSLQ more than students in the control group. Scores from the MSLQ indicated that students in the treatment group used more learning strategies and showed more motivation. This study relied on participant self-reports which may or may not have been accurate. Najmi, Blackwell and Warren (2011) investigated the use of SRL strategies within an alternate reality gaming environment that follows the principles of problem-based learning. In a qualitative analysis, they discovered that several important skills conducive to SRL were also exhibited by students in this environment.

Findings from these studies indicate that learning experiences centered on tasks and problems may provide opportunities for students to practice SRL and SDL skills. However, additional research on which aspects of task and problem-centered learning environments lead to the development of learner self-direction is needed.

Overall, a wide variety of principles and practices are advocated by researchers for providing student control of the learning situation, providing guidance for how to direct aspects of learning and for centering learning on problems or tasks. To date, there is not a generally agreed upon comprehensive model for fostering learner self-direction.

Principles for Fostering Learner Self-Direction

The research and theory literature described above was synthesized for prescriptive principles for fostering learner self-direction in education. These principles were sought to guide instructional design activities intended to foster learner self-direction and will be presented and supported in this section. Four main prescriptive principles for fostering learner self-direction in formal education can be extracted from SDL theory, models and research:

- Match the level of self-directed learning required in learning activities to learner readiness;
- Progress from teacher to learner direction of learning over time;
- Support the acquisition of subject matter knowledge and learner self-direction together; and
- Have learners practice self-directed learning in the context of learning tasks.

The first principle for fostering learner self-direction involves matching the level of SDL required in learning activities to learner readiness (Bolhuis, 2003; Brockett & Hiemstra, 1991;

Grow, 1991; Hammond & Collins, 1991; Knowles, 1975). Adult learning literature acknowledges that individuals may be highly self-directing in some situations and not in others, or that they may be somewhere in between high and low on the self-directing continuum (Candy, 1991; Knowles, 1980; Knowles et al., 1998). Learners (whether adults or not) with more SDL experience and domain knowledge will likely be more ready to self-direct their own learning than those who lack this experience and knowledge (Candy, 1991; Grow, 1991). This principle applies to SDL activities that include allowing learners to set learning goals, specify what will be learned, determine the pace of learning, and evaluate learning outcomes (Hiemstra, 1994). If a learner is required to do these activities without regard to readiness, he or she may fail to learn or increase in learner self-direction (Brockett & Hiemstra, 1991; Candy, 1991).

Findings from studies of SDL and SRL indicate that many learners are not ready to completely control a learning situation, and may need to first experience teacher-directed learning (Howland & Moore, 2002; Raidal & Volet, 2009). Dynan, Cate and Rhee (2008) found that students whose SDL readiness is matched to a requisite learning structure increased in self-direction over the course of a semester to a greater degree than those who were not matched. Similarly, Bhat, Rajashekar and Kamath (2007) found that a high level of SDL activities helped high performing students learn while these activities did not benefit lower performing students. These findings suggest that matching the level of SDL activities required to learner readiness may be important for helping students learn and increase in learner self-direction.

The second principle advocates progressing from teacher to learner direction of learning over time (Bolhuis, 2003; Brockett & Hiemstra, 1991; Candy, 1991; Grow, 1991; Meichenbaum & Biemiller, 1998). This principle takes a learner from his or her current level (as suggested in principle one) toward higher self-direction over time. Prescriptive models of SDL offer practices

for gradually increasing learner direction of the learning process. For example learners can be increasingly allowed to set learning goals, specify what will be learned, choose learning resources and evaluate learning outcomes as a learning experience progresses (Grow, 1991; Hiemstra, 1994). Such an approach should take into account the first principle and provide learners SDL activities that match their readiness. Learners' abilities to self-direct may increase as opportunities to self-direct learning are increasingly offered (Bolhuis, 2003; Grow, 1991).

Researchers have suggested that shifting learning responsibility toward learners over time by scaffolding and fading support for SRL and SDL skills is vital for the teaching of self-direction (Azevedo, Cromley, & Seibert, 2004). Hadwin, Wozney and Pontin (2005) followed the SRL development of graduate students in a research methods course for several months. They found that the general process in this setting involved teacher-direction that progressed to co-direction and finally student-direction of the learning process. This shift toward student direction of the learning process was also found in elementary school classrooms in which students are considered high in SRL (Perry, VandeKamp, Mercer, & Nordby, 2002). Similarly, Schunk and Rice (1993) found that fading self-regulatory instructions were superior to self-regulatory instructions that were not faded in helping students with reading problems to self-regulate their learning. These studies suggest that gradually increasing learner direction of the learning process may foster learner self-direction.

The third principle for fostering learner self-direction involves supporting the acquisition of subject matter knowledge along with learner self-direction. Cognitive strategies (such as those required for learner self-direction) require the use of intellectual skills (concepts, rules, etc. of a discipline) which require basic knowledge of subject matter (Gagné, 1985). Theoretical models of SDL have acknowledged that some domain knowledge is necessary for learners to be able to

take responsibility for learning (Bolhuis, 2003; Grow, 1991). Learners should be introduced to relevant domain knowledge including underlying principles, procedures for knowledge acquisition, and generalizability of knowledge and practices, as they practice self-direction (Bolhuis, 2003; Vermunt & Verschaffel, 2000).

Extensive domain knowledge may also enable learners to free up working memory for processes related to self-regulation and self-direction of learning (Sweller, Van Merriënboer, & Paas, 1998). For example, experts are hypothesized to have tightly organized and elaborate knowledge structures that help them chunk memory for superior performance, monitoring and adjustment (Bransford, Brown, & Cocking, 2003; Chi, 2006). When investigating the connection between subject matter and SRL skills, Glaser and Brunstein (2007) found that providing instruction on both subject matter and SRL skills was more effective for helping students to control their learning than simply teaching subject matter. Similarly, Cotterall and Murray (2009) provided SDL opportunities to students in a language learning class including allowing students to decide what to learn and allowing them to choose resources to use for learning. The authors conclude that these elements of the class structure along with subject matter acquisition contributed to an increase in learner self-direction.

The fourth principle for fostering learner self-direction advocates practicing SDL in the context of learning tasks. Studies of self-directed learners describe these learners as task-oriented, with the practical aim of applying learning to a specific task (Houle, 1961; Tough, 1979). Consequently, models of SDL have advocated providing learning that is centered on tasks that learners are likely to encounter in the future (Bolhuis, 2003; Hammond & Collins, 1991). As learners engage in these tasks, they may be required to do such SDL activities as: (a) selecting learning tasks appropriate to personal learning needs (preflection; van Merriënboer &

Sluijsmans, 2009); (b) autonomously engaging in deliberate practice activities to achieve learning goals (Ericsson, 2006; Ericsson et al., 1993); (c) finding, evaluating, and applying information to complete tasks and solve problems (Bolhuis, 2003; Candy, 1991); (d) monitoring and adjusting learning activities as needed (Garrison, 1997); and (e) determining ways in which personal performance needs to be improved (reflection; Bolhuis, 2003; van Merriënboer & Sluijsmans, 2009). Practicing SDL in the context of tasks may foster learner self-direction while increasing the relevance and usefulness of learning activities.

Connections have been made in the literature between the implementation of problem-based and task-centered learning and increases in learner self-direction (Gurses, Acikyildiz, Dogar, & Sozbilir, 2007; Hung et al., 2008; van Merriënboer & Kester, 2008; Stewart, 2007). Woods (1996) found that student self-perception of SDL ability increased over time in a problem-based learning environment. As mentioned previously, Blumberg and Michael (1992) went beyond student perception and measured self-direction using self-reports of SDL, program evaluations and library circulation data over time within a partially teacher directed and problem-based curriculum. They observed significant increases in students' SDL activities based on this data. Sungur and Tekkaya (2006) also found that a problem-based learning environment enhances learner self-direction more than a “traditional” lecture-based environment.

These principles for fostering learner self-direction in formal education have implications for the design of instruction and can be implemented in a variety of learning settings. While these principles provide general guidelines for the design of instruction, task-centered models provide more specific guidance for sequencing learning tasks, shifting responsibility for learning toward students, and supporting the acquisition of subject matter knowledge and learner self-direction together.

Task-Centered Learning

Task-centered models in education share three main characteristics. The first characteristic is that tasks that are based on real world performance are used as the main learning activity (van Merriënboer & Kester, 2008). These tasks are sequenced from easy to difficult and support and guidance is given to learners to help them perform the tasks. Support is faded as learners increase in their knowledge and skill (i.e., as learners increase in their ability to perform tasks, demonstration, coaching and feedback are reduced). The second characteristic of task-centered models is that they integrate knowledge from different domains or classifications – the learning process is holistic in nature and knowledge is bound to a learning task. The third characteristic of task-centered models is a focus on transfer of learning.

Task-centered learning has been influenced by a variety of instructional design and learning concepts. The concept of integrative objectives in instructional design is at the root of task-centered learning (Gagné & Merrill, 1990). Influences have also come from component display theory (Merrill, 1983), elaboration theory (Reigeluth, 1979), and cognitive apprenticeship (Collins, Brown, & Newman, 1989). Other influences for task-centered learning come from andragogy, motor learning, and psychology (van Merriënboer & Kester, 2008).

The work of Gagné and Merrill (1990) on the concept of integrative instructional objectives which combine subordinate objectives into a meaningful whole has influenced the use of the whole task. Component display theory (Merrill, 1983) offers instructional design guidance on the presentation and application of knowledge, giving preference to activities that allow learners to apply and use knowledge over memorization and recitation activities. Elaboration theory (Reigeluth, 1979, 1999) advocates finding the simplest version of a task that still

resembles what a person might do in professional practice and involving learners in increasingly complex versions of this task as time goes on.

Along these same lines, Collins, Brown and Newman (1989) proposed a model of teaching and learning called cognitive apprenticeship that provides direction on the teaching of complex tasks through guidance that takes the form of modeling, coaching, scaffolding, articulation, reflection and exploration. Cognitive apprenticeship attempts to combine education and apprenticeship models of learning to support contextual and social learning activities (Collins, Brown, & Holum, 1991).

In a cognitive apprenticeship approach (Collins et al., 1989), a teacher performs a target task while pointing out important performance aspects, articulating the reasons why the task is done in a certain way and explaining the thought processes that are needed to complete it (modeling). Learners are also asked to do the task with teacher guidance that provides tips and feedback (coaching). A teacher fades this guidance over time (scaffolding). Learners explain personal thought processes while performing the task (articulation). These learners also monitor personal performance, determining ways in which it can be improved (reflection). In addition, learners are required to perform more tasks without modeling or coaching as a way to practice newly learned skills and integrate performance into everyday life (exploration). In cognitive apprenticeship, a progression from teacher direction to learner direction of the learning situation is advocated as the learner becomes more proficient at task performance (Collins et al., 1991).

The focus on task performance within a supportive environment advocated by cognitive apprenticeship and the other previously discussed models has led to task-centered and prescriptive models of teaching and learning. Two task-centered models that have received much recent attention in the literature are Merrill's first principles of instruction (Merrill, 2002a) and

van Merriënboer's four-component instructional design model (van Merriënboer & Kirschner, 2007). These models will be briefly explained and synthesized to show components of task-centered learning.

First Principles of Instruction

Merrill (2002a) reviewed several different instructional design theories, models, programs and practices for general prescriptive principles of instruction that he describes as fundamental to effective, efficient and engaging instruction. In his review, Merrill identified elements common to most learning situations and hypothesized that learning would be facilitated to the degree that these principles are explicitly implemented (Merrill, 2002a). These principles are prescriptive in nature and can be implemented in a wide variety of learning environments.

The first principles of instruction are as follows:

1. Learning is facilitated when learners are engaged in a task-centered approach
(Merrill et al., 2008, p. 174);
2. Learning is facilitated when existing knowledge is activated as a foundation
for new knowledge;
3. Learning is facilitated when new knowledge is demonstrated to the learner;
4. Learning is facilitated when new knowledge is applied by the learner; and
5. Learning is facilitated when new knowledge is integrated into the learner's
world (Merrill, 2002a, pp. 44-45).

In short, these principles involve activation, demonstration, application and integration within the context of a real-world task. Perhaps the most important principle is the task-centered principle in which learning is facilitated when learners are engaged in a task-centered approach. In the activation principle, learner prior knowledge should be activated (or increased if needed)

as part of the learning process. The demonstration principle indicates that learning will be enhanced when learners receive a demonstration of the to-be-learned skills. The application principle indicates that learners must apply their knowledge and skills to tasks or problems. Finally, the integration principle prescribes having learners integrate new skills and knowledge into everyday life by demonstrating, reflecting upon, discussing, and defending them. Taken together, these principles make up a set of prescriptions for instructional design (Merrill et al., 2008; Merrill, 2002a). An instructional design model was created based on these first principles (Merrill, 2002b) and studies have explicitly implemented first principles as a framework for instructional strategies (e.g., Francom, Bybee, Wolfersberger, & Merrill, 2009; Mendenhall et al., 2006).

Four-Component Instructional Design

Prior to the identification of first principles of instruction, van Merriënboer, Jelmsa and Paas (1992) proposed a task-centered instructional design model called four-component instructional design (4C/ID). This model was developed to support the learning of complex cognitive skills. The 4C/ID model has been refined and presented in later publications (van Merriënboer, 1997; van Merriënboer & Kirschner, 2007). The four components in the 4C/ID model are learning tasks, supportive information, procedural information and part-task practice (van Merriënboer & Kirschner, 2007). Similar to the assumptions of first principles of instruction, the assumption of 4C/ID is that these four basic components are an essential part of learning complex cognitive skills.

Learning tasks are the tasks that learners complete and are based on real-life tasks (van Merriënboer & Kirschner, 2007). These tasks may include problem-solving, reasoning, procedural tasks and other activities. Learning tasks provide the center on which everything else

in the learning experience depends and are thus vital to instructional design based on the 4C/ID model. Supportive information is the information needed to complete non-routine aspects of learning tasks (van Merriënboer & Kirschner, 2007). It is information about the domain(s) in which the task resides and is used for the reasoning and problem-solving aspects of tasks. Procedural information is the information needed to complete recurrent or routine aspects of learning tasks (van Merriënboer & Kirschner, 2007). This information has been referred to as just-in-time information and is best given when learners are ready to apply it. The fourth component of the 4C/ID model is part-task practice. The 4C/ID model takes into account the need to practice some skills to a high level of automaticity. Part-task practice involves giving learners a lot of practice at doing a single part of a task and is best implemented within the context of a larger whole task (van Merriënboer & Kirschner, 2007).

Common Elements of Both Models

The creators of first principles of instruction and the 4C/ID model have both acknowledged the compatibility between these two models (see van Merriënboer & Kester, 2008; Merrill et al., 2008). The most important aspect of both 4C/ID and first principles of instruction is centering teaching and learning on tasks. Various prescriptions for the use of tasks are given by these models (see figure 2). Both models advocate using tasks that learners are likely to encounter in the future. Learners should be engaged in a progression of tasks from easy to difficult. Merrill (2002a) distinguishes this approach from the common topic-centered approach to teaching. A task-centered approach aims to provide only information that is relevant to the completion of the learning tasks. A topic centered approach, by contrast, often focuses on the covering of certain topics deemed worthy of transmission without the application of such topics to a task (Merrill, 2007).

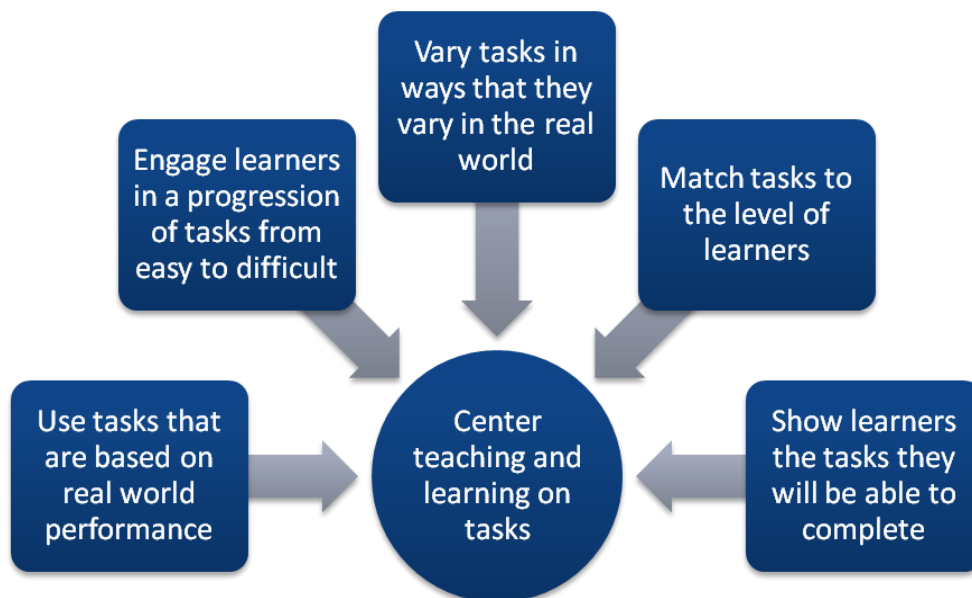


Figure 2. General task-centered learning prescriptions (van Merriënboer, 1997; van Merriënboer & Kirschner, 2007; Merrill, 2002a, 2007).

The 4C/ID model suggests that tasks should be matched to the level of the learners to give them an appropriate challenge (van Merriënboer & Kirschner, 2007). This may include simplifying the task to have a limited number of variables or completing certain aspects of the task for learners. Also, learners begin with relatively easy tasks and with much support and later progress toward more difficult tasks as they are able. Solving a progression of similar tasks allows learners to abstract information and cognitive strategies from a single task instance and transfer this learning to other tasks (van Merriënboer, 1997). Tasks should vary in the ways that they vary in outside-of-school performance. These task-centered elements retain many of the same prescriptions of a cognitive apprenticeship approach such as modeling, coaching, scaffolding and exploration (Collins et al., 1989).

The Effects of Task-Centered Learning

Several studies have been reported of implementations that are consistent with task-centered learning. Findings from these studies can be categorized by the type of measurements that were taken, which include student satisfaction, learning and performance and SDL skills. This discussion is limited to implementations of instructional designs based on task-centered strategies that measure student satisfaction and performance in educational settings. The implementations reviewed are also limited to those that were implemented subsequent to the formulation of the 4C/ID model (van Merriënboer, 1997; for a review of relevant implementations occurring before 4C/ID, see van Merriënboer et al., 1992).

Student Satisfaction

Some studies have measured student reactions toward a task-centered learning approach with generally positive results. Two such studies made use of student self-reports on satisfaction within a task-centered learning experience. Mendenhall et. al. (2006) implemented task-centered learning in a fully online component of an entrepreneurship course in a higher education setting. The online module featured several entrepreneurship tasks that helped students learn about starting their own business. This study involved only a small sample of students (n=13) in a pilot course but overall students were very satisfied with the content of the entrepreneurship module and offered positive comments in interview sessions. Francom, et. al. (2009) implemented task-centered learning in two freshman level biology classes. Students were involved in tasks that fit biology topics such as genetics, ecology, and the scientific method. In an end-of-class survey, the majority of students felt that the course gave them the opportunity to apply knowledge in meaningful ways. Students indicated that they preferred this type of course to other general

education courses they had taken. These results were based in self-reported data from 88 students, with students indicating subjective feelings about the course.

In contrast to the above studies that purposefully implemented task-centered course designs, an exploratory research study investigated the correlation between student satisfaction and perception of first principles of instruction within existing classes (Frick, Chadha, Watson, Wang, & Green, 2009). This study used various self-reported learning and satisfaction measurements in a survey format. Participants were enrolled in existing college courses from a variety of institutions. Variables such as mastery of learning, learning progress, learning time, and satisfaction with teacher and class, were correlated. A total of 140 students responded in 89 different subject areas. In this study, student perceptions that first principles of instruction were exhibited in class significantly correlated with class satisfaction ($p = .83$) and teacher and class ratings ($p = .86$). This study relied on student perceptions of their classes rather than direct observation, but it was conducted in a wide variety of institutions and courses.

These preliminary studies indicate that, in general, students have positive reactions to task-centered learning. The majority of students gave satisfactory comments about their experiences. Aspects of task-centered learning experiences that are believed to lead to student satisfaction include providing learning activities that are relevant to performance outside of school, allowing students to apply and synthesize rather than memorize and recall knowledge, and providing appropriate support to help students do these activities.

Learning/Performance

In addition to student satisfaction some studies have measured learning outcomes from task-centered learning implementations. These implementations include both secondary school and higher education settings.

Within a higher education setting, Lim, Reiser and Olina (2009) investigated the effect of task-centered learning in a software course. Students learned to create a gradebook using spreadsheet software. The two conditions for this study included a task-centered group (based on the 4C/ID model; van Merriënboer & Kirschner, 2007) and a part-task group in which constituent skills were taught to students. A total of 51 undergraduate students participated in this study. Three measurements were administered to students: a part-task achievement test; a whole-task test; and a transfer test. No significant differences were found between students in the conditions on part-task achievement test performance, but significant differences were found on whole-task and transfer test performance. Where differences were found, students in the task-centered learning condition performed better than those in the part-task condition. Findings from this study indicate that performance may only be significantly better on whole-task performance and transfer tests, rather than part-task tests. These findings support the hypothesis that task-centered learning improves learning transfer (van Merriënboer & Kester, 2008; van Merriënboer & Kirschner, 2007; Merrill, 2002a).

As previously mentioned, Frick et al. (2009) studied correlations between student's self-reported implementations of first principles of instruction and variables such as mastery of learning, learning progress, and learning time. The study participants were also higher education students, but this study investigated several different courses from different institutions. The highest correlation occurred between perceived learning progress (student feelings of whether they learned a lot) and implementation of first principles of instruction. Significant correlations were found between academic learning time and implementation of first principles of instruction. Mastery of learning was not as highly correlated, but still significant. While causality cannot be

inferred from this study, the correlations do provide further support for the implementation of task-centered learning in higher education courses (Frick et al., 2009).

A follow-up study involving the same course evaluation instrument was again implemented (Frick, Chadha, Watson, & Zlatkovska, 2010). This study improved upon the previous design by using whole class samples and an independent instructor (rather than self-reported) assessment of student mastery. A total of 464 students responded to the course evaluation instrument from 12 different classes. Results from this study showed a high correlation between the existence of first principles of instruction in a class (as perceived by students) and student mastery of course content.

In contrast to the above two studies – which relied somewhat on student self-reports – Sarfo and Elen (2007) implemented a high school technical course based on the 4C/ID model in Ghana and independently assessed learning. Educators implemented a task-centered teaching approach focused on deliberate practice and complex learning in a building design course. A total of 129 students participated in this study that had three conditions: task-centered learning without the use of information and communication technologies (ICT); task-centered learning with the use of ICT; and a traditional learning environment based on previous instructional design models. Measurements of learning included a variety of retention and transfer test items in pre- and post-tests. No significant differences were found between the ICT and non-ICT conditions. Significant differences in change from pre- and post-tests were found with significantly higher performance among students in the task-centered condition (Sarfo & Elen, 2007). This study provides support for the use of task-centered learning for high school-age learners.

Self-Directed Learning Skills

Few studies have focused on the effects of task-centered learning on SDL skills although an increase in such skills is a hypothesized outcome of task-centered learning (van Merriënboer & Kester, 2008). One line of research in this area has focused on the use of SDL portfolios to help learners with learning tasks. Within the framework of the 4C/ID model of instructional design, Kicken, Brand-Gruwel, van Merriënboer and Slot (2008b) implemented a portfolio program based on the informed self-directed learning model. This model gave students support to help them gradually move toward SDL through the use of an electronic portfolio and other activities. Hairdressing students were given opportunities to practice self-direction by formulating learning goals, choosing their own tasks to work on (with support to help them make good choices), and conducting self-assessment of their hairdressing skills. Preliminary findings reported among 10 students indicated that students felt that their skills were enhanced when using this SDL tool within a task-centered learning environment. However, the findings related to SDL were limited to student perceptions of the experience. A follow up study (Kicken et al., 2009) indicated that students who were given specific advice and guidance on how best to use the SDL portfolio self-directed their learning more effectively than those who only received performance feedback.

Based on these reported studies, it seems probable that using task-centered learning should increase student performance on application and transfer of learning over the use of non-task-centered instructional strategies or instructional design models. Task-centered learning may also lead to increased learner self-direction. Caution must be used when interpreting these results, since instructional design is a situated activity and a single implementation of a task-centered learning strategy in one setting may not cleanly transfer to another. However, these

reported studies come from a variety of different settings and seem to indicate that at least on application and transfer measurements, students performed better after experiencing task-centered learning. Few of the studies reported results on learner self-direction although conceptual connections between task-centered learning and learner self-direction have been referred to in the literature (e.g., van Merriënboer & Kester, 2008; van Merriënboer & Sluijsmans, 2009).

The Connection Between Task-Centered Learning and Learner Self-Direction

There are connections between task-centered instructional strategies and SDL theory and research which may not be obvious on the surface but which become clear upon a more thorough examination. Each SDL episode can be viewed as having three main components: a process, person, and context (Brockett & Hiemstra, 2010). The *process* involves the sequence of events that a learner experiences when taking responsibility for personal learning. The *person* refers to personal skills and abilities that enable a learner to learn independently. The *context* deals with factors surrounding the learning experience in its setting (Brockett & Hiemstra, 2010; Merriam et al., 2007). All of these elements can be connected to task-centered learning.

Processes of Self-Directed Learning and Task-Centered Learning

Overall, studies of SDL depict a process in which learners become engaged in real-world tasks, seeking out and evaluating information with the aim of completing the learning, formulating learning goals and staying motivated to accomplish them, self-monitoring performance while performing tasks, and constructing meaning from personal experiences (Bolhuis, 2003; Brockett & Hiemstra, 1991; Garrison, 1997; Tough, 1979). The SDL process can be described as having four phases: initiation, acquisition, performance, and assessment (see

figure 3). These phases are not necessarily performed in the same order by each learner and learners may skip a phase or go back as needed.

At the beginning of the SDL process, learners initiate the learning by deciding what knowledge and skill to learn and attempting to gain this knowledge and skill. The impetus for engaging in a learning task often comes from a life change (such as a change in job responsibilities) resulting in the need to perform tasks not previously performed by the learner (Spear & Mocker, 1984; Tough, 1979). At the beginning of the SDL process, learners plan learning activities that will enable them to perform a needed task. They also choose learning resources they will use to learn. At this point in the process, learners may not have a clear idea of their final goal for the learning experience. Adjustments to the learning process are usually needed.

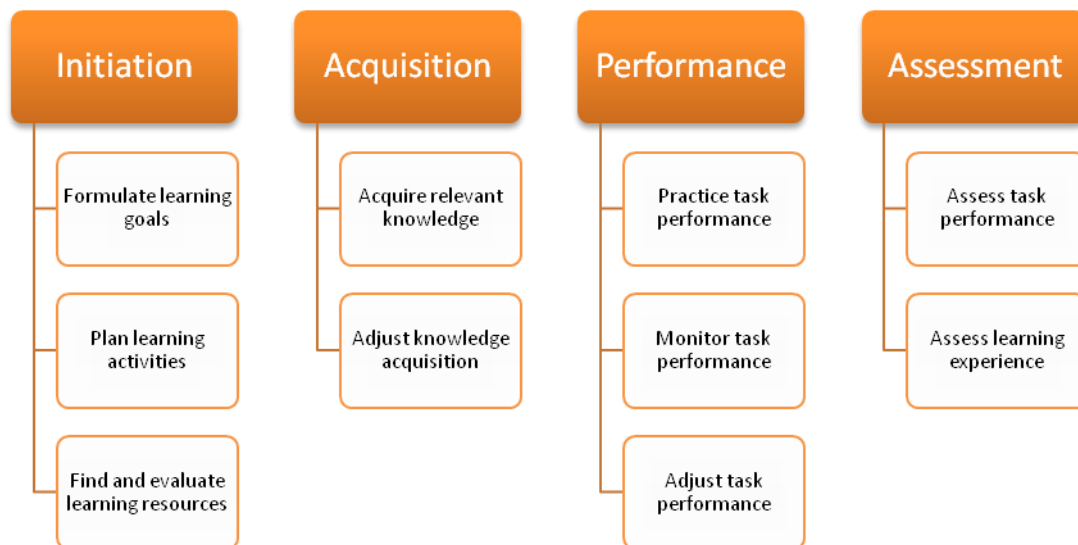


Figure 3. Phases of the self-directed learning process.

During the acquisition phase of SDL, learners acquire knowledge relevant to the task they desire to perform and adjust their knowledge acquisition as needed (Bolhuis, 1996; Tough, 1979). Knowledge acquisition activities may include obtaining and learning relevant materials from chosen learning resources, including involving one's self in formal educational opportunities, learning from non-human resources (e.g., a book, video or the internet), and talking to experts. Learning resources provide knowledge that will be used to reach personal learning goals.

In the performance phase of SDL, information is applied to a useful end. Learners usually have a practical goal for their SDL project and they test if their knowledge acquisition helps them meet these goals (Tough, 1979). For example, a learner might try applying knowledge gained from attending a leadership seminar to his or her own current leadership experience with sales staff. During the performance phase, a reflective learner might monitor his or her own performance and adjust this performance as necessary. A learner may discover a need to return to the acquisition phase of the SDL process during the performance phase. Monitoring and adjustment of performance can occur repeatedly as a self-directed learner applies knowledge to tasks again and again. Over time, the self-directed learner gains a stronger conceptual understanding of a subject area through reflection on multiple experiences (Garrison, 1997). SDL that is initiated for learning's sake alone may not include a performance phase.

In the assessment phase of the SDL process, learners self-assess their knowledge acquisition and performance. Assessment of knowledge and skills gained may involve comparison of one's own skills to a standard or to a peer's skill level (Garrison, 1997). This assessment may lead learners to initiate or perform further learning processes if their own

assessment indicates areas that need improvement. Assessment of learning may also help a learner to determine what strategies to take for future learning projects.

Task-centered learning provides learners with opportunities to carry out many of these SDL processes. Task-centered learning can also be adjusted to allow increased learner responsibility to perform the SDL processes in the initiation, acquisition, performance, and assessment phases (see table 4).

In the initiation phase, learners initiate learning tasks based on real-world performance. In task-centered learning, a teacher or instructional designer generally chooses tasks for learners to perform and provides guidance on how to perform a task, but learners are often given the responsibility of planning how to accomplish a task and choosing what resources to use to learn in relation to the task. Learners must determine how the information in resources can be used for knowledge acquisition and performance. To increase opportunities for SDL, teachers can also give learners a choice of learning tasks to complete with guidance on which tasks to select (Kicken, Brand-Gruwel, & van Merriënboer, 2008a). Learners can also be given responsibility for planning resources to use for learning. A moderate way of doing this might involve providing an initial set of resources to learners and then encouraging them to seek further resources as needed. At the extreme, learners might be required to find all learning resources necessary to complete a task. The amount of self-direction required in a learning situation should match the level of learner readiness for SDL (Bolhuis, 2003; Candy, 1991; Grow, 1991).

Task-centered learning provides support for self-direction in the acquisition phase. In task-centered learning, a variety of resources and information are given to learners to help them perform tasks. Supportive and procedural information are offered to learners using relevant media (van Merriënboer & Kirschner, 2007). Task-centered learning provides such information

freely at the beginning of the learning process but then fades this information as learners gain expertise. This gives learners an opportunity to carry out and adjust knowledge acquisition activities with increasing autonomy. For a more self-directed experience, learners could be required to find, study and apply all information on their own in a task-centered learning environment.

Table 4

Self-directed learning process activities provided by task-centered learning

Learning Phase	SDL activities already provided in a task-centered learning environment	SDL activities that can further be provided within a task-centered learning framework
Initiation	<ul style="list-style-type: none"> • Learners initiate a task based on real-world performance • Learners plan how to accomplish a learning task • Learners choose some resources to use for learning • Learners decide how to apply information to task performance 	<ul style="list-style-type: none"> • Learners can choose learning tasks to perform • Learners can be required to find all resources for learning
Acquisition	<ul style="list-style-type: none"> • Information is provided to learners more directly at first and then faded over time 	<ul style="list-style-type: none"> • Learners can be required to find, study and apply all information on their own
Performance	<ul style="list-style-type: none"> • Learners apply recently learned information to the completion of tasks • Learners receive personalized guidance on their performance that is faded over time • Learners self-monitor and adjust task performance as needed 	<ul style="list-style-type: none"> • Learners can be required to monitor and adjust task performance early in the learning process
Assessment	<ul style="list-style-type: none"> • Sequences of tasks provide self-assessment through reflection 	<ul style="list-style-type: none"> • Learner self-assessment can be required through comparison with a standard or peer

Task-centered learning also provides learners with opportunities to practice skills in the performance phase of the SDL process. Task-centered learning requires learners to apply their recently acquired knowledge to the completion of tasks. Such performance is closely related to the SDL performance phase in which acquired knowledge is applied to a task (van Merriënboer & Sluijsmans, 2009). Over time, learners gain a conceptual understanding from multiple experiences (van Merriënboer, 1997; Merrill, 2007). In task-centered learning, a teacher may provide personalized guidance for the performance including coaching and feedback that is faded over time. Task performance requires learners to self-monitor and adjust their learning as needed. Teachers can reduce the amount of support they give to learners for task completion, requiring learners to self-direct these aspects of their learning. At the extreme, learners might be required to monitor and adjust their own performance at the beginning of the learning experience, although this will likely be difficult for learners who lack the necessary skills.

Finally, task-centered learning also provides learners with opportunities to practice skills in the assessment phase of the SDL process. Task-centered learning requires learners to complete sequences of tasks. This may provide a natural way of self-assessing performance as learners reflect upon their performance on previous tasks and abstract conceptual understanding from multiple experiences (van Merriënboer, 1997). Self-assessment can also be increased in task-centered learning when teachers require learners to self-assess and adjust performance by comparing it to course criteria or a peer's performance (van Merriënboer & Sluijsmans, 2009).

In sum, many aspects of the SDL process are practiced in task-centered learning. Additional SDL practice can be given to learners by adjusting task-centered learning to allow increased learner choice and autonomy in the initiation, acquisition, performance and assessment phases of SDL. When structuring learning environments, teachers must use caution and avoid

overloading unprepared learners with too many SDL activities (Brockett & Hiemstra, 1991).

Cognitive load theory (Sweller, 1994) may provide useful guidance on how much responsibility to give to learners in a learning situation (van Merriënboer & Sluijsmans, 2009).

Personal Skills and Abilities

Within the SDL process, personal skills, abilities, and attributes play an important role. First, learners may need a certain amount of subject matter knowledge before they can self-direct their own learning and make quality learning choices within a domain (Brockett & Hiemstra, 1991; Candy, 1991). This subject matter is not enough, however, as a learner might also need motivational and metacognitive skills enabling them to: (a) select learning tasks appropriate to personal learning needs (preflection; van Merriënboer & Sluijsmans, 2009); (b) autonomously engage in deliberate practice activities to achieve learning goals (Ericsson, 2006; Ericsson et al., 1993); (c) find, evaluate, and apply information to complete tasks and solve problems (Bolhuis, 2003; Candy, 1991); (d) monitor and adjust learning activities as needed (Garrison, 1997); and (e) determine ways in which personal performance needs to be improved (reflection; Bolhuis, 2003; van Merriënboer & Sluijsmans, 2009).

Task-centered learning also provides learners with opportunities to develop many of these skills. For instance, learners receive domain knowledge (supportive information) and procedural knowledge through demonstration or presentation to help them perform tasks. As mentioned previously, learners may learn to find, evaluate, and apply information in the completion of tasks. Learners engaged in learning tasks may also formulate and carry out learning goals, engaging in deliberate practice activities in order to achieve such goals. Reflection skills may be practiced as learners assess performance and adjust within a single task or from task to task in a progression. Some task-centered strategies have been employed which

give learners opportunities to choose future tasks based on past task performance (preflection; van Merriënboer & Sluijsmans, 2009; van Merriënboer & Kirschner, 2007).

The Learning Context

Each SDL process takes place within a learning context. Studies have shown the importance of context to SDL which includes certain life events, work experiences and other performance needs (Merriam et al., 2007). A study of context can focus on different aspects of a learning situation including the context surrounding a particular learner (i.e., gender, socio-economic status, culture etc.), the context in which learning takes place (i.e., the classroom), and the performance context (i.e., the “real-world” context in which performance of learned skills will take place). A task-centered approach does not inherently account for the social context surrounding a particular learner, but such an approach takes into account both the learning and performance contexts (van Merriënboer, 1997; Merrill, 2002a). Task-centered approaches require learners to apply the knowledge and skills to be learned by situating them within the context of a learning task. As learners practice tasks that are similar to real-world performance, they have the opportunity to take into account at least some aspects of the context in which the task will be performed including the resources used in the task, task difficulty, constraints, and affordances.

Needed Research Suggested by the Literature

More research is needed to determine what learning experiences lead to an increase in learner self-direction. Additional research is also needed on the effects of task-centered learning.

Learner Self-Direction

Information from the studies reviewed in this chapter indicates that further research is still needed to determine which types of support and guidance are most effective at enhancing learner self-direction, which types of students are helped by this approach, and which aspects of task-centered learning environments lead to the development of learner self-direction. At the same time, measures of student learning performance should be taken to assure that students are still able to improve in these areas. The literature indicates that learners with higher metacognition and academic achievement tend to do well in SDL situations (Bhat et al., 2007; Howland & Moore, 2002). Working memory has been considered important for directing and regulating one's own learning (Flavell, 1979; Zimmerman, 2002). Thus, finding out student's basic abilities (such as working memory) should be considered important in studies of learner self-direction.

Several instruments have been validated and used to measure a learner's ability or readiness to self-direct their own learning. Quantitative instruments include the self-directed learning readiness scale (SDLRS; Guglielmino, 1977), the Oddi continuing learning inventory (OCLI; Oddi, 1986), the learner autonomy profile (Confessore & Park, 2004), and personal responsibility orientation self-directed learning scale (PRO-SDLS; Stockdale & Brockett, 2011). Each of these instruments use likert-scale questions that participants answer within a questionnaire.

A holistic study could implement a learning environment fully based on principles for fostering learner self-direction and the effects could be measured. However, since there is a dire need for practical advice on fostering learner self-direction in realistic settings, studies that implement certain principles for fostering learner self-direction should be conducted within the

constraints of real classrooms to measure the effects and report relevant instructional design decisions.

Task-Centered Learning

More research is needed to determine the effect of task-centered learning on student performance as well as higher order outcomes such as self-direction. The research conducted thus far is compelling yet still preliminary. While there seems to be an abundance of reports of the use of task-centered learning (see van Merriënboer & Kester, 2008; Merrill et al., 2008), there is a paucity of empirical research on this topic, especially with regard to effects on learning, higher-order learning, and self-direction. More studies that investigate the type of knowledge and skills fostered and the elements of task-centered learning that lead to these knowledge and skills are needed. More research is also needed to determine new assessment methodologies for higher-order learning outcomes such as the expertise development of students within task-centered learning environments (Spector, 2003, 2006). Additionally, research is needed to support the use of task-centered learning in different settings and with different populations. Investigating how task-centered learning works (or doesn't work) in different domains may help us answer important questions about the efficacy of task-centered learning.

Task-Centered Learning for Learner Self-Direction

Perhaps most importantly, the effect of task-centered instructional strategies on learner self-direction should be studied. Higher education institutions are beginning to take notice of the importance of developing SDL skills (Guglielmino, 2008), but in order to determine if a particular method of teaching leads to such skills, empirical measurements are needed. Qualitative inquiry might also be employed in task-centered learning situations to determine

learning factors from a student perspective and attain a richer understanding of task-centered learning environments.

If in a task-centered learning environment learners are engaging in processes similar to the SDL process and using similar skills, then traditional measurements of readiness for SDL may show at least moderate increases between pre- and post-assessments. A study that implements aspects of task-centered learning within the constraints of a realistic setting and measures learner self-direction may be most useful given the need for more research that can transfer from setting to setting. Such a study could report on the course design, how it was influenced by task-centered learning and learner self-direction, and show results on students' understanding of science concepts and learner self-direction.

Summary

SDL theory and research stem from studies of adults' independent learning projects and has influenced much of what we know about adult learning theory (Merriam, 2001; Merriam et al., 2007). Self-direction in learning has been conceptualized in many different ways in the literature, including self-directed learning, learner control, personal responsibility, learner self-direction, and self-direction in learning (Brockett & Hiemstra, 1991; Candy, 1991; Houle, 1961; Merriam et al., 2007; Tough, 1979). A major focus of the literature is on ways to foster learner self-direction, or the ability of learners to self-direct and self-regulate independent learning processes (Merriam et al., 2007). Fostering student ability to learn independently is a worthy goal for higher education because of an extant increase in career mobility rates and differences between what is learned in school and what is practiced outside of school (Guglielmino, 2008; Resnick, 1987). Several national reports in the United States also indicate the need for preparing

graduates with learner self-direction (The Secretary of Education's Commission on the Future of Higher Education, 2006; The Secretary's Commission on Achieving Necessary Skills, 1991; U. S. Bureau of Labor Statistics, 2008).

Studies measuring increases in learner self-direction indicate that improvements are shown in environments that provide students with some control over the learning situation, or give support and guidance for self-direction and center learning on tasks or problems. Four main principles for fostering learner self-direction have been explained and supported based on the SDL literature. These principles include: (a) matching the level of self-directed learning required in learning activities to learner readiness; (b) progressing from teacher to learner direction of learning over time; (c) supporting the acquisition of subject matter knowledge and learner self-direction together; and (d) having learners practice self-directed learning in the context of learning tasks (Bolhuis, 2003; Brockett & Hiemstra, 1991; Grow, 1991; Hammond & Collins, 1991; Houle, 1961; Knowles, 1975; Meichenbaum & Biemiller, 1998; Tough, 1979).

Task-centered models share three main characteristics: a sequencing of tasks from easy to difficult with fading support; an integration of knowledge from different domains; and a focus on learning transfer (van Merriënboer & Kester, 2008). Task-centered models provide specific guidance for the sequencing of learning tasks, the shifting of responsibility for learning toward students, and for supporting the acquisition of subject matter knowledge and learner self-direction together (van Merriënboer, 1997; van Merriënboer & Kirschner, 2007; Merrill, 2002a, 2007).

Studies have shown that students report being very satisfied with task-centered learning (Francom et al., 2009; Frick et al., 2009; Mendenhall et al., 2006). Studies have also linked task-centered learning experiences with equal or higher learner performance on learning and transfer

tests (Lim et al., 2009; Sarfo & Elen, 2007). Preliminary studies point to a positive relationship between task-centered learning and SDL skills (Kicken et al., 2008b, 2009). Conceptual connections between task-centered learning and learner self-direction can be made on the SDL dimensions of process, person and context (Brockett & Hiemstra, 2010; Merriam et al., 2007).

Future research is needed to determine the effects of differing learning environments on learner self-direction. Research is also needed to determine the effects of task-centered learning on learning performance as well as higher-order outcomes such as learner self-direction. There is also an urgent need for additional empirically-based and practical guidelines for fostering learner self-direction within realistic classroom settings, outlining the course design and reporting on students' understanding of concepts, and learner self-direction outcomes.

CHAPTER III

METHODOLOGY

College graduates need skills related to independent learning in order to keep up with career and life changes (Guglielmino, 2008), yet there is no currently agreed upon method to foster learner self-direction. There is a need for empirical investigations to determine the effect of learning environments based on learner self-direction. The purpose of this study was to investigate the effect of a task-centered learning approach in a large-enrollment general education biology course (*Concepts in Biology*) on learner self-direction and students' understanding of science concepts. In this study, aspects of task-centered learning and self-directed learning (SDL) were implemented within the constraints of a realistic environment (a university general education biology course). The degree to which participants learned science concepts and exhibited learner self-direction was measured. This study was guided by two main research questions and a sub-question:

1. What is the effect of an undergraduate science course designed with a task-centered approach on learner self-direction?
 - a. What are participant perceptions of their own self-direction and engagement in task activities during the course?
2. What is the effect of an undergraduate science course designed with a task-centered approach on students' understanding of science concepts?

Research Setting

The setting for this study was an introductory general education biology course (*Concepts in Biology*) in the department of biological sciences at a large public university in the southeast United States. *Concepts in Biology* introduces students to the principles, theories, and laws of biological science including the scientific method and criteria for making a valid scientific argument. Because this course focuses on general science concepts, it is not limited to biological content areas. Undergraduate students from a wide variety of majors take *Concepts in Biology* to fulfill general education science requirements. The total number of students enrolled in each section of this course each fall is 130-350 and each spring is 130-350, with lower numbers during the summer. From fall 2010 to early spring 2011, a section of the *Concepts in Biology* course was redesigned by a course design team which included the course instructor. Learning tasks were designed to require students to apply their scientific knowledge to realistic problems and projects during the course of the semester. These learning tasks were designed to help students integrate science knowledge into everyday life. Six learning tasks received a preliminary formative evaluation in the summer 2010 semester and revisions and changes were completed for implementation during spring, 2011.

Participants

Students in *Concepts in Biology* are generally not biology majors and take the course because of general education science requirements. These students come from a variety of backgrounds and majors and are at differing grade levels (freshman through senior). Student age levels range from 18 years to about 50 years. Because students have widely differing backgrounds, they are expected to come to *Concepts in Biology* with widely varying levels of

ability to take responsibility for their own learning. Most students in *Concepts in Biology* have had somewhat similar science learning experiences in high school. However these students vary greatly in the time it has been since they experienced science learning in high school. At the end of the current study, a total of 138 students were enrolled in the treatment section and 311 were enrolled in the control section.

Research Design

Quasi-experimental quantitative methods were used in this study. Quasi-experiments are used when random assignment of participants is not possible or practical (Kirk, 1995). In this study two sections were used, one as a control group and one as a treatment group without random assignment. These factors are elements of a quasi-experimental non-equivalent control group study (Campbell & Stanley, 1963; Cook & Campbell, 1979; Gall, Borg, & Gall, 1996). Two *Concepts in Biology* sections, which served as control and treatment sections, were taught in the 2011 spring semester. One section was taught using teacher-directed, in-class presentations and group work related to note taking and learning activities. The other section featured learning tasks that required students to apply their science knowledge. These sections were both taught by the same instructor.

A quasi-experimental design was appropriate for this study due to its feasibility and its ability to advance knowledge in the field through generalizability. Research experiments have the goal of determining cause and effect relationships that can be replicated beyond the original research setting (Gall et al., 1996; Kirk, 1995). In a quasi-experiment, the lack of random assignment decreases internal validity, but this type of study is commonly used in educational settings because of its feasibility (Gall et al., 1996). Quasi-experiments allow for comparison of

different conditions on specific measures, such as the comparison of the two spring 2011 *Concepts in Biology* sections. Inferential statistical techniques were used to determine if changes were the result of the treatment or random error (Gravetter & Wallnau, 2004). These statistical techniques also adjusted for the differences in number of students between control and treatment sections.

Research Conditions

The two conditions in this study are the regular *Concepts in Biology* course section as it was taught before the redesign (control condition), and the redesigned *Concepts in Biology* course section with learning tasks (treatment condition). The redesign centered learning on tasks that are based on what non-biology majors are expected to do outside of school with their science knowledge. This allowed students to become engaged in learning tasks during five to six weeks of the 15 week semester.

Control

In the control *Concepts in Biology* section, students learned through textbook readings, pre-class assessments, online discussions, in-class lectures (including response system questions). Student knowledge was assessed using six end-of-unit and final exams. Students completed textbook readings to introduce them to basic science and biology concepts. Pre-class assessments were used before each class for two main reasons, first, to assure that students read the required material in the textbooks by testing their knowledge of textbook content, and, second, to introduce students to additional biology and science concepts. These pre-class assessments are setup as quizzes within the *Concepts in Biology* course learning management system. Online discussions allowed students to discuss biological concepts. In-class lectures

further explored biology and science concepts and required students to respond to knowledge and application level questions using a classroom response system. Additionally, the control group was involved in note taking activities in which groups of students took detailed notes on class lectures and posted them online. Other students were required to review these notes and vote on the best note-taking group, which received bonus points in the class.

Treatment

The treatment *Concepts in Biology* section included many of the same elements that were in the control section including readings, pre-class assessments, online discussions and lectures. However the treatment section did not include note-taking activities but did include learning tasks (see appendix A) that require students to apply their science and biology knowledge gained from textbook readings, pre-class assessments, lectures and discussions. In the treatment *Concepts in Biology* section, groups of students did major learning tasks designed to help them apply subject matter knowledge to complete a meaningful task. The learning tasks were based on what non-biology majors are expected to do outside of school with their science knowledge. Example learning tasks include the creation of an information card on sustainable and non-sustainable fish and the building of an information document explaining why a certain food is unhealthy (see table 5).

Within each learning task, students were: (a) introduced to the learning task; (b) taught biology concepts relevant to the task; (c) shown how biology concepts can be used to complete the task through modeling; (d) directed to complete the task; and (e) assessed on their task performance. This process was repeated in each learning task. A total of six learning tasks were offered in this section. Student groups were all required to complete the first learning task (which included skills required for other learning tasks such as information seeking and scientific

claims) and student groups had the option of choosing the other two learning tasks that they wanted to complete. Students groups were required to choose either task two or three, and they were also required to choose one of either task four, five or six. All of the student groups were required to do a total of three learning tasks during the semester.

Table 5

Titles, descriptions and formats of the learning tasks implemented in the treatment Concepts in Biology section (see also Appendix A)

Task title	Task description	Task format
Task 1: Testing claims	Student groups find and evaluate a claim that is used to convince the public either to use or avoid one of the following: a dietary supplement, current fad food, bioengineered food, sugar substitute, etc.	Document
Task 2: Worst food in america	Student groups create a graphic to convince someone of the unhealthy nature of a certain food item	Document with a graphic
Task 3: Fish futures flyer	Student groups create a flyer to inform consumers of the need to purchase fish from sustainable sources	Informational flyer
Task 4: Vaccination debate	Student groups create a media piece to convince the public either to use or avoid one vaccine that is currently available	Multiple formats allowed (flyer, video, audio podcast, slides, etc.)
Task 5: Cancer: what are my options?	Student groups create a graphic to describe a chemotherapy drug and use the information found to advise someone about how this drug works and how effective it is at treating cancer	Document with a graphic
Task 6: Human reproduction myth buster	Student groups work to inform peers about an aspect of human reproduction in which there are rampant misconceptions	Multiple formats allowed (survey, video, flyer, etc.)

Instruments

In order to determine changes in learner self-direction and learning among students in differing treatment groups, this study used four main instruments: (a) a working memory test; (b)

a science concepts test (QPS); (c) the personal responsibility orientation self-directed learning scale (PRO-SDLS; Stockdale & Brockett, 2011); and (d) a task survey. Each instrument plays a part in answering the research questions of this study. Throughout the *Concepts in Biology* course design process, design team observations were also made to provide a description of key design and development decisions.

Working Memory Test

Since basic working memory capacity is important for activities related to SDL and SRL (Flavell, 1979; Zimmerman, 1994, 2002), a working memory test (see appendix B) was implemented. This test was implemented once to all participants in each condition (control and treatment) early in the spring 2011 semester. This test was adapted from prior studies of working memory (Engle, 2005; Unsworth, Redick, Heitz, Broadway, & Engle, 2009; Unsworth, Spillers, & Brewer, 2010), condensed and put online for student access. This working memory test was provided by the Georgia Institute of Technology's attention and working memory lab and has been validated and used in a variety of studies over the past 20 years (see Engle, 2005; La Pointe & Engle, 1990).

The working memory test is an operation span test, in which participants must retain words while solving simple math problems. A single math problem is presented first (for example, is $[2/2] + 4 = 6$) and the participant is prompted to click yes or no. Participants only have 6 seconds to answer the math problems. Then, when the participant has clicked an answer, a word (such as "cloud") is shown for two seconds. The next math problem comes up and then another word. After a sequence of words and math problems has been presented, the test prompts participants to enter all of the words in the set. Each set varies the number of words and math problems from two to six. There are a total of 40 words that participants have to type in.

Because participants are required to retain words while also solving math problems, the working memory test measures attention along with basic working memory. Data from this test were used as a covariate in the study to help account for some of the variability among participant scores on other instruments in the *Concepts in Biology* course.

Science Concepts Test

The *Concepts in Biology* development group created a 19-question Quantitative Process skills instrument (QPS; see appendix C and D) that measures students' understanding of science concepts. Questions in this instrument are multiple choice. Many of the questions are considered higher-order questions in which students must apply biology knowledge and make conclusions based on data. However the QPS also features lower-order questions asking students to calculate simple math and science solutions.

QPS test items have been aligned with the university's general education science objectives. This instrument features four factors covering different areas of science concept understanding and inquiry. Factor one includes questions designed to determine student ability to describe methods of inquiry for scientific knowledge and distinguish between science and pseudoscience. Factor two includes questions that ask students to make inferences and predictions based on quantitative information. Factor three includes questions about the use of scientific information in science developments and public policy issues. Factor four includes questions that determine student ability to use graphical/symbolic methods to organize and interpret data. The QPS instrument was tested in the summer and fall 2010 courses and analyzed for point-biserial correlation between individual responses and overall averages. These formative evaluations also revealed needed changes to remove non-distracters, adjust questions that were unclear and create question choices based on students' short-answer responses.

In the present study, the QPS was administered at the beginning and end of the control and treatment sections to all participants (first and last days of class). Since the QPS has two forms, half of the students in each section took form A at the beginning of the semester and then took form B at the end of the semester. The other half of the students in each section took form B at the beginning of the semester and then took form A at the end of the semester.

Personal Responsibility Orientation Self-Directed Learning Scale

The PRO-SDLS (see appendix E) was developed and validated by Stockdale (2003) as an instrument to measure learner self-direction among students who are enrolled in a higher education course. This instrument is based on Brockett and Hiemstra's (1991) personal responsibility orientation model of SDL. While other instruments have been implemented to measure self-direction in learning (e.g., Confessore & Park, 2004; Guglielmino, 1977; Oddi, 1986), the PRO-SDLS was used for this study because it is based on recent and holistic conceptualizations of SDL (Stockdale & Brockett, 2011). This instrument uses likert-scale questions that participants answer within a questionnaire. Four factors were both created and derived from the instrument: two based on the teaching and learning transaction (initiative and control) and two based on learner characteristics important for SDL (self-efficacy and motivation). In a PRO-SDLS validation study (Stockdale & Brockett, 2011), internal consistency was found to be .81 for initiative, .78 for control, .82 for motivation, and .78 for self-efficacy. The PRO-SDLS was found to have an overall Cronbach's alpha reliability of .91 (Stockdale & Brockett, 2011).

In this study, the PRO-SDLS was administered at the beginning and end of the control and treatment *Concepts in Biology* sections to all participants. This instrument allowed a

determination of whether changes occurred during the semester and if these changes were different for the control and treatment groups.

Task Survey

A task survey that focuses on student engagement, ownership, and self-direction was administered as part of this study (see appendix F). This task survey contains likert-scale questions that ask participants to indicate the degree to which they agree with statements about their learning within the most recent learning task. These questions were derived from a review of the SRL and SDL literature as indicators of self-direction activities during the learning tasks. The questions covered key areas such as goal-setting, time management, self-monitoring, information evaluation, self-reflection, task strategies, self-evaluation, help-seeking and outcome attributions. The survey also features three open-ended questions about learner self-direction and perceived task authenticity. The task survey questions were intended to be used to determine why changes did or did not occur in the QPS and PRO-SDLS over time. This task survey was administered to participants in the treatment group after they completed each learning task.

Design Team Observations

Throughout the *Concepts in Biology* course design process, observations were made of the design team's major activities. The purpose for these observations was to provide a description of key design and development decisions and actions that led to the final design of *Concepts in Biology*. To meet this aim, notes were taken in each full design team meeting and a record of design-related correspondence was kept.

Procedures

In a nonequivalent control-group design, a pretest and posttest are used on measurement instruments in both a control and treatment group that are not randomly assigned (Campbell & Stanley, 1963; Gall et al., 1996). In education, these control and treatment groups are usually pre-existing classes of students. In this study, one spring 2011 *Concepts in Biology* section (treatment) was compared with another (control) on quantitative measurements (QPS and PRO-SDLS; see figure 3). The working memory capacity test was administered once to each participant (in both control and treatment sections), and the task survey was administered to treatment-group participants after they completed each of their learning tasks.

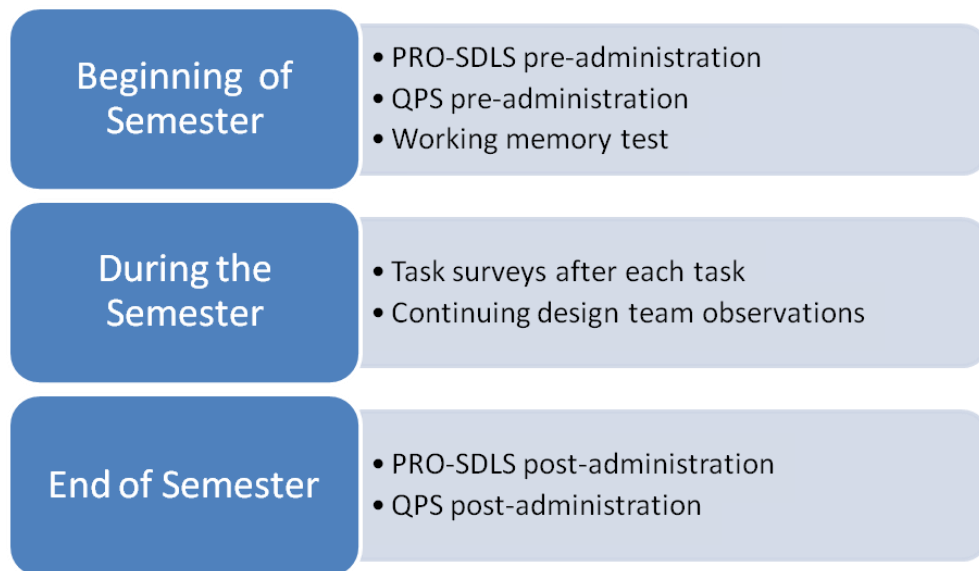


Figure 4. Data collection instruments and administration for this study.

Beginning of the Semester

Within the first two weeks of the semester, the QPS and PRO-SDLS were administered to students in both the treatment and control groups. The PRO-SDLS was administered outside

of class time online and the QPS was administered in class. About half of the students in *Concepts in Biology* received form A and the other half received form B of the QPS. Also within the first few weeks of the semester, the working memory test was administered online to students. These activities were included in the course as regular elements of learning. Scores from both conditions were kept separate and stored for later data analysis.

During the Semester

During the semester, the task survey was administered to treatment group participants after they completed each learning task. All groups of students were required to complete the first learning task, thus, all students were given the opportunity to complete the task survey after the completion of this learning task. Student groups could choose to complete either task two or three. These groups also had to choose one task to complete out of tasks four, five and six. Because these tasks were spread out during the semester, students filled out the task survey only when they completed the most recent task. About half of the students filled out the task survey after the second learning task and the other half of students filled out the task survey after the third learning task. Finally about a third of the students filled out the task survey following completion of the fourth learning task, another third filled out the task survey after the fifth learning task, and another third filled out the task survey after the sixth learning task. Throughout the semester, design team observations were also made by the researcher. These observations focused on key decisions and actions taken in the design process and ultimately provide a description of the *Concepts in Biology* course design process.

End of the Semester

At the end of the semester, the PRO-SDLS and QPS were administered to participants. The PRO-SDLS was again administered online and the QPS was administered in class. Students who received QPS form A for the pre-test received form B for the post-test and vice versa.

Assumptions

Common assumptions in a quantitative approach follow positivist and post-positivist epistemologies including the existence of a reality separate from individuals and the measurability of phenomena (Crotty, 1998; Johnson & Onwuegbuzie, 2004). One assumption with this approach is the existence of internal validity, or that there is a link from measured outcomes to the conditions in the study (Krathwohl, 1998). In this study, learner self-direction was measured through the use of the PRO-SDLS, and task data were collected using a task survey. Both are questionnaires that students fill out themselves. The assumption with the use of a questionnaire is that students are responding honestly and accurately to the instrument. Another assumption is that the QPS actually measured the conceptual knowledge it intended to measure, and students thoughtfully tried to use their science knowledge to respond to it rather than just randomly choosing answers. An assumption related to the working memory test is that students did not “cheat” on this test by writing words down for easy recall.

Another assumption in this quasi-experiment is that any changes manifested in the PRO-SDLS and QPS instruments from pre- to post-tests are caused by the learning experience and not other nuisance variables such as history and maturation (Campbell & Stanley, 1963). Findings from this quasi-experiment are assumed to be generalizable to similar settings and participants

(Krathwohl, 1998). In this study the findings are designed to be generalizable to other higher education institutions that have student populations similar to those at the original setting.

A final assumption with this study is that the differences in enrollment within each section did not have a significant effect on the outcomes of the study. Because of timing constraints on the course instructor, the treatment section enrollment was capped at 150 students and two teaching assistants were employed to assist students with learning task activities and grade students' learning tasks. It was not possible to also cap the enrollment in the control section because of departmental constraints and student demand for general education biology courses.

Limitations

In this study it was not possible to randomly assign students to differing conditions because students enrolled in the course sections themselves. Threats to validity in quasi-experiments may include differences between the treatment and control groups that are attributed to, but not caused by, the treatment (Gall et al., 1996). Another threat is the effect of pre-tests on post-test outcomes, since the experience of responding to an instrument may affect future responses to the same instrument (Cook & Campbell, 1979). Also, it is difficult to attribute changes in pre- and post-scores to the conditions of the study rather than history and maturation (Campbell & Stanley, 1963; Gall et al., 1996) because of the length of the study (one semester). The comparison between control and treatment sections and the collecting of pre- and post-measurements is thought to reduce the likelihood that changes are because of these nuisance variables; however this is still a limitation in this study.

This study also relied upon instruments that students fill out themselves, the QPS was filled out by students in class and the PRO-SDLS, task survey and working memory test were filled out online. Limitations with the use of the QPS include the possibility that students randomly guessed the correct answer or got questions wrong for which they have the prerequisite knowledge. Limitations with the use of the PRO-SDLS include the possibility that students answered randomly or answered based on what they thought might be correct behavior rather than actual behavior. Limitations with the use of the working memory test include the lack of a supervising researcher to assure that participants did not write down words to memorize them. Since there is a time limit for each word and question, it is assumed that participants did not have time to write down words.

Another limitation with this study stems from its dynamic nature. Since the *Concepts in Biology* course is an actual college course, negotiations occurred during the semester (such as the enrollment cap) that may have had effects on how the learning occurred in the course. The design team observations were used to report on the final course design as it actually turned out and briefly explain important design decisions to help mitigate this issue.

CHAPTER IV

RESULTS

The purpose of this study was to investigate the effect of a task-centered learning approach in a large-enrollment general education biology course (*Concepts in Biology*) on learner self-direction and students' understanding of science concepts. Two *Concepts in Biology* sections were used as control and treatment conditions. Both the control and treatment sections included readings, pre-class assessments, online discussions and lectures. However, the treatment section featured learning tasks that groups of students were required to complete, and centered learning and teaching activities on these tasks, while the control section featured group note-taking activities. The research questions in this study are:

1. What is the effect of an undergraduate science course designed with a task-centered approach on learner self-direction?
 - a. What are participant perceptions of their own self-direction and engagement in task activities during the course?
2. What is the effect of an undergraduate science course designed with a task-centered approach on students' understanding of science concepts?

Five main instruments were used to answer the research questions: (a) a basic working memory test adapted from prior studies of working memory (Engle, 2005; Unsworth et al., 2009, 2010); (b) a science concepts test (QPS) developed by the course design team, which included the researcher and the *Concepts in Biology* instructor; (c) the personal responsibility orientation

self-directed learning scale (PRO-SDLS; Stockdale & Brockett, 2011); (d) a task survey that focused on student engagement, ownership and self-direction; and (e) observations of the design team's major activities.

Data Analysis

Data from the PRO-SDLS pre- and post-tests were analyzed using analysis of covariance (ANCOVA). Working memory and pre-scores served as covariates. Post-scores served as the dependent variable and the condition (control or treatment) served as the independent variable. Data from the QPS were analyzed using repeated measures analysis of variance (ANOVA) with QPS scores as the dependent variable and the condition (control or treatment) as the independent variable. Using similar techniques, further analysis of both QPS and PRO-SDLS instrument factors were used to determine any further statistical differences between the conditions. Task survey responses to likert-scale questions were analyzed with repeated measures ANOVA to determine if any questions received significantly higher scores than other questions. The SPSS statistical software package was used to analyze quantitative data. In addition, task survey open-ended responses and design team observation data were synthesized and categorized qualitatively.

PRO-SDLS

Data from the PRO-SDLS were scored and students with missing responses were removed. Pre- and post- PRO-SDLS scores were aligned by student along with working memory test scores. ANCOVA was used to analyze differences between the control and treatment groups controlling for pre PRO-SDLS scores. An alpha level of .05 was chosen for this analysis. This comparison between treatments was designed to show if there was a learner self-direction gain

within one group to a greater degree than the other group. Students' working memory scores accounted for a significant amount of variability in the PRO-SDLS scores, $F(1, 188) = 5.31, p = .022$, thus working memory was included as a covariate in the overall and factor analyses. In the final ANCOVA model for PRO-SDLS analysis, the covariates were pre PRO-SDLS scores and working memory test scores, the dependent variable was student scores on the post PRO-SDLS and the independent variable was the condition (control or treatment). Also, a type three method for computing sum of squares was used to adjust for sample size inequalities between control and treatment sections (Macnaughton, 1998; Shaw & Mitchell-Olds, 1993).

Additional data analysis on the PRO-SDLS factors was also conducted. The PRO-SDLS features two main factors (the teaching-learning transaction and learner characteristics) and two factors within each main factor (initiative and control within the teaching-learning transaction factor; self-efficacy and motivation within the learner characteristics factor). All of these factors were analyzed using the same statistical techniques as the overall score (ANCOVA) to help determine any changes resulting from the treatment.

QPS

Data from the QPS were scored and students with missing responses were removed. Pre- and post- QPS scores were aligned by student along with working memory test scores. Two important assumptions of ANCOVA were not met with the QPS data. The first assumption was violated when a strong relationship was found between covariate scores and the groups under investigation. If there is a relationship between covariate scores and groups – a phenomenon which can result from a lack of random assignment of participants to groups – biased ANCOVA analyses are likely to result, especially type one errors (Evans & Anastasio, 1968; Jamieson, 2004; Lord, 1967; Miller & Chapman, 2001; Wainer, 1991; Wainer & Brown, 2004; Wright,

2006). This bias was compounded given that a second assumption of ANCOVA was not met: the covariate was not shown to be a reliable measurement (Jamieson, 2004; Kirk, 1995). In this study, both of these assumptions were not met because there was a significant relationship between the covariate and section, $F(1, 280) = 13.934, p < .001$. Also, the covariate was not measured reliably as evidenced by the low reliability Cronbach's alpha scores (form A=.361 and form B=.586) on the pre-test.

Because of these unmet assumptions, repeated measures ANOVA techniques were used to determine differences between control and treatment groups on QPS scores. An alpha level of .05 was chosen for this analysis. In this analysis it was determined that working memory scores did not account for a significant amount of variability in the scores, $F(1, 224) = 2.530, p = .460$, thus working memory was not included in the overall analysis and factor analysis. In addition, a type three method for computing sum of squares was used to adjust for sample size inequalities between control and treatment sections (Macnaughton, 1998; Shaw & Mitchell-Olds, 1993). Despite extensive efforts to improve this instrument, reliability on the post-test was still below acceptable levels. Pre-test scores showed a Cronbach's alpha of .361 for form A and .586 for form B. Post-test scores showed a Cronbach's alpha of .548 for form A and .477 for form B. Thus, results from this instrument must be interpreted with caution.

Additional data analysis on QPS data was conducted on each of the four factors (methods of inquiry, making inferences, scientific information and graphical methods). These factors were analyzed using the same statistical techniques as the overall QPS scores to determine effects resulting from the treatment.

Task Survey

Data from the task survey are both quantitative and qualitative. A total of 16 questions from the task survey are likert-scale questions that allow quantitative analysis and three questions are open-ended comment questions. Invalid responses were removed from the data. Responses provided by individuals who did not consent to the research study were also removed.

Some controversy exists among researchers on the proper statistical analysis technique for likert-scale questions (see Gregoire & Driver, 1987; Norman, 2010; Rasmussen, 1989). Some researchers have argued that ordinal data such as data that results from likert-scale questions should be analyzed with non-parametric tests (Gardner & Martin, 2007). However, others have stressed that parametric tests on likert-scale data are acceptable – especially with an adequate sample size and enough (five or more) items on the likert scale – as such tests have continued to show correct analysis results even when some assumptions (such as homogeneity of variance) are violated (Carifio & Perla, 2008; Norman, 2010; Rasmussen, 1989). Accordingly, the likert-scale questions within the task survey were analyzed by assigning a number to each response from strongly agree (6) to strongly disagree (1). Seven of these questions were focused on the learning task overall and nine asked students about key self-directed and self-regulated learning behaviors they felt they exhibited during the learning task. Repeated measures ANOVA techniques were used to compare one survey question to another with planned pairwise comparisons using bonferroni adjustments to determine statistical significance between high and low scores for each question. An alpha level of .05 was chosen for each overall analysis and alpha levels of .0071 and .0056 were used on the planned pairwise comparisons of the overall and self-direction/engagement analyses respectively. The purpose of this analysis was to determine if there were any questions that received significantly higher or lower scores than

other questions. This analysis was designed to show the degree to which certain student-reported self-direction and engagement activities were present while students completed the learning tasks.

Open-ended comments from the task survey were first analyzed within each learning task to place responses within a category. For example one student gave this comment: “The aspect of learning how to find scholarly, relevant, recent, and reputable articles was realistic...” This comment was placed in the “information seeking” category because it featured a description of information seeking activities. In some cases longer responses were placed in more than one category. Consider, for example, the response: “The project was very self-directed. Yes there was a rubric, but it was really your own ideas and claims. No one forced you into boring subjects for research. With those features, I could take charge fairly easily.” This response was placed in two categories, “personal motivation/interest” and “choice in learning,” because it clearly involved aspects of both categories. After all of the open-ended questions were analyzed from each learning task, the categories from each question were combined into overall categories. This was done by comparing the same question across each learning task and combining similar categories together to give an overall picture of student responses to the three task survey open-ended questions. This analysis revealed the reasons that students chose a certain learning task, the aspects of learning tasks that students felt were realistic, and the aspects of learning tasks that students felt made them take charge of their own learning.

Design Team Observations

Design team observation data were synthesized in order to explain significant design decisions made during the course. The synthesis process included a complete reading of all meeting observations and notes and categorization of these into major decisions which affected

the course design. For example, the following note was taken during a design meeting: “Instruction (3.5 days) was added showing how to find evaluate and apply scientific information.” This note was placed under the decision entitled “past task reviews and revisions,” along with other notes that corresponded to this decision because this added instruction was a direct result of reviews that the instructor made of previously implemented learning tasks. In this way, a final list of major decisions was completed to fully describe the final *Concepts in Biology* course design as it occurred throughout the semester.

Pre-Test Results

In order to determine the equivalency of control and treatment participants at the beginning of this study, statistical analyses were conducted on pre- measurements to determine any significant differences between the control and treatment sections. These analyses were conducted using data gathered at the beginning of the semester.

PRO-SDLS

PRO-SDLS pre-test means for the control and treatment sections were ($M = 86.303$) and ($M = 85.806$) respectively. A total of 310 participants took the pre PRO-SDLS: 208 from the control section and 102 from the treatment section. A one way ANOVA on these scores revealed no significant difference between total PRO-SDLS control and treatment section scores, $F(1, 309) = .155, p = .694$. No significant differences were found in any of the PRO-SDLS instrument factors between control and treatment section scores on the pre-test.

QPS

The QPS pre-test score means for the control and treatment sections were ($M = 9.985$) and ($M = 11.041$) respectively. A total of 394 participants took the pre QPS: 272 from the control

section, and 122 from the treatment section. A one-way ANOVA showed that these mean differences were statistically significant, $F(1, 392) = 12.88, p < .001$. Significant differences were also found between pre-test scores for three of the four factors in this instrument: including methods of inquiry (factor one), making inferences (factor two), and graphical methods (factor four). The QPS pre-test showed low internal reliability levels on both form A (Cronbach's alpha = .361) and form B (Cronbach's alpha = .586). It is not known whether these significant differences among students in the control and treatment groups on the QPS pre-test are a result of error in measurement (due to low internal reliability levels) or actual differences in students' understanding of science concepts.

Working Memory

Means for working memory test scores within control and treatment sections were ($M = 34.53$) and ($M = 34.67$) respectively. A total of 275 participants took the working memory test, 187 from the control section, and 89 from the treatment section. A one-way ANOVA on working memory test scores showed no statistically significant differences between control and treatment sections on the working memory test scores, $F(1, 274) = .049, p = .826$.

Based on these data collected at the beginning of the semester and an additional survey of student demographic responses, no significant differences were found between students in the control and treatment groups with regard to self-reported GPA, age, prior science courses taken, class level, working memory and self-direction. Significant differences were found between control and treatment sections in students' understanding of science concepts as measured by the QPS, however the internal reliability of this instrument was below acceptable levels.

Design Team Observations

An analysis of notes taken during design team meetings and correspondence reveals major decisions made during the design process of the *Concepts in Biology* course. The first and perhaps most significant decision made within the design team was to conduct an in-depth review of all student tasks from the previous semester with the purpose of informing further development and revision of the learning tasks. The instructor reviewed student tasks and made changes to the tasks based on the review. This review resulted in changes to the treatment section design including:

- Development of more specific rubrics for each learning task;
- Addition of instruction showing how to find reliable information;
- Addition of instruction showing how to make and evaluate a scientific claim;
- Adjustment of tests to align more closely to the learning tasks; and
- Addition of specific subject matter instruction (for example, in one learning task it was determined that students did not know enough about fish populations and sustainability).

Based on changes to the section design and learning tasks, the instructor indicated a high level of satisfaction with the newly-revised section design and learning tasks. She perceived that students have submitted higher quality learning tasks that make better scientific arguments and use more reliable sources than previous courses. Student peer-grading was also observed to be more accurate than that of previous semesters. Students also expressed high satisfaction with the learning tasks and had fewer issues and questions about them.

The next major decision affecting the treatment section design was designing a course learning plan format for the online aspects of the treatment section. The design team determined that task-centered learning activities could to make it difficult for students to determine what

they should do each day and week. The team decided to organize the assignments and activities in a chronological learning plan format online. In this format, each day of the semester listed the general topic, assignments due before class, and planned activities. The design team worked together to come up with naming and file conventions for these items.

At the beginning of the semester, the instructor observed that students had some difficulty getting used to this new format. It was speculated that this was because of student's lack of experience with such formats. However, by the middle of the semester, students had little if any confusion about what to do in the course and seemed to know what to do for each day.

Many design team decisions had to be made because of a lack of resources in the form of time or personnel. For example, the *Concepts in Biology* instructor decided to cap enrollment in the treatment section at 150 students in order to lower the grading and teaching workload. The control section cap remained at 350. Observations of the curriculum indicated that the amount of work that students did during the semester did not significantly vary from control to treatment section. However, the amount of work that the instructor had to do was not equivalent because the learning tasks in the treatment section required more time-consuming grading and feedback processes. Two teaching assistants were also employed in the treatment section to help with task-related aspects of the course.

The design team also decided that out of a possible six learning tasks, each group of students would only be required to complete three learning tasks. This decision came from the realization that the *Concepts in Biology* instructor did not have enough time to grade all learning tasks sufficiently if students completed six. Therefore, all students were required to complete the first learning task (which provided students with important skills that would be used in the other learning tasks), and then choose which of the next two learning tasks (tasks two and three) they

wanted to complete. Student groups also had the opportunity to select either task four, five or six to complete. In this way, there was sufficient time to give students formative feedback and in-depth evaluation of each of the learning tasks.

Design team decisions were also made to try to equalize the workloads of students in the control and treatment sections. Tests and note taking activities were used in the control section to substitute for the learning tasks in the treatment section. The amount of work was observed to be similar between the sections when taking into account test study time and note taking in the control section. In-class times were equivalent overall and subject matter coverage was the same with a few exceptions: during the semester, the control section spent about three and a half days learning about evolution while the treatment section had learning task group work time and did not learn about evolution. The sequence of units differed from the control to treatment section as a result of almost a week of class cancellations at the beginning of the semester due to inclement weather. All PowerPoint presentations given in both sections were identical and the same final exam was administered in both sections.

In sum, several important decisions and activities affected the design of the *Concepts in Biology* course. These include a full review of previously implemented learning tasks which led to key revisions to the course, a course learning plan format implementation, an enrollment cap on the treatment section, a student choice of three learning tasks, and efforts to equalize the student work load between the control and treatment sections.

Research Question 1

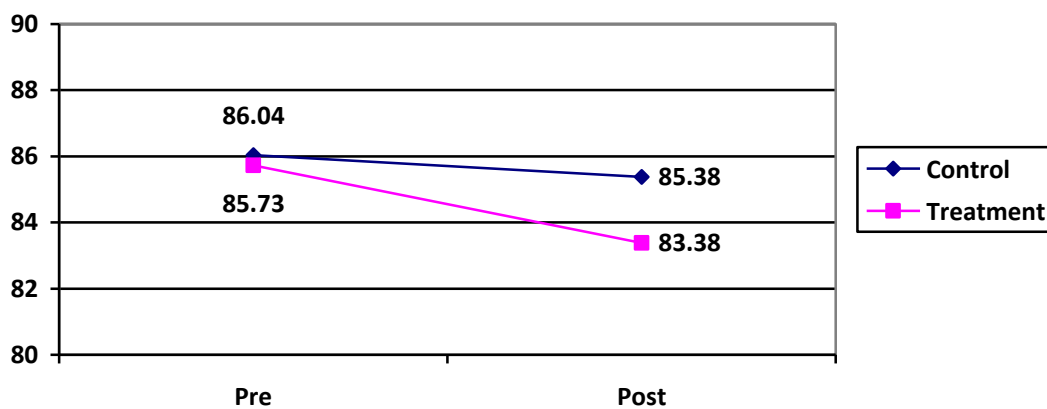
What is the effect of an undergraduate science course designed with a task-centered approach on learner self-direction?

It was hypothesized that participants in the treatment (task-centered approach) section would show a higher improvement in learner self-direction than participants in the control section. Data from the PRO-SDLS and working memory test were used to investigate this hypothesis. Table 6 shows the means and standard deviations for both the control and treatment PRO-SDLS scores.

Table 6

Number of participants, means and standard deviations of PRO-SDLS scores in the control and treatment sections

Section	n	Pre		Post	
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Control	121	86.04	10.48	85.38	11.05
Treatment	71	85.73	9.53	83.38	9.27



A total of 192 participants took both the pre and post PRO-SDLS and working memory test. Levene's test of equality of error variances was not significant on overall PRO-SDLS

scores, $F(1,190) = 3.34, p = .069$, indicating that the assumption of homogeneity of variance between the groups was met. Analysis of covariance (ANCOVA) revealed no significant difference between overall control and treatment PRO-SDLS scores when taking into account working memory test scores and pre PRO-SDLS scores, $F(1, 188) = 3.138, p = .078$, partial $\eta^2 = .016$. ANCOVA also found no significant differences between control and treatment sections on any of the instrument factors including initiative, control, teaching-learning transaction, self-efficacy, motivation, and learner characteristics (see table 7).

Table 7

Results from ANCOVA tests of PRO-SDLS factors between control and treatment conditions

Factor	<i>F</i>	<i>p</i>	η^2	Pre		Post	
				<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Initiative	3.422	.066	.018				
Control				17.94	3.17	18.23	3.31
Treatment				18.31	2.88	17.90	2.95
Control	.194	.660	.001				
Control				22.26	3.31	22.17	3.77
Treatment				22.01	2.94	21.86	2.75
Teaching-Learning Transaction	2.031	.156	.011				
Control				40.20	5.38	40.40	5.93
Treatment				40.32	4.99	39.76	4.71
Self-Efficacy	2.433	.120	.013				
Control				23.33	3.17	23.28	3.60
Treatment				23.38	3.02	22.66	3.01
Motivation	1.710	.193	.009				
Control				22.51	3.68	21.69	3.40
Treatment				22.03	3.48	20.96	3.77
Learner Characteristics	3.137	.078	.016				
Control				45.84	5.76	44.98	5.77
Treatment				45.41	5.36	43.62	5.48

These findings do not support the hypothesis that participants in the treatment (task-centered approach) section would show a higher improvement in learner self-direction than

participants in the control section. Findings indicated no significant differences between the control and treatment section measures of learner self-direction.

Research Subquestion 1a

What are participant perceptions of their own self-direction and engagement in task activities during the course?

The task survey was used to gather student perceptions of their own self-direction and engagement within the learning task activities. Each time a group in the treatment condition completed a task, group members were given the opportunity to fill out this task survey. A total of 218 responses were received in the task survey. Findings from the task survey are divided into three categories: responses to questions about the learning tasks overall; responses about specific self-direction and engagement activities during the learning tasks, and; open-ended responses. The open-ended responses asked students about the reasons they chose to do tasks, the realistic aspects of the learning tasks, and the aspects of learning tasks that helped students take charge of their own learning. Because the learning tasks were called projects in class, students sometimes referred to the learning tasks as projects in their survey responses.

Responses to questions about the tasks overall

Students responded to seven questions about the learning tasks overall. These responses were scored on a scale from one to six (strongly disagree to strongly agree) and statistically compared to one another using a repeated measures analysis of variance (ANOVA). This comparison was made to see if any questions received agreement scores significantly higher or lower than other questions. In this way, responses to questions could be categorized as high or

low in student agreement. A comparison of student responses to these questions aims to show student perceptions of the activities that were and were not supported in the learning tasks.

Mauchly's test of sphericity was significant, $W = .514$, $p < .001$, indicating that variance was not homogenous between all of the question scores. Thus, a Greenhouse-Geisser adjustment was applied to the repeated measures ANOVA analysis. The analysis revealed differences among the seven questions about the learning tasks overall, $F(6, 206) = 67.415$, $p < .001$, partial $\eta^2 = .242$. Planned pairwise comparisons with bonferroni adjustments ($\alpha = .0071$ or $.05/7$) revealed differences between the questions (see table 8).

Table 8.

Means, standard deviations and p-values for post-hoc tests of mean difference with bonferroni adjustments

Question	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7
1	4.17	1.27	-	.268	<.001*	<.001*	.001*	<.001*	1.000
2	4.36	1.23		-	.151	<.001*	<.001*	.012*	.914
3	4.61	.92			-	<.001*	<.001*	1.000	<.001*
4	3.21	1.21				-	<.001*	<.001*	<.001*
5	3.81	1.06					-	<.001*	.004*
6	4.70	.88						-	<.001*
7	4.16	.87							-

Question 1: This project was realistic, that is, it represented what I might do in real life.

Question 2: I will use the information that I learned in this project when this class is over.

Question 3: I found many of my own learning materials to complete this project.

Question 4: I did this project because I wanted to, not because I had to.

Question 5: During this project, I did more than what was required so that I could learn more about biology concepts.

Question 6: During this project, I had to take charge of my own learning.

Question 7: This project was easy for me to do.

Note. Values marked with an asterisk are statistically significant.

Perhaps the most significant findings from this analysis involves questions three (found learning materials) and six (take charge of learning), which received significantly higher

agreement than all of the other questions. This high agreement indicates that students reported that finding learning materials was a significant aspect of their learning task experiences.

Students also reported that they took charge of their learning during the learning tasks.

Questions four (wanted to) and five (did more than required) received significantly lower agreement than all of the other questions. This indicates that students reported a low sense of personal motivation to do the learning tasks. Students also reported lower agreement that they did not take the initiative to learn more than what was required.

Responses about specific self-direction and engagement activities

In the task survey, students also responded to nine additional questions about their own self-direction and engagement activities during the learning tasks. These responses were scored on a scale from one to six (strongly disagree to strongly agree) and statistically compared to one another using repeated measures ANOVA (see table 9). This comparison was made to see if any questions received significantly higher or lower agreement than other questions. In this way, responses to questions could be categorized as high or low in student agreement. A comparison of student responses to these questions aims to show student perceptions of the self-direction and engagement activities that were or were not supported in the learning tasks.

Mauchly's test of sphericity was significant, $W = .526, p < .001$, indicating that variance was not homogenous between all of the question scores. Thus, a Greenhouse-Geisser adjustment was again applied to the repeated measures ANOVA. The analysis revealed differences among the seven questions about the learning tasks overall, $F(8, 205) = 45.254, p < .001$, partial $\eta^2 = .176$. Planned pairwise comparisons with bonferroni adjustments ($\alpha = .0056$ or $.05/9$) revealed significant differences between the questions.

Perhaps the most significant finding from the post-hoc pairwise comparisons is that questions four (information accurate) and seven (consulted requirements) received significantly higher agreement than all of the other questions. Students reported that the learning tasks often required them to evaluate information and consult class requirements.

Table 9.

Means, standard deviations and p-values for post-hoc tests of mean difference with bonferroni adjustments

Question	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7	8	9
1	4.29	1.01	-	1.000	.002*	<.001*	.203	.002*	<.001*	1.000	1.000
2	4.14	1.10		-	.139	<.001*	1.000	1.000	<.001*	1.000	1.000
3	3.89	1.04			-	<.001*	1.000	1.000	<.001*	.001*	.044*
4	5.09	.78				-	<.001*	<.001*	<.001*	<.001*	<.001*
5	4.06	.98					-	1.000	<.001*	.339	1.000
6	3.95	.97						-	<.001*	.002*	.058
7	4.77	.79							-	<.001*	<.001*
8	4.27	.94								-	1.000
9	4.23	1.04									-

Question 1: I made and followed a detailed plan to complete this project.

Question 2: I had to adjust my personal schedule in order to complete this project.

Question 3: I often thought about whether I was making adequate progress during this project.

Question 4: During this project, I had to determine if the information I used was accurate.

Question 5: During this project, I discovered new ways to improve my own learning.

Question 6: At the beginning of this project, I considered alternative ways to accomplish it.

Question 7: I often consulted the class project requirements as I completed this project.

Question 8: During this project, I thought about when to ask others to help me and when not to.

Question 9: I was in complete control of my own success during this project.

Note. Values marked with an asterisk are statistically significant.

Question three (adequate progress) had the lowest average agreement, significantly lower than many of the other questions. Thus, students did not report thinking about their own learning progress as much as many of the other self-direction and engagement activities.

Overall, responses from likert-scale questions on the task surveys indicate that students responded with lower agreement for items that focused on personal initiative and motivation, as well as personal learning progress monitoring. Students gave high agreement to items that focused on information seeking and overall personal learning control during learning tasks. Students also reported high agreement when asked if they often consulted class requirements to help them complete learning tasks.

Open-ended questions

Three main open-ended questions were asked within the task survey:

1. I chose to do this project over the other possible projects in class because:
2. The aspects of this project that were realistic were:
3. The aspects of this project that made me take charge of my own learning (if any) were:

Each question was analyzed to synthesize and categorize student responses.

Reasons for choosing tasks. The first question revealed students' reported reasons for choosing a certain learning task over other possible tasks in the treatment section. Task one provided a foundation of information seeking, synthesis and evaluation skills that would be used in all of the following learning tasks. Therefore, all students were required to complete this task and student responses to this question in task one were not used as part of this analysis. The reasons for choosing learning tasks that students reported included a general interest in the subject matter and task activities, personal interest in the subject matter, knowledge of societal issues and misconceptions related to the task, future usefulness and relevancy of the task, a lack of personal knowledge of the subject matter in the task, perceived ease of task completion, and advantageous timing of tasks within the semester.

The most commonly given reason for choosing a learning task was a general interest in the task subject matter and activities. One student responded: “this project interested me more and it seemed more applicable to everyday life.” As was typical in this section, another student chose a learning task by comparing his or her interest in completing the two possible learning tasks: “[the project I chose] seemed a lot more interesting than the fish project.” More in-depth responses were also given by students about the specific aspects of the learning tasks that interested them. Generally this interest centered on certain aspects of the subject matter covered within the task such as vaccines, cancer, food, etc. For example, one student indicated some level of intrinsic interest with the *vaccination debate* task: “I wanted to examine the vaccines being promoted as preventions for cervical cancer due to HPV...I wanted to determine if this approach was a valid one.” Another student indicated a moderate interest in knowing more about the subject matter in the *cancer, what are my options* task: “Cancer has always been an interesting topic for me and I do not know much about it.”

Students also reported that interest in learning tasks also stemmed from student prior experience. One student mentioned an important personal experience related to the *cancer, what are my options* task: “I also find it very interesting because my grandmother passed away from cancer and I wonder if we had been more informed about treatment options if it might have helped.” In sum, students reported that personal interest, whether general or focused on a specific aspect of a learning task, affected student’s task choices.

Perhaps the second most cited motive for choosing a learning task was a perceived close relationship of the task to life experience. Student comments often revealed that the learning task was chosen because it was “relatable to me,” “would benefit me later in life,” or “would have more impact on my daily life.” One more specific area of interest within life experience was

future usefulness of the skills or information learned in the task. For instance, one student commented on his or her need to know the information from the *worst food in America* task to help make personal decisions:

Every day I face a choice of which food to grab and I want my decision to benefit my body not harm it[...]his project helped to understand what to look for in food labels that should be a sign of a “bad” food.

Another student discussed a similar personal need to be informed for future vaccinations: “The subject interests me[,] I received vaccinations and will have to choose whether or not to give them to my children...”

Another reason that students gave for choosing a learning task was the perception that the subject matter of the task had a societal connection or value. Students often indicated that they chose a learning task based on its connection to some existing perception or need in our current society. This connection included general societal values (e.g., “fish sustainability is important in our lives”) and more specific prevailing public misconceptions or stances about the subject area of the learning task. One student indicated that such misconceptions and stances became a reason for choosing the *human reproduction myth buster* task: “My group thought this would be an interesting project because you learn about the different misconceptions about birth. It was interesting to see different people’s stand on the topics.” Some students also indicated the role that media may have in affecting societal values. For instance one student said the following: “there is always [sic] some pop science story in the news about how a popular food is bad for you, I wanted to learn how to investigate for myself.” Based on the above comments and areas of focus, students reported that the connection between the learning task and daily life affected their task choices.

Additional categories of reasons for learning task choices include perceived ease in doing the task and task timing. Some students indicated that they chose a learning task because it seemed easier to complete overall, either because some aspect of the task (such as finding relevant information) seemed easier or because students had more prior knowledge of the task subject area. Interestingly, one student stated that his or her group had significant personal experience related to the *cancer, what are my options* task: “Two of the members of my group are cancer survivors, so we decided that this project would be the easiest and most interesting because of their personal insight.” Another student indicated a desire for the group to complete learning tasks earlier in the semester which affected their task choice: “my group decided it would be best to take the initiative and finish our projects as soon as we could.” In sum, students indicated that they chose certain learning tasks because they thought they might be easier to do or provide a more opportune schedule than other tasks.

Finally, six respondents cited a lack of knowledge in the subject matter area as a reason they chose learning tasks. One such student responded: “Cancer has always been an interesting topic for me and I do not know much about it.” The number of respondents who cited a lack of knowledge as a factor in their learning task choices was very low compared to the other reasons given for choosing tasks.

In sum, students reported choosing learning tasks based on a variety of reasons. These reasons included general or personal interest in the learning task activities or subject matter, societal issues and concerns that are related to learning tasks, future usefulness of knowledge and skills used in the task, a need to learn more about the subject matter featured in the task, ease of learning task completion, and the timing of learning tasks in the semester.

Realistic aspects of tasks. The second open-ended question revealed what students perceived were realistic aspects of the learning tasks in the treatment *Concepts in Biology* section. An analysis and synthesis of student responses revealed that students judged a task as realistic based on activities conducted during the completion of tasks that included coordinating teamwork activities, conducting information seeking and evaluation activities, and making scientific arguments. Students also felt aspects of the learning tasks that make a connection to life experience such as societal concerns and personal connections were realistic.

A large number of students indicated aspects of learning tasks that were realistic because they featured experiences and concerns related to realistic public health, goods and services. These issues ranged from actual business products currently on the market, to common diseases and treatments. This connection was intentionally designed to be a part of the learning tasks, thus it is not surprising that students mentioned it in their comments. One student indicated the potential importance of findings like those generated in the *fish futures flyer* task: “Although I don't eat yellow-fin tuna, the statistics that my group compiled were realistic and relevant to today's fishing industry.” In addition to industry relevance, students often discussed the relationship that learning tasks have to societal concerns. One such student humorously discussed both personal and societal connections to the *worst food in America* task: “America is fat, I'm trying to lose weight (the two are unrelated).” Another student soberly related the importance of his or her task findings:

The fact that our entire project is targeted at college kids makes it incredibly realistic.

Students are the most frequent drinkers of energy beverages so it is important that they know all the ingredients they are putting in their bodies and how those ingredients can effect [sic] them.

A comment from still another student discussed the use of real data about tuna fish: “We found real data about the numbers of the tuna and how they could potentially be dwindling to an unsafe number.” As was hoped for, students reported finding realistic connections between the subject matter in learning tasks and current public and societal issues.

Many of the learning tasks were designed to be realistic by requiring students to investigate claims made by the media about topics related to biology. Thus many of the comments made by students discussed how these media claims are sometimes false. One student wrote: “People come into contact with issues regarding pregnancy every day. The information we gathered concerning our ‘sex myth’ is very helpful to find out the answer to these questions instead of continuing to spread the rumors around.” Another student discussed the differences of opinions that exist about vaccines: “It was realistic to find out about what the news is actually saying about a vaccine and what it really does to you.” Based on these comments it is apparent some students perceived that learning tasks allowed them to explore discrepancies between media claims and scientific data.

Personal connections to the learning tasks were also abundantly cited by students as examples of the realistic nature of tasks. One student noted that the *worst food in America* task “...kind of opened my eyes to some food choices and made me think more about what I ate.” Another student was given the opportunity to investigate a drug that he or she would have potentially used:

Accutane is a drug that my dermatologist recommended for me, but my mom vetoed, because she had done the research behind the drug and knew the dangers. I wanted to practice researching on a subject relevant to my life as well as others'.

Along these same lines, the future usefulness of skills in the learning tasks was mentioned by other students. One student said: “In the future I will probably be interested in doing further research to determine for myself if a product is safe or in my best interest to consume...” Another student indicated the importance of knowing how to make a decision based on the best data: “People are always advocating certain foods for health benefits and preaching against others because they're ‘bad for you.’ It's very realistic to have to go into the real world and decide why something is or is not healthy.” A very personal decision was also the subject of another student’s comment about the realistic nature of the *human reproduction myth busters* task: “Most people want to get pregnant in their lifetime, and I want to be pregnant at the time I choose!” In sum, students reported making abundant personal connections to the learning tasks, whether based on past personal experience or future decision-making needs.

A majority of students also cited information seeking and evaluation activities as realistic aspects of learning tasks. One student discussed the importance of such skills for survival: “Throughout our lives we are going to have to research different things and decide whether or not they are valid and what products could potentially put us or our loved ones at risk.” Another student also discussed information seeking and evaluation as useful for a future learning setting: “The aspect of learning how to find scholarly, relevant, recent, and reputable articles was realistic because I need these skills when researching for other classes.” Students also commonly indicated that the synthesis and evaluation of these information sources is a realistic endeavor. One student stated that “...determining valid information, verifying the credentials of the authors/sources, and how it relates to the warrant [is realistic].” Another student felt that “Testing sources for credibility and being able to construct a valid argument for one's claim” was a realistic aspect of a learning task. Overall, students seemed to believe that information seeking,

synthesis and evaluation are realistic activities that occurred regularly as they completed the learning tasks.

In the learning tasks, information seeking, synthesis and evaluation activities led to students making scientific claims or arguments. Such claims and arguments were also seen by many students as realistic aspects of the learning tasks. One student said that “The real life knowledge and technique development that can be used to derive one's own conclusions about similar subject matter” was a realistic aspect of a learning task. Another student said: “My group focused on how music enhances brain activity and development. This is a concept that is often public knowledge and the subject of conversation. We had to prove, though, that there was evidence to back up our claim.” So the process of information gathering leading to making claims that was a part of the learning tasks was also seen as realistic by students.

Finally, students perceived group work and time management activities as realistic aspects of the learning tasks even though these activities were not directly related to the course subject matter. A reflective student who evidently played a group leadership role, wrote:

I had to work in a group, and I had to meet a deadline. I also had to trust other group members. I tried to let up a bit this time and let people do their work without micromanaging. Unfortunately, I do not think it turned out as well this time, and so I feel like I will have to be really picky with everyone for the next project. This is realistic though and shows me how to learn from the past & plan for the future.

In a similar reflective comment on group work, another student asserted: “This was a realistic experience of working in groups. It showed me the difficulties of working with this type of setup, and hopefully I have learned how to be more effective in this type of situation in the future.”

Another management aspect of the learning tasks was uncovered in an additional comment: “I

had to manage my time and finish the tasks assigned to me.” Thus, students also perceived group work and time management-related activities as realistic aspects of the learning tasks.

Overall, students felt that a wide variety of learning task aspects were realistic. These learning task aspects included coordination activities related to teamwork, information seeking and evaluation activities, scientific argumentation, and connections between learning tasks and life experience.

Aspects of tasks that made students take charge of their own learning. When asked what aspects of the learning tasks made students take charge of their own learning, students responded with a wide variety of comments. Student responses were synthesized and categorized to show general aspects of the learning tasks that helped them take charge of their learning. These aspects ranged from information seeking and evaluation activities, information application and synthesis activities, learning choices, personal and group management processes and management of personal motivation.

Information seeking and evaluation were activities that students reported helped them take charge of their own learning. A student wrote about his or her learning during information seeking activities:

Because I had to do extensive research to find the best source, I did learn a lot in the process. I read multiple articles, some good, some not, about scientific experiments and the latest research of energy drinks. I learned more about energy beverages than I expected I would, and I learned a lot about caffeine as well. If I did not take charge and do my research, I would have not learned anything.

Another student discussed the importance of taking charge of personal learning within a learning task: “As always, finding sources and writing are [sic] individual projects. Nobody can help me

write a coherent paragraph and cite sources; if I don't understand it myself, I won't do well.”

Another student discussed the difficulty of finding and using relevant information: “Organizing vague information into relevant information...[f]or this project it was extremely difficult to find relevant information...” The evaluation of information sources was another area of emphasis among students: “We had to find reliable sources and decide what was important information and what was not” was one student’s comment. Another student commented that the “verification of valid sources and being able to interpret the information I found into a coherent argument” was an aspect that required him or her to take charge of learning. Based on these and previous comments from students, information seeking and evaluation activities likely played a central role in the course learning tasks.

Similar to information seeking and evaluation activities, students also reported that information application and synthesis aspects of the tasks also helped them take charge of their own learning. Students often mentioned that the learning tasks made them go beyond a basic understanding of subject matter. To make this point, students used phrases such as “really understand,” and “making sure I know,” indicating a depth of learning required as part of the learning tasks. Students often attributed this depth of learning to the information application and synthesis required in the learning tasks. One student wrote: “This project wasn't only about gathering information, but also presenting this information to influence people's opinions. I had to truly understand all the information and draw accurate conclusions before presenting it to others.” Another student made a fitting comment about information synthesis and application:

I had to apply the information I learned in class to an actual example. I had to really make sure I understood the information...I had to find sources, read, understand, and summarize everything in relation to my knowledge from class.

It is interesting to note that some students stressed that these important information evaluation and synthesis activities occurred outside of the classroom. The fact that these activities were completed outside of the classroom seemed to be a significant aspect of these students' definition of taking charge of learning. One student commented about the importance of getting information on his or her own: "making sure that I knew about the subject [b]y getting information outside of what we talked about in class." Another student discussed a possible positive aspect of doing work on one's own: "I had to do my own research, which I enjoy, to contribute my part to the group. We weren't necessarily going over the topics concerning our project in class, so it wasn't repetitive." Thus, students felt that because they were required to do information application and synthesis activities outside of class, they had opportunities to take charge of their own learning.

Another aspect of the learning tasks that students indicated helped them take charge of their own learning was choice in learning. Many aspects of the learning tasks were specified, such as due date, length and format. However, students had a lot of choice in the learning tasks including the specific topic (e.g., which food or vaccine to investigate) the sources used for research, sequencing of learning task activities, and group work logistics. Some students characterized these choices as a lack of instruction or guidance, as one student mentioned: "because we were given little instruction on how to do this project, the group had to figure it out on its own." Another student indicated that the learning task requirements led to his or her taking charge of learning: "I thought the project requirements weren't very clear, so we had to be creative and figure out how to learn about the topic in our own way." Another student voiced an initial feeling of trepidation from the lack of guidance, but also saw its positive side:

I feel like this class in general is mainly about learning on our own. This is really scary for me because science is not my strongest area and I respond much better to more direction and structure. For these projects, we are responsible for the research and the organization of the results, which makes it vital for us to teach ourselves and exercise our critical thinking skills as adults. In that way, it is positive for us to learn on our own.

Another student stressed that a choice of topic allowed more personal interest in a learning task: “The project was very self-directed. Yes there was a rubric, but it was really your own ideas and claims. No one forced you into boring subjects for research.” One student succinctly summed up learning choices: “There was [sic] a wide variety of ways to get the project done. It was up to me and my group to determine the best way and what evidence we would include.”

Many students also reported that group work – including the division of labor and management of meeting time – provided opportunities to take charge of learning. One student explained how his or her group worked together: “As a group we had to depend on one another for help and assistance because we did not have a teacher there giving us instructions, we had to develop our own ideas and put them into action.” Another student gave a more in-depth view of what happened during group work:

By paraphrasing some information from articles, I was learning how to interpret scientific studies. A big part of learning is listening to others and using what we hear to better comprehend a concept. Through group work, I observed several perspectives on our claim, which modified some of the reservations I had about it to begin the project.

Another student further reported on the group logistics: “While everyone did their part I was very conscious of making sure the project came together cohesively.” Still another student indicated that group logistics led to his or her group taking charge of learning:

...my group had a specified time limit to complete this project. Therefore, we had to use our time wisely and decide when to work on this project. We could not simply wait to the last minute. Further, we had to figure out how to evenly divide up the labor so that one person was not going to be doing the whole project.

Based on these responses, students reported that group work provided an opportunity for them to take charge of their own learning through time and group management activities.

Finally, a handful of students reported that personal motivation and interest led them to take charge of learning during learning tasks. One student described how his or her personal motivation functioned: "I had to find alternative ways of making the project seem interesting to me so that I'd research it deeper." Another student discussed going beyond the minimum requirements of the learning task because of personal interest: "I did some outside research on the topic that was not necessary to put in the group one. This research allowed me to better understand certain biological concepts such as the steps our body takes in order to give birth and the effects of hormone levels on the future child's health." Additional students reported that a personal interest in the subject matter of the learning task led them to take charge of their learning.

In sum, students indicated that a wide variety of learning task aspects helped them take charge of their own learning. These learning task aspects included information seeking and evaluation activities, information application and synthesis, learning choices, personal and group management processes, and management of personal motivation.

Research Question 2

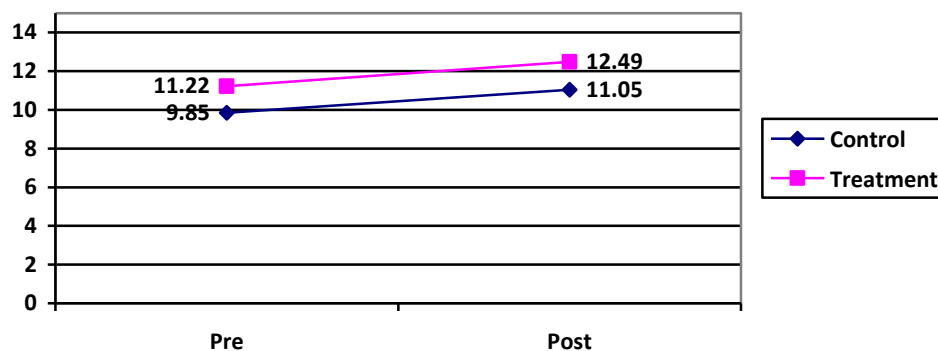
What is the effect of an undergraduate science course designed with a task-centered approach on students' understanding of science concepts?

It was hypothesized that participants in the treatment (task-centered approach) section would show a higher improvement in students' understanding of science concepts than participants in the control section. Data from the QPS and working memory test were used to investigate this hypothesis. Table 10 shows the means and standard deviations for both the control and treatment QPS scores.

Table 10.

Number of participants, means and standard deviations of QPS scores in the control and treatment sections

Section	n	Pre		Post		Difference
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
Control	203	9.85	2.77	11.05	2.65	1.20
Treatment	79	11.22	2.70	12.49	2.48	1.27



A total of 282 participants took both the pre and post QPS test. Mauchly's test of sphericity was not significant, $W = 1.00$, $p > .05$), indicating that variance was homogenous between the QPS pre- and post- tests and that there was no need for degrees of freedom

adjustments on the data. Repeated measures ANOVA revealed no significant interaction between total control and treatment QPS scores, $F(1, 280) = .046, p = .830$, partial $\eta^2 < .001$. Repeated measures ANOVA also found no significant interactions between any of the control and treatment QPS factor scores (see table 11).

Table 11.

Results from repeated measures ANOVA tests of QPS factors between control and treatment conditions

Factor	<i>F</i>	<i>p</i>	η^2	Pre		Post		Difference
				<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
1: Methods of inquiry	.016	.900	<.001					
Control				2.28	1.00	2.68	.91	.40
Treatment				2.76	.90	3.14	.78	.38
2: Making inferences	.001	.981	<.001					
Control				1.44	.82	1.67	.79	.23
Treatment				1.66	.83	1.89	.80	.23
3: Scientific information	.288	.592	.001					
Control				4.75	1.56	4.97	1.50	.22
Treatment				5.11	1.43	5.46	1.44	.35
4: Graphical methods	.007	.926	<.001					
Control				1.38	.88	1.72	1.04	.34
Treatment				1.68	1.07	2.01	.94	.33

These findings do not support the hypothesis that participants in the treatment (task-centered approach) section would show a higher improvement in students' understanding of science concepts than would participants in the control section.

Summary

Results from the PRO-SDLS and QPS instruments show no significant difference in changes from pre- to post- scores among the control and treatment conditions in this study. These

results suggest that students in control and treatment sections changed the same amount in students' understanding of science concepts and in learner self-direction over the course of the semester. Results from the task survey indicate that students reported finding many of their own learning materials and taking charge of their learning as they completed learning tasks. However students reported a low level of personal initiative or intrinsic motivation, giving low agreement to questions about these aspects of their learning task performance. In task survey questions about self-direction and engagement, students reported that they often had to determine if information was accurate during the learning tasks and they often consulted class requirements while completing learning tasks. However students reported a low level of personal monitoring of progress while they completed these tasks. Open-ended responses to the task survey indicate that students reported choosing to do certain learning tasks because of general or personal interest in the subject matter, societal issues and misconceptions related to the learning tasks, future usefulness or relevancy of the task, ease of task completion, and advantageous timing of tasks. Students indicated that learning tasks were realistic because students had to coordinate teamwork activities, find and evaluate information, and make scientific arguments within subject-matter areas that were pertinent to current societal and personal issues. Students reported that learning tasks made them take charge of their own learning because they supported information seeking and evaluation activities, information application and synthesis activities, learning choices, personal and group negotiation and management activities, and personal motivation management activities.

CHAPTER V

DISCUSSION

The purpose of this study was to investigate the effect of a task-centered learning approach in a large-enrollment general education biology course (*Concepts in Biology*) on learner self-direction and students' understanding of science concepts. Two *Concepts in Biology* sections were used as control and treatment conditions. Both the control and treatment sections included readings, pre-class assessments, online discussions and lectures. However, the treatment section featured learning tasks that groups of students were required to complete, and centered learning and teaching activities on these tasks, while the control section featured group note-taking activities. The research questions in this study are:

1. What is the effect of an undergraduate science course designed with a task-centered approach on learner self-direction?
 - a. What are participant perceptions of their own self-direction and engagement in task activities during the course?
2. What is the effect of an undergraduate science course designed with a task-centered approach on students' understanding of science concepts?

This chapter discusses the findings and implications of this research study. Each research question is discussed in light of findings from the study. These findings are compared to previous findings in the literature. The implications of these findings for practice and research are also discussed.

Research Question 1

What is the effect of an undergraduate science course designed with a task-centered approach on learner self-direction?

The hypothesis that participants in the treatment (task-centered approach) section would show a higher improvement in learner self-direction than participants in the control section was not supported. The results showed no significant difference between control and treatment sections on changes in learner self-direction measures. These findings suggest that a course featuring learning tasks may not foster learner self-direction to a greater degree than a course that does not feature such learning tasks. These findings also suggest that implementing learning tasks within a higher-education course may not decrease students' level of learner self-direction. New forms of teaching and learning – such as task-centered learning – need also to be tested for significant detrimental effects on learning or other constructs such as learner self-direction. This study suggests that implementing learning task activities may not have a detrimental or beneficial effect on learner self-direction.

Task-centered learning engages learners in a progression of tasks that learners are likely to encounter in the future (van Merriënboer, 1997; van Merriënboer & Kirschner, 2007; Merrill, 2002a, 2007). A task-centered approach generally offers a high level of guidance and feedback for novices. In this study, participants were undergraduate non-biology majors with limited prior knowledge. Consequently, there was a need to provide students with support and guidance at the beginning of the semester. This support and guidance took the form of presentations showing how to find, evaluate and synthesize data with the aim of making valid scientific claims. However this support and guidance may also have restricted students from practicing learner self-direction. Students may not have exercised enough of their own personal influence and

intrinsic motivation on the learning process during the first few learning tasks in the *Concepts in Biology* course. The approach of providing and then fading support and guidance – while effective for learning – may not be effective for fostering self-direction unless implemented for a long enough time until students have full control over their own learning processes. Perhaps only at this point would there be a significant increase in measurements of learner self-direction. For novices who are just beginning to understand a complex domain, this required time period may be longer than only a single semester. A study by Kicken et al. (2009) – which showed significant changes in learner self-direction – was implemented over about 40 weeks. This was almost three times the length of the current study. However, Sungur and Tekkaya (2006) showed significant changes in learner self-direction over only a single semester when using problem-based learning.

Kicken et al. (2008b) showed that students perceived that their self-directed learning (SDL) skills were enhanced when they had the opportunity to formulate learning goals, conduct self-assessment and choose learning tasks with the help of an online portfolio that supports these activities. However in this study, findings were limited to student perceptions of their own SDL skills. A follow-up study using the same online portfolio found that students who received advice and guidance on how to use the online portfolio self-directed their learning more effectively than those who only received performance feedback (Kicken et al., 2009). The current study implemented learning task choices, and allowed peer-assessment, but did not support self-assessment of learning and student formulation of learning goals to a high degree. Also, in the current study there was no detailed portfolio to provide students with help in self-directing their learning. Thus, student self-assessment and formulation of learning goals with the help of a detailed learning portfolio may help students increase in learner self-direction.

In addition, Kicken et al. (2009) used multiple instruments to measure SDL skills, including interviews, observations, self-assessment quality scores, task selection quality scores, and learning needs assessments. In another study that showed changes in learner self-direction in a problem-based learning environment, Sungur and Tekkaya (2006) also used multiple instruments to measure learner self-direction. The current study relied upon one primary instrument (the PRO-SDLS), which may not have provided a sensitive enough measure of the multifaceted concept of learner self-direction.

There are several other possible reasons for the lack of significant difference on self-direction change between the control and treatment groups. One possible reason for these findings is the low number of learning tasks that students completed during the semester. Originally it was planned to have students complete six learning tasks throughout the course of the semester, but because of logistical and contextual constraints this number was reduced to three. Design team observations indicated that in the treatment group, student's task-related activities comprised about five to six weeks during the 15-week semester. Student activities between the learning tasks in the treatment group were very similar to the activities in the control group. While the exact number of tasks needed for optimal learning is not given in the task centered learning literature, it is implied that the majority of learning in such environments is centered on learning tasks (van Merriënboer, 1997; van Merriënboer & Kirschner, 2007; Merrill, 2002a, 2007). For instance, Kicken et al. (2009) implemented a total of eight major learning tasks over 40 weeks, each task containing three to twelve sub-skills. The amount of learning tasks in the *Concepts in Biology* treatment section was much lower and may not have been sufficient to show changes on measurements of learner self-direction.

Another potential reason for the findings is that certain aspects of the learning tasks may have been inadequate to foster learner self-direction. Data from the task survey show how students perceived aspects of the learning tasks. Students reported high agreement to questions asking if they found many of their own learning materials for the tasks and took charge of their own learning. However, students also reported low agreement to questions of intrinsic motivation (e.g., “I did this project because I wanted to, not because I had to,” and “during this project, I did more than what was required so that I could learn more about biology concepts”). Based on these reports, students may have carried out learning activities based on *extrinsic* motivation (Cordova & Lepper, 1996; Deci & Ryan, 1985). As indicated in the literature, an *intrinsic* motivation for taking initiative to complete learning tasks and learn is an especially important aspect of learner self-direction (Garrison, 1997; Zimmerman, 1998) which may not have manifested sufficiently in the current study.

The open-ended questions about why students chose a learning task over other possible choices may also provide more information about this issue. In many responses to this question, students reported that they chose a learning task based on a general interest in the subject matter of the task or because of the relationship between the task and life experience. However, another large group of students responded that they made a learning task choice because they felt that it was easier to do or because it was scheduled early in the semester. Only a handful of students reported that they chose to do a learning task because of an intrinsic desire to learn something new or a lack of personal knowledge of the subject matter.

Questions from the task survey about specific self-direction and engagement activities may also provide additional information about the non-significant learner self-direction findings. The question, “I often thought about whether I was making adequate progress during this

project,” received lower agreement than all of the other questions on self-direction and engagement in the task survey. Students may not have sufficiently reflected on their learning progress during the learning tasks or adjusted their learning as needed. This reflection upon and adjustment to personal learning processes is commonly cited as important to learner self-direction in the literature (e. g., Garrison, 1997; Zimmerman, 1998, 2001). One reason for a possible lack of reflection or adjustment might have been the specific guidance and direction on how to do the learning tasks that was given to students in the current study. For instance, many of the learning tasks provided directions on the steps to take, including choosing a topic and dividing group labor (see appendix A). Similarly, students also reported in the task survey that they often consulted class requirements to help them complete learning tasks. However, a focus on teacher-provided class requirements may have the effect of shifting a student’s focus away from the monitoring of personal progress (see Verkoeijen, Rikers, Winkel, & van den Hurk, 2006).

Group learning processes may have been another reason for a possible lack of personal monitoring and adjustment in this study. Open-ended responses to the task survey suggest that students may have monitored progress as part of a group, or that group leaders may have done a lot of the progress monitoring for the group. Students often mentioned doing their own part, dividing up labor, and coming back together to discuss findings. It could be that group leaders provided most of the progress monitoring and adjustment directions for the group, which would have the effect of lowering the number of students who had to carry out these activities. Some students reported in open-ended comments that they took a role in the monitoring of learning progress, but it could be that the students who reported these aspects of tasks were the group leaders.

Open-ended responses from the task survey indicate that students felt a variety of aspects of the learning tasks were realistic including teamwork coordination, information seeking, scientific argumentation, and connection to life experience. Students also reported taking charge of their own learning because of a variety of task aspects such as information seeking, information application, learning choices, group management and personal motivation. Overall there were a variety of task aspects that were perceived as realistic by students and that students felt helped them take charge of their learning. It could be that in the current study, these aspects of the learning tasks also helped students gain a more realistic perception of their own abilities with regard to self-direction. For example, during the learning tasks, students often had to find and synthesize actual scientific information to make an argument. After students had made a rough draft of a task, they received formative feedback about their own success or failure at making a valid scientific argument. This process may have given students a more realistic view of their own strengths and weaknesses with regard to controlling their own learning processes, which might have manifested itself in the end-of-semester PRO-SDLS scores.

Another possible reason for the lack of significant findings on learner self-direction may be that the PRO-SDLS is measuring learner self-direction as a rigid or stable personal characteristic rather than a changeable attribute. Some of the literature on the measurement of self-direction and self-regulation views these concepts as difficult to change within just a short time period (e.g., Guglielmino & Guglielmino, 2008, 2006; Litzinger et al., 2003; Preczewski, 1997). Still other researchers view and measure these constructs as changeable, some within a semester's time (e.g., Cleary & Zimmerman, 2004; Dynan et al., 2008; Gabrielle et al., 2006).

Overall, findings from this study suggest that a task-centered learning approach does not necessarily result in greater increases in learner self-direction more than an approach that is not

centered on tasks. This may be because of the high level of support and guidance provided to learners in the task-centered learning approach in the current study. Another reason for the lack of significant findings may include items implemented in other successful studies such as student self-assessment, goal formulation, a detailed learning portfolio and multiple measurements of learner self-direction. Other reasons for the lack of significant difference may include the low amount of learning tasks used in the treatment section, aspects of the learning tasks that were inadequate at fostering learner self-direction, a more realistic personal view of learning abilities that students gained over the semester, and the possibility of measuring a rigid personal characteristic instead of a changeable attribute.

Research Subquestion 1a

What are participant perceptions of their own self-direction and engagement in task activities during the course?

Responses to the task survey show that students felt that the learning tasks supported a variety of self-direction and engagement activities. Important activities commonly cited by students included information seeking, evaluation and synthesis activities. As mentioned in design team observations, these information literacy activities were a focus of the course as students were required to make valid scientific claims based on real data. Thus it is not surprising that students reported doing these activities within the learning tasks. Prior studies have documented student difficulties when using hypermedia to find, evaluate, and apply information (Azevedo et al., 2004, 2008). In the current study, the first learning task and supplemental instruction seemed to help decrease some of these difficulties. Indeed, task one, *testing claims*, was almost completely focused on supporting students in finding and evaluating credible sources

to make a scientific claim. The instructor provided students with tools that they could use to determine if a particular information source was accurate. Students also learned the elements of scientific argument and the aspects of these elements that make such arguments credible. These activities were designed to provide students with a foundation for the other learning tasks in which they would continue to use these same information literacy skills. Such information literacy-related activities have commonly been cited as part of problem-based and task-centered learning experiences in prior literature (Edens, 2000; Savery & Duffy, 1995).

Student's open-ended responses to the task survey also highlighted information seeking, evaluation and synthesis activities as aspects of learning tasks that were realistic and helped students take charge of personal learning. Students often reported that information seeking activities were realistic because of the likelihood that students would need to seek information and investigate claims in the future. The learning tasks featured information seeking and evaluation activities in a variety of subject areas. In the first task, groups of students were required to choose a claim made in the current media and investigate it using quality information sources. A variety of claims were investigated including claims about the benefits of energy drinks, and existing prescription drugs. The other learning tasks also required students to find, evaluate and synthesize information in order to come to a conclusion. Each learning task required students to make a decision based on the information sources they found. Because information seeking, evaluation and synthesis activities were so prevalent within the learning tasks, it is no surprise that students mentioned that these activities were a significant part of their own experience.

Students also reported that information seeking and evaluation activities often occurred without the immediate assistance of an instructor. After being shown how to find valid sources of

information, groups of students usually carried out these activities independently throughout the *Concepts in Biology* treatment section. While the instructor was available for consultation, most students found and evaluated information sources on their own, requiring them to take charge of their own learning processes.

It was hoped that the realistic nature of learning tasks provided in the treatment section would motivate students to take a personal or intrinsic initiative in learning. In a prior study of authentic computer-based tasks, students who were intrinsically motivated exhibited more exploratory learning patterns than extrinsically motivated students (Martens, Gulikers, & Bastiaens, 2004). In the current study, however, students were more likely to report that they completed learning tasks because of course requirements rather than personal motivation. Also students reported lower agreement to the task survey question that asked about going beyond class guidelines to learn more than what was required.

Students in the *Concepts in Biology* course are not generally biology majors, so they may have viewed the information learned as only useful in the present course. However, in findings from the open ended questions, students indicated that the skills gained would likely be useful for future endeavors. One possible explanation for this discrepancy lies in the distinction between subject-matter knowledge and learned skills. In reporting the future usefulness of certain learned items, students often mentioned “peripheral” skills such as finding, evaluating, and synthesizing information, working with a group, making scientific claims, etc. They did not mention biology subject matter knowledge. Indeed, one major goal of the *Concepts in Biology* treatment section was to provide non-biology majors with skills that they would actually use in real-world contexts. This is consistent with the purposes of task-centered learning (van Merriënboer, 1997; van Merriënboer & Kirschner, 2007; Merrill et al., 2008; Merrill, 2007), and

other studies that have found that students are more practically-oriented than their faculty counterparts (Myers, 2008; Voss & Gruber, 2006).

Similarly, in open-ended responses to the task survey students pointed out a personal connection to the learning tasks in many different ways. Students reported that they often chose learning tasks because they related to other aspects of life. Students often reported choosing to do a learning task because the skills gained could be used after the *Concepts in Biology* course, whether in a future course or real-world setting. This finding is consistent with the SDL literature in which learners are expected to become involved in a learning experience based on its valence, or likelihood that the learning task will meet a personal or future need (Garrison, 1997). However, another reason that students reported choosing certain learning tasks over others was because of prior experience. This prior experience ranged from prior courses in the subject area to personal experiences with concepts presented in the tasks. As mentioned previously, some students in *Concepts in Biology* reported choosing learning tasks because they had some knowledge of the subject matter featured in the learning task. For example, one group chose to do the *cancer, what are my options* task because two of the group members were cancer survivors. The adult learning literature frequently mentions the important role that the prior experience of learners can play in the learning process (e.g., Knowles, 1980; Knowles et al., 1998).

Students also reported choosing learning tasks based on less learning-oriented values as well. In the *Concepts in Biology* treatment section, it was hoped that students would choose tasks because of a lack of subject matter knowledge or skill related to the task, or because of a personal interest in some aspect of the task. While this was the case for many students, others reported choosing a learning task because they thought it would be easier to do or would better

fit their schedule. While these are not deemed valid reasons to choose learning tasks in order to improve one's own learning, they clearly influenced groups in their decision-making process. Such values were also discussed by Clark (1982), in which students made incorrect learning choices based on perceived enjoyment and ease in learning. Other studies have more recently shown the difficulties inherent in providing learners with learning choices including determining the right amount of choice and the right amount of choice guidance (Rieber & Noah, 2008; Rieber & Parmley, 1995).

In the task survey, students responded that they often consulted learning task requirements as they completed learning tasks. The design team observations outlined adjustments and updates to the project descriptions and rubrics to make the learning task requirements more clear and accessible to students. Aside from saving the instructor time, the elaborated task descriptions and rubric also helped students improve their peer-grading processes. Without these updates, students may not have consulted these task requirements as much as they did in the *Concepts in Biology* treatment section. However, with the adjustments, anecdotal design team observations indicated that student tasks were of higher quality and students graded each other's learning tasks more accurately. These learning task revisions also decreased the already high workload of the instructor.

Students responded with low agreement to the question, "I often thought about whether I was making adequate progress during this project." In open-ended responses to the task survey, students often discussed being assigned their own part of the group work. As mentioned previously, students could have monitored and adjusted their progress as a group rather than individually. If this was the case, one member of the group may have taken a leadership role and assigned work to other group members. Group members who were not involved in the

monitoring and adjustment of group progress might have reported that they did not monitor personal progress because this was handled on the group level. A handful of open-ended student survey responses talk about taking a role in the division of group labor and the setting of time limits, but it could be that the people who reported these aspects of learning tasks were the group leaders. Future surveys should include questions about the role of the group leaders and group members in monitoring and adjusting learning progress to clarify this issue.

Overall, student task survey responses indicated that students felt the tasks required and supported information seeking, evaluation and synthesis activities. These types of activities were designed to be a part of the learning task experience. Students often reported choosing learning tasks based on general or personal interest or perceived ease of task completion. Students also reported that they used information literacy skills to make valid scientific claims. Because of these activities, students reported that tasks were realistic and that they required students to take charge of their own learning.

Research Question 2

What is the effect of an undergraduate science course designed with a task-centered approach on students' understanding of science concepts?

The hypothesis that participants in the treatment (task-centered approach) section would show a higher improvement in students' understanding of science concepts than participants in the control section was not supported. The results showed no significant difference between control and treatment sections on changes in students' understanding of science concepts (as measured by the QPS). These results must be interpreted with caution because the QPS was not found to be a reliable instrument despite efforts to increase its reliability prior to the current

study. These findings suggest that a course designed with learning tasks may not necessarily lead to superior gains in conceptual understanding over a course that does not feature learning tasks. As previously mentioned, new forms of teaching and learning – such as task-centered learning – should be tested for significant detrimental effects on student learning. This study suggests that implementing learning task activities may not have a detrimental effect on conceptual understanding. Students in both control and treatment sections increased in conceptual understanding scores to about the same degree.

In addition to the QPS, a 57-question final exam was administered to both control and treatment sections. Although this instrument was not a formal instrument used as part of the research design and reliability and validity information was not obtained, it provides some interesting insight into the current study. The majority of this final examination was focused on biology content knowledge, however a handful of questions also covered application and synthesis level questions. Students in the control section significantly outperformed students in the treatment section overall on the exam (when controlling for pre-QPS scores). More specifically, control section students outperformed treatment section students in questions on reading and interpreting graphical data, and making basic calculations. However, students in the treatment section significantly outperformed students in the control section in exam questions on creating appropriate graphs from data, suggesting that a more applied form of knowledge may have been supported in the treatment section.

Prior findings with the use of problems or tasks at the center of the learning experience have also discovered that students tend to gain as much content knowledge as students in more traditional learning environments (Albanese & Mitchell, 1993; Dochy, Segers, Van den Bossche, & Gijbels, 2003; Gallagher & Stepien, 1996; Vernon & Blake, 1993). However, some studies of

task-centered learning specifically reported superior learning gains in a task-centered group (Lim et al., 2009; Sarfo & Elen, 2007). For instance, Lim et al. (2009) compared learning performance in a task-centered learning experience to a part-task learning experience in a spreadsheet software course. They found that students in both conditions performed the same on a part-task test, yet students in the task-centered condition outperformed students in the part-task condition on a whole-task and transfer test. Similarly, Sarfo and Elen (2007) also found superior learning among students in a task-centered approach over students in an approach that did not include tasks. The instruments in these studies can be contrasted to those in the current study. Both prior studies implemented higher-order performance based measures. In the case of Lim et al. (2009), differences between the groups only existed on whole-task and transfer measurements, and not on lower-order part-task measurements. In the current study, performance and transfer tests – which may have detected important differences between control and treatment students – were not implemented.

Accordingly, the QPS may not have been a sensitive enough instrument to capture the learning that occurred in this study. Difference scores between pre- and post-measurements show minimal gains in students' understanding of science concepts even after students had a semester of exposure to science content and practice. The fact that students only increased 1.20-1.27 points during the semester is further evidence suggesting that this instrument was not sensitive enough to measure the conceptual understanding increases that may have occurred among students in this study.

Similarly, design team observations indicate that the learning tasks were created with specific application goals in mind, including supporting students in making scientific arguments and in information seeking and evaluation activities. None of these goals pertain to student

content knowledge acquisition. In task survey responses, students commonly reported the information seeking, evaluation and synthesis activities that they conducted. It is likely that students in the treatment section improved much more in these areas over students in the control condition (which was more focused on content knowledge). However, the QPS may have measured both content knowledge and the higher-order learning that comes from these types of application activities, resulting in the non-significant findings. This is in line with previous discussion in the literature about the applied nature of knowledge and skill gained in learning experiences that focus on application of knowledge and problem-solving (Hmelo-Silver, 2004; Hung, Bailey, & Jonassen, 2003; Hung et al., 2008).

Similarly, students reported finding many of their own learning materials and taking charge of personal learning in the task survey. However, the direct outcomes of these activities would not necessarily be students' understanding of science concepts. Prior studies have indicated that centering learning on applied problems and tasks leads to higher-order outcomes, including more flexible knowledge, problem-solving skills, and collaborative teamwork (Hmelo & Lin, 2000; Hmelo-Silver, 2004; Hung et al., 2003; Jonassen, 2003). In the current study, students likely increased in information seeking, information evaluation, and perhaps time, personal or group management skills. The practice of these important skills may have taken time away from student processes that led to the acquisition of biology concept knowledge measured in the QPS. However, fostering an applied knowledge base was indeed an explicit goal of the *Concepts in Biology* treatment section.

In addition, learning tasks likely featured a narrower yet deeper base of knowledge than the lectures and exams featured in the control section. In the control section, lectures, exams and note-taking activities focused on a broad amount of concepts. However, the learning tasks were

not broad in their concepts. In the task survey, students often reported choosing a specific product or service to investigate for the task. Students further reported that they had to go beyond a surface-level understanding of the concepts that were applied in learning tasks. In open-ended comments, students also connected this deep understanding to the aspects of the learning tasks that required them to apply and synthesize these concepts. Centering learning on applied problems and tasks has previously been linked to deeper, yet narrower learning (Hung et al., 2003). It could be that in the treatment section, students gained a depth of knowledge within specific concept areas, but did not gain as much of a breadth of knowledge as students in the control section. Student's learning tasks in the current study reflected a depth of knowledge in specific concept areas; however, some of this knowledge depth was not likely reflected in QPS scores. The breadth versus depth argument of curriculum and concept coverage has been debated in the educational research literature for many years (Hirsch, 2001; Hung et al., 2003; Schwartz, Sadler, Sonnert, & Tai, 2009).

Student task survey responses reported lower agreement to questions dealing with personal initiative (e.g., "I did this project because I wanted to, not because I had to," and "during this project, I did more than what was required so that I could learn more about biology concepts"). Assuming that personal initiative positively affects students' understanding of science concepts, a reason for the lack of difference in this understanding between the two sections could be that students did not exercise this initiative within the learning tasks. A prior study by Martens, Gulikers and Bastiaens (2004) showed that intrinsically motivated students working on an authentic task tended to have more exploratory information seeking behaviors than extrinsically motivated students. This willingness to go beyond class requirements and explore content further may be required for enhanced student learning in a task-centered learning

approach. Open-ended task survey responses also highlight another aspect of personal initiative. Students reported choosing learning tasks based on ease of task completion and the timing of tasks rather than a need to know certain information or skill. This reported lack of personal initiative could have influenced whether students studied and learned material to a sufficient level.

Overall, findings from this study suggest that students' understanding of science concepts may increase to the same degree in a task-centered learning approach that it does in an approach that does not feature learning tasks. However, other reasons for the non-significant findings may also exist. The QPS may not have provided a sensitive enough measure of students' understanding of science concepts and higher-order skill. Additional reasons for the non-significant findings may include application skills among the treatment students that were not measured by the QPS, differences in depth and breadth of knowledge gained among the different conditions, and a reported lack of personal initiative among treatment students.

Implications

Several implications can be drawn from the findings. First, this study suggests that task-centered learning activities may affect learner self-direction the same as activities that are not task-centered. While the connection has been made between high self-direction and task-centered learning (see Kicken et al., 2008b, 2009; van Merriënboer & Sluijsmans, 2009), there is still a paucity of empirical evidence supporting the superiority of task-centered learning for supporting learner self-direction over non-task-centered approaches to learning. Task-centered learning differs from pure problem-based learning because it provides learners with specific types of support and guidance. This support and guidance – depending on how it is structured and

provided – may not allow students enough autonomy to practice learner self-direction to a high degree. Pure problem-based learning may be a more effective way to increase students' SDL skills (Hung et al., 2008). However, the support and guidance provided through task-centered learning may be important for acquisition of specific knowledge and skill in long-term memory (Kirschner et al., 2006; Mayer, 2004).

Another implication suggested by this study is that student gains in conceptual understanding may be no higher in task-centered learning than in other forms of learning. This implication should be interpreted with caution, since the reliability of the QPS instrument was not well-established. Prior findings of task-centered learning implementations have shown superior learning gains among students in a task-centered condition (Lim et al., 2009; Sarfo & Elen, 2007). The difference between prior findings and the current study could be explained by the type of measurements used. In the prior studies, instruments that were focused on higher-order performance were implemented. In the current study, a performance-based assessment was not used.

Other implications of this study stem from findings in the task survey. Student responses suggest aspects of learning tasks that may be keys to fostering learner self-direction. For instance, a personal intrinsic motivation to choose and complete a learning task may be required for a learner to practice learner self-direction. This intrinsic source of motivation might be a key to helping learners take the initiative to go beyond course requirements to learn more concepts. Preliminary studies have shown that experience as a student in higher education does not necessarily increase a student's ability to self-direct learning (Gow & Kember, 1990; Litzinger, Wise, Lee, Simpson, & Joshi, 2001; Preczewski, 1997). Challenges to fostering learner self-direction also continue to exist in higher education environments, which may include teacher

reluctance and curricular constraints (Bolhuis, 2003; Candy, 1991; Hiemstra, 1994). It may be appropriate to allow student choice and initiative when students have sufficient prior knowledge of the subject area or when they have sufficient prior experience self-directing their own learning (e.g., Bolhuis, 2003; Cotterall & Murray, 2009; Eshel & Kohavi, 2003; Meichenbaum & Biemiller, 1998).

Another aspect of learning that may be especially important to learner self-direction is the monitoring of personal learning progress (Garrison, 1997; Zimmerman, 1998, 2001). Participants in this study indicated lower agreement to items in the task survey asking about such monitoring. It may be that personal monitoring processes that can occur during learning tasks provide important learner self-direction skills, but these personal monitoring processes may not have sufficiently manifested among students within the current study.

In task survey responses, students often reported that the learning tasks were realistic. Students also indicated that they would use the skills that they practiced after the semester was over. One of the major goals of the treatment section was to provide students with the opportunity to practice skills and learn new information that would be relevant and useful to them in the future. A task-centered approach like the one presented in this study may help students to see the relevance and usefulness of knowledge and skill gained in a course. The student perception of relevance and usefulness may become more and more important in the future in an increasingly competitive educational market with a new generation of technologically adept students (Barnes, Marateo, & Ferris, 2007; Myers, 2008; Taylor, 2010; Twenge, 2009).

Implications for Practice

Several suggestions can be offered for future practitioners who may implement task-centered learning in an existing college course based on experience from the current study. These

include choosing tasks that better support intrinsic motivation, providing detailed performance rubrics to students, formatively evaluating learning tasks, providing proper support for information seeking and evaluation activities, assuring clarity in the course design, and providing adequate feedback to students on learning task performance.

As mentioned previously, students reported low agreement with items in the task survey that focused on intrinsic motivation. The reported lack of intrinsic motivation could have negatively affected students' understanding of science concepts and learner self-direction. In future implementations of task-centered learning, tasks could be designed to better support constructs that are hypothesized to lead to intrinsic motivation such as student autonomy, competence, and relatedness (Cordova & Lepper, 1996; Deci & Ryan, 1985; Lepper & Cordova, 1992; Ryan & Deci, 2000).

In the current study, the instructor implemented detailed rubrics in an effort to support higher student performance on learning tasks, and students reported that they often reviewed these task requirements to help them do the learning tasks. Future instructors who implement a task-centered learning approach are advised to provide detailed rubrics to students that outline performance criteria and the degree to which students are expected to meet these criteria.

In this study the detailed rubrics came about because of a formative evaluation of the task-centered approach in previous courses. Improvements to the learning tasks themselves were also made based on formative evaluation processes in which the instructor read and re-evaluated each student's finished learning task from a previous semester. It is suggested that future implementations of task-centered learning rely upon continuous formative evaluation as a way to improve student's learning experiences. Based on formative evaluation, the instructor in the current study also added key instruction to the treatment section on information literacy skills.

Approaches that center learning on problems and tasks often require students to seek out and evaluate information (Edens, 2000; Hmelo & Lin, 2000; Hmelo-Silver, 2004; Savery & Duffy, 1995). Instructors should prepare students to be competent in these information literacy activities.

Another suggestion for future implementations of task-centered learning is to assure that the course activities and sequence are understandable to students. Students might not be accustomed to a course that features learning tasks. In the current study, a course learning plan format was implemented to help students know what to do each day and each week. In addition, students received guidance and feedback on their learning task progress by submitting a rough draft of the learning task. This guidance and feedback helped students to understand if they were approaching the learning task appropriately and making adequate progress.

Several challenges may arise when a researcher or instructor attempts to implement a task-centered learning approach within an established college course. First, many colleges and universities have curriculum requirements in which certain topics are required to be covered in each course. A task-centered approach often requires an increased depth of learning, which usually means more learning time spent within a specific topic area. This may mean sacrificing some breadth of topic coverage in the course.

Even though in the current study students submitted learning tasks in groups, it took significantly more time for the instructor to grade the learning tasks than it did to grade student exams and assignments in the control section. In the current study, the instructor took the time to provide preliminary feedback on each of the learning tasks before the tasks were finished and then graded the learning tasks when they were done. This was a significant challenge for the instructor because it meant blocking out significant portions of time for grading. The time that it

took to grade learning tasks was a primary reason that the instructor decided to feature only a limited number of learning tasks in the *Concepts in Biology* treatment section.

Suggestions for Future Research

Suggestions for future research in task-centered learning and learner self-direction begin with a recommendation to further explore task-centered learning approaches and their effect on differing student outcomes. In the current study it was not possible to implement a true experimental research design in which participants were randomly assigned to the conditions. However future research could make stronger inferences of causality with full random assignment of participants (Cook & Campbell, 1979; Kirk, 1995).

Also, it is suggested that more than one measurement of learner self-direction be used in future studies. Previous studies report changes in learner self-direction based on a variety of measurements which may include interviews, observations, and self-assessment quality scores (Kicken et al., 2009; Sungur & Tekkaya, 2006). Future studies should also more sensitively measure higher-order learning outcomes using performance, application and transfer-based assessments in order to target the type of learning that occurs in a task-centered learning approach.

In the area of self-regulated learning (SRL), recent methodologies for measurement of have emphasized its contextual nature (Greene & Azevedo, 2010; Winne, 2010). Thus researchers have advocated using both unobtrusive and obtrusive measurements repeatedly taken during a learning event in which learners self-regulate, particularly within computer based learning environments (Greene & Azevedo, 2010; Schraw, 2010). These same principles of measurement could be used within a classroom setting in the form of more frequent online and

face-to-face measurements of aspects of self-direction and self-regulation in learning. For instance, within a setting similar to the *Concepts in Biology* course, measurements of students' self-regulation and self-direction could be taken several times as students are working on a learning task or several times during the semester. Changes in these measures from one to another may provide important information about the aspects of the learning tasks or phases in the semester that affect students' SRL and SDL processes. Such measurements may also provide information about students' metacognition and motivation levels over time.

Also, future studies should examine the role of group dynamics in self-direction and self-regulation. In the current study, some student reports suggested that self-direction activities were handled on the group level. These group activities could have affected the degree to which individual students practiced learner self-direction. Findings from prior studies indicate that individual student goals may affect regulation processes within the group (Volet & Mansfield, 2006). However, additional research could focus on the relationship between group level regulation and individual self-regulation. Student's self-regulation and self-direction activities within groups have been measured using observations, interviews and questionnaires (Volet & Mansfield, 2006; Volet, Summers, & Thurman, 2009).

In addition, the nature and number of the learning tasks implemented in future studies need to be considered in comparison to those used in the current study. As previously mentioned, the current study implemented three learning tasks for each group of students and these tasks comprised a little more than a third of the semester. Future research should implement a higher number of learning tasks in a larger portion of the semester. Doing so may lead to more significant findings of learner self-direction because students would have more opportunities to gain greater expertise and take charge of their own learning. Also, a study which implements

task-centered activities over a longer period of time may allow responsibility for learning to be fully shifted to the learner. This may in turn allow learners to practice learner self-direction to a greater degree. As in the current study, future implementations of task-centered learning activities should report on the number, length, complexity and other relevant aspects of the learning tasks to give the reader a full understanding of the implementation. Such reports could also lead to further research in which there is greater fidelity of implementation of task-centered learning environments (Century, Rudnick, & Freeman, 2010; O'Donnell, 2008).

Future research could also compare the implementation of differing types of learning tasks. In the current study, students responded with lower agreement to items in the task survey that ask about personal progress monitoring. Learning tasks could be designed to help students self-monitor progress and the effects of these learning tasks could be compared with tasks that do not support monitoring processes. Students also reported low levels of intrinsic motivation for completing learning tasks. Future research could examine the relationship between this type of motivation and task-centered learning activities by supporting student autonomy, competence, relatedness as well as other constructs associated with intrinsic motivation (Deci & Ryan, 1985; Lepper & Cordova, 1992; Malone & Lepper, 1987; Ryan & Deci, 2000).

Kicken et al. (2009) found improvements in learner self-direction when students were able to formulate their own learning goals and self-assess personal performance. In the current study, most of the learning goals were formulated by the instructor rather than the students. Also students were rarely given the opportunities to self-assess task performance, however, students did assess peer performance on the learning tasks. Future studies could feature learning tasks that allow students to self-assess performance and formulate personal learning goals. Also Kicken et al. (2009) used a detailed performance portfolio that pointed out key aspects of quality

performance to students and scaffolded students' SDL processes. The effects of this type of portfolio should be measured in future studies. In the current study, the instructor made extensive use of detailed rubrics and assignment directions to guide student progress, however, the instructor did not implement a detailed online portfolio to help students complete the learning tasks.

Additionally, greater attention to fulfilling the principles for fostering learner self-direction – as presented in the literature review section of this current study – needs to be addressed by future researchers. These principles include the following: (a) match the level of self-directed learning required in learning activities to learner readiness; (b) progress from teacher to learner direction of learning over time; (c) support the acquisition of subject matter knowledge and learner self-direction together; and (d) have learners practice self-directed learning in the context of learning tasks. The instructional design of the current study did not fully implement all of these principles, but instead focused more attention on a task-centered learning approach. However, future studies could implement a design focused on these principles, which would include SDL activities in the initiation, acquisition, performance and assessment phases of the learning tasks. Each phase of the task completion process could be specifically designed to allow learners to practice more learner self-direction skills within the task-centered learning framework. Then a researcher could measure effects on learner self-direction and conceptual understanding. As was completed in the current study, formative evaluations of each learning task would be crucial to this approach.

Future research could also focus on student perceptions of relevance and usefulness of a task-centered design. In the current study, students responded that they felt that learning tasks were highly relevant and useful to them. However, no systematic comparison was made between

control and treatment sections on these perceptions. As higher-education institutions compete for students, student perceptions of the relevance of learning within each institution may become an important aspect of an institution's continued success.

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APPENDIX A

LEARNING TASKS

Group Project 1: Testing Claims

Assignment: Your group will need to find and evaluate a claim that is used to convince the public either to use or avoid one of the following: a dietary supplement, current fad food, bioengineered food, sugar substitute, etc. that relates to biomolecules in your body (lipids, carbohydrates, proteins).

Step 1 (Due January 19th):

- **Groups come up with a claim:** Which type of energy drink, sugar substitute, antioxidant supplement, diet pill, etc. would you consider ingesting? Do a quick google search to come up with what people might be saying about this substance. Are there some specific technical terms that will help you find the research behind this diet? (For example searching for information about the flat belly diet reveals in the fine print that it is based on consumption of monounsaturated fatty acids). Determine exactly what the promoters or health watch groups claim about this substance or diet. **This is your claim.**

Step 2 (Due January 21th)

- **Evidence:** Each member of your group will need to find some evidence (research and data in the form of references) that helps you decide whether or not the study was scientific or pseudoscientific and how that would affect your decision about ingesting that material. Each member of your group will need to post (in the last questions for your pre-class assessment for that date) as well as physically hand in a list of at least 5 references that relate to your claim before the start of class on (January 14th). Be sure to include the search engine you used to find the references and the search terms you used. Some good places and ideas for guiding your search:
 1. **Magazines Focusing on Science for the General Public:** The following magazines have excellent review articles for the general public that describe interesting scientific studies and explain the original articles they refer to: Scientific American (www.sciam.com), Discover (<http://discovermagazine.com/>) American Scientist (<http://www.americanscientist.org/>).
 2. **Refining your Search Terms:** Don't just do a blind search, ask yourself: What am I specifically looking for?" Clarify this question and your search criteria by referring to this mnemonic device: PICO. P=*Person or problem*. I=*Intervention*. C=*Comparison*. O=*Outcome*.

Person or problem: Describe the person or problem.

Intervention: What is the supplement or diet therapy you are researching?

Comparison: Are there any alternative products to compare with your supplement?

Outcome: How will the person benefit from this treatment? Is this benefit measureable, say in weight lost or gained, blood pressure readings, or blood test results?

For example, your question could be, “In non-obese adults [P], does the Flat Belly Diet [I], compared to a placebo [C], decrease weight [O]”. After developing your question using the PICO system, you need to build a list of search terms, or keywords, in order to perform a search and narrow down your results.

First, identify key terms specific to your question. In this case the key terms are obese adults, Flat Belly Diet or monounsaturated fatty acid diet, placebo, and weight loss. Next, you want to list any alternate spellings, synonyms, and truncations—for example, “obes*” is a truncation of “obese.” Using an asterisk (*) to truncate a word means that further letters can be added to that word in a search and other similar terms will come up in the results, such as “obesity.” Finally, use these keywords and phrases in various combinations and orders to conduct your search and filter down the results to a manageable number—for example, do a search of “monounsaturated” and note the number of results, then conduct a search of “monounsaturated AND obes*” and note the difference and specificity of the results.

In class we will have a science librarian come to help you understand how to choose a Science-Based Database to search for primary and secondary sources (UGA Libraries has access to many of these original articles, Monica Pereira). Here are a few possible places to search:

- **ADA Evidence Analysis Library**

www.adaevidencelibrary.com

The American Dietetic Association's (ADA's) Evidence Analysis Library (EAL) is the initial resource for RDs and DTRs to consult because it is a synthesis of the most relevant nutritional research housed within an accessible, online, user-friendly library. Check the EAL first for evidence-based answers to dietetic practice questions. In addition, the EAL is developed by ADA members for ADA members and is a free member benefit of the Association. **Tip:** *Earn continuing professional education credit while learning to use the EAL. RDs and DTRs can receive one credit for completing the EAL Tutorial, located in the Professional Development section of ADA's Web site (<http://www.eatright.org/ealtutorial/>). The tutorial contains four modules, each 12-15 minutes in length, with questions to answer at the end of each module.*

- **PubMed**

www.PubMed.gov

PubMed is the next on the list because it comprises more than 19 million citations for biomedical articles from MEDLINE and life science journals. Citations may include links to full-text articles from PubMed Central or publisher Web sites. To find applicable research articles, it is important to use the correct Medical Subject Headings (MeSH). Use the MeSH database located on the front page to help build a list of keywords and conduct a proper search. The MeSH database is a veritable thesaurus of health science terms. **Tip:** *Look for a tutorial on ADA's Web site on using PubMed and ordering articles through Loansome Doc, a PubMed service.*

- **GoPubMed**

www.gopubmed.org/web/gopubmed

Hoping to skirt some of the work of building a PubMed search? Try GoPubMed, a semantic search engine. These types of engines purport to answer questions. For example, a search of “What are the effects of methyl mercury on breastfeeding?” brings up five documents that contain the words methyl, mercury, and breastfeeding. GoPubMed queries Medline and returns results in two panes. The left pane has the citations broken down by what-where-who-when categories. These categories are links to subcategories such as treatment or etiology. The right pane shows the results currently selected. **Tip:** *To find highly published authors in a subject, enter in subject and click the “Top Author” tab. The statistics tab displays top authors, journals, cities, and countries for papers related to entered terms.*

- **Google Scholar**

http://scholar.google.com/

Looking for research outside the health sciences domain? Google Scholar claims to provide “a simple way to broadly search for scholarly literature.” Note: While many results are peer-reviewed, not all are; some of the results come from sources outside of academia or any recognized and/or regulated research institution. **Tip:** *To find out who cited your article, or an article you are interested in, do a search of the title. When you've found the article in the results, click on “Cited by” beneath the citation.*

Step 3 (Rough Draft Due January 24th): Your group will need to complete an article describing your claim, the evidence you found to support your claim, and warrant that connects the two, and a conclusion. You have seen examples of other students' work in class when we did the rubric practice and Making Arguments PowerPoint.

- **Divide up the labor:** Does one member of your team have good artistic skills? Does one member have better writing skills, organizing skills, or researching/math/graphing skills?

These are four different roles that you could choose to assign each or your teammates to do. Once you have divided up the jobs, you've got your Acknowledgements section started, so you can move on to the next step. Be sure to get reflections from each member at the end of the project and compile them together into a single statement. Use the rubric as a guide to insure you have all the components covered (**see step 4 below for complete rubric**).

- **Make a plan:** By class time, Monday (January 24th), what will you have accomplished? What will you have accomplished by the end of class on Monday (rough draft of project posted by midnight on that date)? How will you get your materials to each other so that they are reviewed by all and finally posted by the deadline indicated?
- **Include your Graphic with a figure legend:** Be sure to include and reference images, graphs, or data you find online. If you need help, be sure to post to the discussion forums, there may be someone who can help answer your question. If there is any missing data, titles, axis titles, etc., on the figures and graphs that you find, then feel free to add them in using Microsoft Word or another word processor. Be sure to mention what you changed from the originally posted graphic and why you did so in your discussion of the graphic. Remember, you must include a figure legend that provides your warrant (i.e. your reasoning through a valid scientific argument to explain whether the evidence supports the claim.) You also need to make a recommendation or conclusion based on your reasoning.
- **Compile and Post:** All members of the group **MUST** review the rough draft before it is posted using the rubric as a guide. UGA's "Academic Honesty" Policy clearly describes prohibited conduct (such as plagiarism.) Another example, unauthorized assistance, specifically pertains to this group project. "Submitting a group assignment, or allowing that assignment to be submitted, representing that the project is the work of all of the members of the group when less than all of the group members assisted substantially in its preparation."

Step 4: Final Drafts (Due January 26)

- Comments on your rough drafts will be posted by class time on **Tuesday, January 25th**. You have class time to revise on Wednesday January 26.
- **Post Final Draft for Group Project 1: Testing Claims: (Midnight, Wednesday, January 26th)** posted to the Discussion Board Category called "Final Drafts of Group Projects for Peer Review" under the Topic "Final Drafts for Group Project 1: Science Pseudoscience." Be sure that they are posted in an easy-to-read format (Microsoft Word (.doc, or .docx), PowerPoint (.ppt or .pptx), or Adobe (.pdf).

Step 5: Peer Review (Due January 28)

- Your group's grade on the project will be determined by peer-review from the other students in the class. (Click on "**Review This Post**" link on the discussion posting for each project.) Every student in the class needs to review at least 3 other groups' postings and give them a score and comments to receive credit for peer review. Be constructive in your comments and bear in mind the components of the rubric.

Rubric for Review of Projects: (50 points)

- **Project Title:** Expressed a clearly stated claim that is evaluated in the project. Title is written as a statement, not a question, which clearly expresses a claim. **(2 points)**
- **Understanding and Relevance:** Scientific concepts and terminology are concisely defined; enough detail and background are provided. Content should be targeted to your peers as an audience. It should be meaningful, relevant, and presented in the context of larger community issues and societal ethics (e.g., harmful or beneficial to humans). **(10 points)**
- **Evidence: Figures/graphs and references:** Evidence to support the claim is described/provided. Figures and graphs are used to educate and persuade. Figure displays biological process. Graph choice is appropriate for data type; components are accurate and complete (e.g., axes; title; scale). Quality and validity of scientific information sources are evaluated (CRAP test). Be sure to annotate the importance of each reference as it supports your argument as well as describing its passing/failing of the CRAP test. You must reference your sources such as literature citations (<http://library.osu.edu/help/research-strategies/how-do-i-cite-references/cse-citation-guide/>), pictures, and help from peers. **(20 points)**
- **Synthesis:** Figure legend provides reasoning through a valid scientific argument to explain whether the evidence supports the claim. Make a recommendation or conclusion based on your reasoning. **(10 points).**
- **Team Reflection:** Answers the following questions:
 - (1) What issues did you encounter through the process of creating this project, e.g., while making graphs and finding resources?
 - (2) How did you weigh opposing evidence when developing your recommendation?
 - (3) How do you anticipate using the skills you mastered doing this project in your life? **(6 points).**
- **Acknowledgements:** Describes team members' contributions in terms of project components and activities required to complete the project. **(2 points)**

Group Project 2: Worst Food in America

“There may be no place on the planet more daunting than the American supermarket. From the produce section to the frozen-food aisle, the modern-day market is loaded with 50,000 food choices, all vying for your hard-earned money. That's why we created the Eat This, Not That! Supermarket Survival Guide, ... to help you cut through marketing mysteries and food-label lies in order to make the smart choices. Some are conspicuous calorie bombs, others are junk food masquerading as healthy food.”

Assignment: Your group will be creating a graphic to convince someone of the unhealthy nature of a food item. The “Worst Supermarket Food” graphic from Women’s Health Magazine that I showed in class is one example, but you are not limited to that format. Remember, your group will need to find what you think is an unhealthy food item and also find supporting evidence for your argument including claim, evidence, and warrant.

Step 1

- **Groups come up with a claim:** The Women's Health Magazine graphic was good. Think about what was convincing about that graphic for you. It was clearly not perfect, though, so also think about how it could have been improved. Did it work to convince you not to eat the food? How could it have worked better? What (if any) source of evidence is used to support the claim that the food is unhealthy? Do a quick google search to come up with what people might be saying about unhealthy foods or just pick your favorite guilty pleasure food. Determine exactly what the promoters or health watch groups claim about this food. **This is your claim.**

Step 2 Rough Draft Due February 11th

- **Divide up the labor:** From your first project, you may have discovered that members of your team have different skills such as artistic, writing, organizing skills, or researching/math/graphing skills. These are four different roles that you could choose to assign each or your teammates to do. Once you have divided up the jobs, you've got your Acknowledgements section started, so you can move on to the next step. Be sure to get reflections from each member at the end of the project and compile them together into a single statement.
- **Make a plan:** February 11th we will have class time devoted to finalizing your project drafts. What will you have accomplished by the beginning of this week? How will you get your materials to each other so that they are reviewed by all and finally posted by the deadline indicated? Who is responsible for posting this rough draft?
- **Evidence:** As a start there are some great Internet sites where you can get information:
 - Scientific American (www.sciam.com), Discover (<http://discovermagazine.com/>) American Scientist (<http://www.americanscientist.org/>) all have excellent review articles for the general public that describe interesting scientific studies and explain the original articles they refer to. For example, one article brought up by searching "food" at Discover Magazine referred to a study where kids were found to indicate preference for food wrapped in a McDonald's packaging
 - Scientific studies can also be directly searched via Google Scholar (www.scholar.google.com) or through PubMed (<http://www.ncbi.nlm.nih.gov/pubmed/>) though you will have to know what you are looking for. Remind yourself about the search terms and library skills that Monica Pereira shared with us last month.
 - Nutritional content of foods:
 - This website introduces you to the food label:
<http://www.healthcare.uiowa.edu/fns/nutritional/foodlabel.htm>
 - These sites that can produce a nutrition label for any food you enter:
 - <http://www.nutrientfacts.com/> (simple and easy to use, pretty basic foods.)
 - <http://www.nutritiondata.com/> (lots of fast food and junk food items!)
 - <http://www.fatcalories.com/> (just fast food restaurants.)
 - http://www.calorieking.com/foods/category.php?brand_id=770&category_id=21&subcat_id=-1&partner= (Calorie King for fast food items)
- **Create your graphic with a figure legend:** You will need to create your own graph for this project so refer to our graphing exercise from last month. If you need help, be sure to

post to the discussion forums, there may be someone who can help answer your question. Check to be sure your graphs and figures are complete with titles, axis titles, etc. If you use images from online, be sure to mention what you changed from the originally posted graphic and why you did so in your discussion of the graphic. Remember, you must include a figure legend that provides your warrant (i.e. your reasoning through a valid scientific argument to explain whether the evidence supports the claim.) You also need to make a recommendation or conclusion based on your reasoning.

- **Compile and Post:** All members of the group **MUST** review the rough draft before it is posted using the rubric as a guide. UGA's "Academic Honesty" Policy clearly describes prohibited conduct (such as plagiarism.) Another example, unauthorized assistance, specifically pertains to this group project. "Submitting a group assignment, or allowing that assignment to be submitted, representing that the project is the work of all of the members of the group when less than all of the group members assisted substantially in its preparation." Be sure that they are posted in an easy-to-read format (Microsoft Word (.doc, or .docx), PowerPoint (.ppt or .pptx), or Adobe (.pdf).

Step 4: Final Drafts (Due February 18th)

- Comments on your rough drafts will be posted by class time on **Monday, February 14th**.
- **Post Final Draft for Group Project 2: Worst Food in American: (Midnight, Wednesday, February 18th)** posted to the Discussion Board Category called "Final Drafts of Group Projects for Peer Review" under the Topic "Final Drafts for Group Project 2: Worst Food in America." Be sure that they are posted in an easy-to-read format (Microsoft Word (.doc, or .docx), PowerPoint (.ppt or .pptx), or Adobe (.pdf).

Step 5: Peer Review (Due February 21)

- Your group's grade on the project will be determined by peer-review from the other students in the class. (Click on "**Review This Post**" link on the discussion posting for each project.) Every student in the class needs to review at least 3 other groups' postings and give them a score and comments to receive credit for peer review. Be constructive in your comments and bear in mind the components of the rubric.

Rubric for Review of Projects: (50 points)

- **Project Title:** Expressed a clearly stated claim that is evaluated in the project. Title is written as a statement, not a question, which clearly expresses a claim. **(2 points)**
- **Understanding and Relevance:** Scientific concepts and terminology are concisely defined; enough detail and background are provided. Content should be targeted to your peers as an audience. It should be meaningful, relevant, and presented in the context of larger community issues and societal ethics (e.g., harmful or beneficial to humans). **(10 points)**
- **Evidence: Figures/graphs and references:** Evidence to support the claim is described/provided. Figures and graphs are used to educate and persuade. Figure displays biological process. Graph choice is appropriate for data type; components are accurate and complete (e.g., axes; title; scale). Quality and validity of scientific information sources are evaluated (CRAP test). Be sure to annotate the importance of each reference as it supports your argument as well as describing its passing/failing of the CRAP test. You must reference

your sources such as literature citations (<http://library.osu.edu/help/research-strategies/how-do-i-cite-references/cse-citation-guide/>), pictures, and help from peers. **(20 points)**

- **Synthesis:** Figure legend provides reasoning through a valid scientific argument to explain whether the evidence supports the claim. Make a recommendation or conclusion based on your reasoning. **(10 points).**
- **Team Reflection:** Answers the following questions:
 - (4) What issues did you encounter through the process of creating this project, e.g., while making graphs and finding resources?
 - (5) How did you weigh opposing evidence when developing your recommendation?
 - (6) How do you anticipate using the skills you mastered doing this project in your life? **(6 points).**
- **Acknowledgements:** Describes team members' contributions in terms of project components and activities required to complete the project. **(2 points)**

Group Project 3: Fish Futures Flyer

“Fishing practices worldwide are damaging our oceans—depleting fish populations, destroying habitats and polluting the water. Informed consumers can help turn the tide.”

Assignment: Your group will be creating a flyer to inform consumers of the need to purchase fish from sustainable sources. This could be a flyer you could post in the cafeteria, supermarket, or as an ad online (like the Wendy's fish fillet).

Step 1:

- **Where to Start: Find a Sustainable Fish Chart:** “Give a man a fish; you have fed him for today. *Teach a man to fish*; and you have fed him for a lifetime.” In this case how can you describe to your peers how easily they can identify an online source/web application for a sustainable fish chart for themselves, so they can feed on fish for a lifetime. Think about how you can let them know the quality of the site (CRAP test), and how easy it is to use the chart.
- **Make it Usable:** As of April 4, 2004, supermarkets are required to label unprocessed seafood as to where it is from and whether it is farm-raised or wild-caught. How can your peers use that information with their chart to identify the most common source for that species in terms of world fishing location to choose a sustainable option? What questions would they need to ask, as well as common terms to use, when they talk to their waiter at a restaurant or supermarket? If you are making a flyer to post at a business, think about how you could convince them that using your flyer would actually help attract “Green” consumers.

Step 2 Rough Draft Due February 18th

- **Divide up the labor:** From your first project, you may have discovered that members of your team have different skills such as artistic, writing, organizing skills, or

researching/math/graphing skills. These are four different roles that you could choose to assign each or your teammates to do. Once you have divided up the jobs, you've got your Acknowledgements section started, so you can move on to the next step. Be sure to get reflections from each member at the end of the project and compile them together into a single statement.

- **Make a plan:** February 18th we will have class time devoted to finalizing your project drafts. What will you have accomplished by the beginning of this week? How will you get your materials to each other so that they are reviewed by all and finally posted by the deadline indicated? Who is responsible for posting this rough draft?
- **Evidence:** Here are some suggestions to important points that you may wish to make:
How do scientists assess the health of a fish population? An excellent graph for your flyer might include how scientists estimate the size and growth rates for these fish populations; or the biggest reason for the difference between a recommended and not-recommended fish (fishing practices, life history strategies like age at reproduction or r or k-selected species, or environmental effects).
 - There are some great Internet sites where you can get information:
 - The Marine Stewardship Council certifies sustainable fisheries across the globe (<http://www.msc.org/track-a-fishery>). For the cod example, I clicked on “Track a Fishery” then, “Certified Fisheries” then “Pacific”, then “Gulf of Alaska Pacific cod” I looked at the assessment downloads and found the final report and determination for longline”. In that report, I found a section called, “Background to the Fishery” that contained information about the species (what they eat, proportion of mature females, etc..)
 - Other sites will tell you what’s in that sandwich
<http://www.slashfood.com/2010/02/23/whats-in-that-fish-sandwich/>
 - Seafood source has interesting market reports:
<http://seafoodsource.com/MarketReport.aspx?id=4911>
 - Monterey Bay Aquarium’s Restaurants and Retailers section has additional information for approaching retailers.
- **Create your graphic with a figure legend:** Your graphic could be a word or pdf document with graphics, or a video clip. It’s your choice but whatever you pick it must include a graph with data to convince the public of the population numbers to back up your argument as well as a descriptive figure legend. You are allowed to use a graph you find online as long as you make additions to ensure your graphs and figures are complete with titles, axis titles, etc. As you use images from online, be sure to mention what you changed from the originally posted graphic and why you did so in your discussion of the graphic. Remember, you must include a figure legend that provides your claim and interprets the evidence described (i.e. your reasoning through a valid scientific argument to explain whether the evidence supports the claim.) You also need to provide a warrant statement that describes if the data and methodology used are appropriate for your claim, and whether the source is reliable. You also need to make a recommendation or conclusion based on your reasoning.
- **Compile and Post:** You will need to create your flyer and post (1) as a rough draft as an attachment to this assignment by one member of your group by February 18th. (I will give comments on your rough drafts on the assignment you post and add it as an

attachment to your original post.) All members of the group **MUST** review the rough draft before it is posted using the rubric as a guide. UGA's "Academic Honesty" Policy clearly describes prohibited conduct (such as plagiarism.) Another example, unauthorized assistance, specifically pertains to this group project. "Submitting a group assignment, or allowing that assignment to be submitted, representing that the project is the work of all of the members of the group when less than all of the group members assisted substantially in its preparation." Be sure that they are posted in an easy-to-read format (Microsoft Word (.doc, or .docx), Adobe (.pdf), or an easy to access video format.

Step 3:

- Comments on your rough drafts will be posted by class time on **Monday, February 21st**.
- **Post Final Draft for Group Project 3: Fish Futures: (Midnight, Friday, February 25th)** posted to the Discussion Board Category called "Final Drafts of Group Projects for Peer Review" under the Topic "Final Drafts for Group Project 3: Fish Futures." Be sure that they are posted in an easy-to-read format (Microsoft Word (.doc, or .docx), Adobe (.pdf), or an easy to access video format.

Step 4: Peer Review (Due February 21)

- Your group's grade on the project will be determined by peer-review from the other students in the class. (Click on "**Review This Post**" link on the discussion posting for each project.) Every student in the class needs to review at least 3 other groups' postings and give them a score and comments to receive credit for peer review. Be constructive in your comments and bear in mind the components of the rubric.

Rubric for Review of Projects: (50 points)

- **Project Title:** Title captures reader's attention and is appropriate for a flyer. Catchy title engages and draws you in. **(2 points)**
- **Understanding and Relevance:** Scientific concepts and terminology are concisely defined; enough detail and background are provided. Content should be targeted to your peers as an audience. It should be meaningful, relevant, and presented in the context of larger community issues and societal ethics (e.g., harmful or beneficial to humans). **(10 points)**
- **Claim and Evidence: Figures/graphs and references:** Figure legend title is a clearly state claim that is evaluated in the graph. Figure legend title is written as a statement, not a question, which clearly expresses a claim. Evidence to support the claim is described/provided. Figures and graphs are used to educate and persuade. Graph choice is appropriate for data type; components are accurate and complete (e.g., axes; title; scale). Quality and validity of scientific information sources are evaluated (CRAP test). Be sure to annotate the importance of each reference as it supports your argument as well as describing its passing/failing of the CRAP test. You must reference your sources such as literature citations (<http://library.osu.edu/help/research-strategies/how-do-i-cite-references/cse-citation-guide/>), pictures, and help from peers. **(20 points)**

- **Synthesis:** Figure legend provides reasoning through a valid scientific argument to explain whether the evidence supports the claim. Make a recommendation or conclusion based on your reasoning. **(10 points).**
- **Team Reflection:** Answers the following questions:
 1. What issues did you encounter through the process of creating this project, e.g., while making graphs and finding resources?
 2. How did you weigh opposing evidence when developing your recommendation?
 3. How do you anticipate using the skills you mastered doing this project in your life? **(6 points).**
- **Acknowledgements:** Describes team members' contributions in terms of project components and activities required to complete the project. **(2 points)**

Group Project 4: Vaccination Debate

"Science is about observation, right?" Lisa Rudley, a mother who has filed a claim in "Vaccine Court" asserting that shots caused her son's autism, told New York's *The Journal News*. "Well, I watched my son descend into illness. I think a mother's observation of her child is valuable."¹

Assignment: Your group will be creating a media piece to convince the public either to use or avoid one vaccine that is currently available. Your media piece could be a flyer, video, or audio podcast (check out "Voicethread," or "Slideshare" free online software to create your piece). You can focus on any issue that thing will help inform and convince the public of your claim. If you claim that the vaccine is effective and your media piece advocates its use, then you must present and defend the data showing that this vaccine is effective compared to not having the vaccine. If your claim is the vaccine is not necessary you must present an argument outlining the reasons why people should refuse the vaccine including the same data for scientific justification behind this argument.

Step 1:

- **Where to start: Come up with your group's idea.** Which vaccine would you consider interesting? What are the ones that you are required to take in order to get into middle school, high school, college? Why are these vaccinations required and why is it so important that the majority of people get vaccinated? What do you know, or think you know about that topic? Find some research and data (pertaining to your vaccine of interest) that helps you decide the biological relevance of the vaccine, social implication of it, and how that would affect your decision about getting the vaccination. Be able to persuade the general public that your decision is the best one concerning this vaccine.

Step 2: Rough Draft Due March 11th

- **Divide up the labor:** As your last project, each of the members of your group should have the chance to work on a different aspect of the project than they have before and use this as an opportunity to learn some of the skills that your teammates have mastered such as graphic design, writing, organizing skills, or researching/math/graphing skills.. Once you have divided up the jobs, you've got your Acknowledgements section started, so you can move on to the next step. Be sure to get reflections from each member at the end of the project and compile them together into a single statement.
- **Make a plan:** March 11th we will have class time devoted to finalizing your project drafts. What will you have accomplished by the beginning of this week? How will you get your materials to each other so that they are reviewed by all and finally posted by the deadline indicated? Who is responsible for posting this rough draft?
- **Evidence:** You MUST include information on one of the following content issues to address the biggest reason for the distinction between recommending or not-recommending the vaccine: (1) Type of vaccine you are describing including how this could contribute to side effects; (2) Rates of infection compared to rates of complications/side effects and herd immunity; (3) Some indication of statistical evidence and the significance of that evidence in supporting your claim.
 - There are some great Internet sites where you can get information:
 - Center for Disease Control (CDC) (<www.cdc.gov>; <www.cdc.gov/vaccines/>; or <www.cdc.gov/vaccines/programs/global/default.htm>)
 - Federal Drug Administration (FDA) <www.fda.gov/BiologicsBloodVaccines/Vaccines/default.htm>
 - World Health Organization (WHO) <www.who.int/topics/vaccines/en/>
 - National Vaccine Information Center (NVIC) <www.nvic.org/>
 - The Vaccine Page (use links...think CRAP test) www.vaccines.org/
 - Of course, scientific studies can also be directly searched via Google Scholar (www.scholar.google.com), Web of Science (available via Galileo on UGA Libraries), or through PubMed (<http://www.ncbi.nlm.nih.gov/pubmed/>.)
- **Create your graphic with a figure legend:** Your media piece could be a word or pdf document with graphics, or a video or audio clip. It's your choice but whatever you pick it must include a graph with data to convince the public of the efficacy of the data that back up your argument as well as a descriptive figure legend. You are allowed to use a graph you find online as long as you make additions to ensure your graphs and figures are complete with titles, axis titles, etc. As you use images from online, be sure to mention what you changed from the originally posted graphic and why you did so in your discussion of the graphic. Remember, you must include a figure legend that provides your claim and interprets the evidence described (i.e. your reasoning through a valid scientific argument to explain whether the evidence supports the claim.) You also need to provide a warrant statement that describes if the data and methodology used are appropriate for your claim, and whether the source is reliable. You also need to make a recommendation or conclusion based on your reasoning.
- **Compile and Post:** You will need to create your media piece and post (1) as a rough draft as an attachment to this assignment by one member of your group by March 11th. (I will give comments on your rough drafts on the assignment you post and add it as an

attachment to your original post.) All members of the group MUST review the rough draft before it is posted using the rubric as a guide. UGA's "Academic Honesty" Policy clearly describes prohibited conduct (such as plagiarism.) Another example, unauthorized assistance, specifically pertains to this group project. "Submitting a group assignment, or allowing that assignment to be submitted, representing that the project is the work of all of the members of the group when less than all of the group members assisted substantially in its preparation." Be sure that they are posted in an easy-to-read format (Microsoft Word (.doc, or .docx), Adobe (.pdf), or an easy to access video format.

Step 3:

- Comments on your rough drafts will be posted by class time on **Monday, March 21st**.
- **Post Final Draft for Group Project 4: Vaccination Debate: (Midnight, Friday, March 25th)** posted to the Discussion Board Category called "Final Drafts of Group Projects for Peer Review" under the Topic "Final Drafts for Group Project 4: Vaccination Debate." Be sure that they are posted in an easy-to-read format (Microsoft Word (.doc, or .docx), Adobe (.pdf), or an easy to access video format.

Step 4: Peer Review (Due March 28th)

- Your group's grade on the project will be determined by peer-review from the other students in the class. (Click on "**Review This Post**" link on the discussion posting for each project.) Every student in the class needs to review at least 3 other groups' postings and give them a score and comments to receive credit for peer review. Be constructive in your comments and bear in mind the components of the rubric.

Rubric for Review of Projects: (50 points)

- **Project Title:** Expressed a clearly stated claim that is evaluated in the project. Title is written as a statement, not a question, which clearly expresses a claim. **(2 points)**
- **Understanding and Relevance:** Scientific concepts and terminology are concisely defined; enough detail and background are provided. Content should be targeted to your peers as an audience. It should be meaningful, relevant, and presented in the context of larger community issues and societal ethics (e.g., harmful or beneficial to humans). **(10 points)**
- **Evidence: Figures/graphs and references:** Evidence to support the claim is described/provided. Figures and graphs are used to educate and persuade. Figure displays biological process. Graph choice is appropriate for data type; components are accurate and complete (e.g., axes; title; scale). Quality and validity of scientific information sources are evaluated (CRAP test). Be sure to annotate the importance of each reference as it supports your argument as well as describing its passing/failing of the CRAP test. You must reference your sources such as literature citations (<http://library.osu.edu/help/research-strategies/how-do-i-cite-references/cse-citation-guide/>), pictures, and help from peers. **(20 points)**
- **Synthesis:** Figure legend provides reasoning through a valid scientific argument to explain whether the evidence supports the claim. Make a recommendation or conclusion based on your reasoning. **(10 points).**
- **Team Reflection:** Answers the following questions:

1. What issues did you encounter through the process of creating this project, e.g., while making graphs and finding resources?
 2. How did you weigh opposing evidence when developing your recommendation?
 3. How do you anticipate using the skills you mastered doing this project in your life? **(6 points).**
- **Acknowledgements:** Describes team members' contributions in terms of project components and activities required to complete the project. **(2 points)**

Group Project 5: Cancer: What are my Options?

In 2006 over 500,000 Americans died of cancer, and the estimated number of cancer cases in 2009 was over 1 million. In spite of these gloomy numbers, chemotherapy drugs are improving every day. But with so many drug choices available how do you know what may be best for you or a loved one undergoing chemotherapy?

Assignment: Your group will be creating a graphic to describe a chemotherapy drug and use the information you find advise someone about how this drug works and how effective it is at treating cancer. Your biggest challenge will be to explain the complexities of how your drug works without overwhelming the reader with jargon. But, you will also need to explain the most likely outcome of taking this drug compared to either no treatment or other treatments in a way that is sensitive. Imagine you are helping a loved one make an informed decision about using this treatment option.

Step 1:

- **Where to start: Investigating your Chemotherapy Drug.** Which drug do you find interesting? You will be allowed to choose from 16 different drugs.
 - Anti-tumor antibiotics: Rubex, Mytomycin C, Daunorubicin
 - Alkylating agents: Cytosan, Platinol
 - Plant Alkaloids/ topoisomerase inhibitors: Taxotere, Camptostar, Toposar, Taxol
 - Antimetabolites: Gemzar, Adrucil
 - EGFR inhibitors (protein tyrosine-kinase inhibitors): Tarceva, Iressa, SPRYCEL, TYKERB, Gleevec
- **Think about the following questions:** What types of cancer does this drug treat? How does the drug effect the cell cycle? What are some other names the drug goes by and what type of drug is it (classification)? Does this drug kill cells or stop cells from growing? Is this drug a general or specific cancer treatment drug? i.e. does it affect healthy cells or just cancer cells, and does it affect multiple types of cancer or just one, why? How severe are the side effects?

Step 2: Rough Draft Due April 1st

- **Divide up the labor:** As your last project, each of the members of your group should have the chance to work on a different aspect of the project than they have before and use this as an opportunity to learn some of the skills that your teammates have mastered such as graphic design, writing, organizing skills, or researching/math/graphing skills. Once you have divided up the jobs, you've got your Acknowledgements section started, so you can move on to the next step. Be sure to get reflections from each member at the end of the project and compile them together into a single statement.
- **Make a plan:** April 1st we will have class time devoted to finalizing your project drafts. What will you have accomplished by the beginning of this week? How will you get your materials to each other so that they are reviewed by all and finally posted by the deadline indicated? Who is responsible for posting this rough draft?
- **Evidence:**
 1. You **MUST** include a graphic communicating and advising someone about how your drug works and how effective it is at treating cancer. A diagram indicating what part of the cell cycle or process of replicating or repairing DNA your drug effects would be most informative. You can do this by modifying any of the images of the cell cycle or structure of DNA from your textbook or class lectures to show how/ where your drug acts. Remember to cite where you obtained your image. Please label the diagram, making it clear at what point your drug acts and what exactly it does.
 2. Your next biggest challenge will be to explain the complexities of how your drug works without overwhelming the reader with jargon. But, you will also need to explain the most likely outcome of taking this drug compared to either no treatment or other treatments in a way that is sensitive. Pretend you know someone with they type of cancer your drug is supposed to treat. Include a short (1-3 sentence) recommendation of this drug to a friend. Would you recommend it, why/ why not? When thinking about your recommendation, consider the possible side effects, cost, and treatment aims of your drug. It would be particularly helpful to include some statistics about the possibly outcomes of treatments (a graph showing the expected outcomes and comparing treatments would be most persuasive as well a easy to understand.
- Rough drafts must be posted attached to this Assignments "Group Project 5: Cancer: What are my options?" by the deadline specified in the Learning Module "Outline of the Course" and the final draft must be posted to the Discussion Board Category called "Final Drafts of Group Problems for Peer Review" under the Topic "Final Drafts for Group Project 5: Cancer: What are my options?" by the deadline indicated in the Learning Module "Outline of the Course". Remember, you will be asked to analyze your example to include the following components:

Rubric for Review of Projects: (50 points)

- **Project Title:** Captures reader's attention and is appropriate. **(2 points)**
- **Understanding and Relevance:** Scientific concepts and terminology are concisely defined; enough detail and background are provided. Content should be targeted to your peers as an audience. It should be meaningful, relevant, and presented in the context of larger community issues and societal ethics (e.g., harmful or beneficial to humans). **(10 points)**

- **Evidence: Figures/graphs and references:** Evidence to support the claim is described/provided. Figures and graphs are used to educate and persuade. Figure displays biological process. Figure legend title is written as a statement, not a question, which clearly expresses a claim. Evidence to support the claim is described and provided. Figure displays biological process. Graph choice is appropriate for data type; components are accurate and complete (e.g., axes; title; scale). Quality and validity of scientific information sources are evaluated (CRAP test). Be sure to annotate the importance of each reference as it supports your argument as well as describing its passing/failing of the CRAP test. You must reference your sources such as literature citations (<http://library.osu.edu/help/research-strategies/how-do-i-cite-references/cse-citation-guide/>), pictures, and help from peers. **(20 points)**
- **Synthesis:** Figure legend provides reasoning through a valid scientific argument to explain whether the evidence supports the claim. Make a recommendation or conclusion based on your reasoning. **(10 points).**
- **Team Reflection:** Answers the following questions:
 - (7) What issues did you encounter through the process of creating this project, e.g., while making graphs and finding resources?
 - (8) How did you weigh opposing evidence when developing your recommendation?
 - (9) How do you anticipate using the skills you mastered doing this project in your life? **(6 points).**
- **Acknowledgements:** Describes team members' contributions in terms of project components and activities required to complete the project. **(2 points)**

Group Project 6: Human Reproduction Myth Buster

“Studies of Internet users have shown that many people turn to the Internet for health information, particularly for sensitive or stigmatized topics such as sexual diseases, contraception, pregnancy, and abortion. Yet the reliability of health information online varies, making the Internet a source of common myths, misconceptions, and urban legends about sexual health.”

Assignment: Your group will be working in some way to inform your peers about some aspect of human reproduction in which there are rampant misconceptions. What are these examples of misconceptions and ignorance? Well, authors of one study analyzed over 1,134 e-mails sent over a 1-year period in 2003 and 2004 to The Emergency Contraception Website (<http://ec.princeton.edu>) and discovered that almost a third of all e-mails contained misconceptions or blatant ignorance about what sexual acts can lead to pregnancy, when pregnancy can occur, how someone can tell when and if they are pregnant, or how various contraceptive agents even work.

Your project could be a survey that you could post online, a video that explains a common misconception (for example timing of fertility, how a specific contraceptive works, or a future contraceptive,) or a flyer that you could post. You will need to create your group project and post (1) as a rough draft as an attachment to this Assignment by one member of your group by the

deadline posted. (I will give comments on your rough drafts on the assignment you post and add it as an attachment to your original post.) Then you will (2) revise and post your graphic to the Discussion Board Category called “Final Drafts of Group Problems for Peer Review” under the Topic “Final Drafts for Group Project 6: Human Reproduction Myth Buster” by the deadline indicated on the discussion board.

Step 1:

- **Where to start: Which ignorance or misconception do you want to focus on?** In the study that was referred to above, the authors discovered that many e-mails hinted that the women using methods of contraceptive were not even sure *why* they were using them. Notably, many were not sure whether they were protected against pregnancy during the placebo week of the pill or patch. In other emails, women assumed that pregnancy could occur and be detected by home tests shortly after intercourse. Still others asked if they could have their period and still be pregnant, while many even thought that emergency contraceptives might be able to impair future fertility or even be life-threatening to women. There are many more, some have been turned into quizzes online, here are a few:

Fertility quizzes:

- <http://www.parents.com/parents/quiz.jsp?quizId=/templatedata/ab/quiz/data/48.xml>
- http://www.babyzone.com/preconception/getting_pregnant/quiz/myth-fact-fertility-iq

STD quizzes:

- http://www.coolnurse.com/std_active_quiz.htm
- <http://www.stdwizard.org/>

Step 2 Rough Draft Due April 15th

- **Divide up the labor:** As your last project, each of the members of your group should have the chance to work on a different aspect of the project then they have before and use this as an opportunity to learn some of the skills that your teammates have mastered such as graphic design, writing, organizing skills, or researching/math/graphing skills. Once you have divided up the jobs, you’ve got your Acknowledgements section started, so you can move on to the next step. Be sure to get reflections from each member at the end of the project and compile them together into a single statement.
- **Make a plan:** April 15th we will have class time devoted to finalizing your project drafts. What will you have accomplished by the beginning of this week? How will you get your materials to each other so that they are reviewed by all and finally posted by the deadline indicated? Who is responsible for posting this rough draft?
- **Evidence:** How can the average person use the information in your graphic to learn more about human reproduction? What questions or common terms would they need to know to understand all they facts?
 1. You **MUST** include information on content issues to address the biggest reason for the re-current misconceptions: A diagram indicating what part of the female reproductive cycle or process of fertilization and how contraceptives work would be most

informative. You can do this by modifying images you find online, but remember to cite where you obtained your image. Please label the diagram, making it clear at what point your drug acts and what exactly it does.

2. Some indication of statistical evidence and the significance of that evidence in supporting your claim.
- **Rough Drafts** must be posted attached to this Assignment “Group Project 6: Human Reproduction Myth Buster” by the deadline specified in the Learning Module “Outline of the Course” and the final draft must be posted to the Discussion Board Category called “Final Drafts of Group Problems for Peer Review” under the Topic “Group Project 6: Human Reproduction Myth Buster” by the deadline indicated in the Learning Module “Outline of the Course”. Make sure each member of your group approves the posted draft. UGA’s “Academic Honesty” Policy clearly describes prohibited conduct (such as plagiarism.) Another example, unauthorized assistance, specifically pertains to this group project. “Submitting a group assignment, or allowing that assignment to be submitted, representing that the project is the work of all of the members of the group when less than all of the group members assisted substantially in its preparation.”
 - Remember, you will be asked to analyze your example to include the following components:

Rubric for Review of Projects: (50 points)

- **Project Title:** Captures reader’s attention and is appropriate. **(2 points)**
- **Understanding and Relevance:** Scientific concepts and terminology are concisely defined; enough detail and background are provided. Content should be targeted to your peers as an audience. It should be meaningful, relevant, and presented in the context of larger community issues and societal ethics (e.g., harmful or beneficial to humans). **(10 points)**
- **Evidence: Figures/graphs and references:** Evidence to support the claim is described/provided. Figures and graphs are used to educate and persuade. Figure displays biological process. Figure legend title is written as a statement, not a question, which clearly expresses a claim. Evidence to support the claim is described and provided. Figure displays biological process. Graph choice is appropriate for data type; components are accurate and complete (e.g., axes; title; scale). Quality and validity of scientific information sources are evaluated (CRAP test). Be sure to annotate the importance of each reference as it supports your argument as well as describing its passing/failing of the CRAP test. You must reference your sources such as literature citations (<http://library.osu.edu/help/research-strategies/how-do-i-cite-references/cse-citation-guide/>), pictures, and help from peers. **(20 points)**
- **Synthesis:** Figure legend provides reasoning through a valid scientific argument to explain whether the evidence supports the claim. Make a recommendation or conclusion based on your reasoning. **(10 points).**
- **Team Reflection:** Answers the following questions:
 1. What issues did you encounter through the process of creating this project, e.g., while making graphs and finding resources?
 2. How did you weigh opposing evidence when developing your recommendation?

3. How do you anticipate using the skills you mastered doing this project in your life? **(6 points)**.
- ***Acknowledgements:*** Describes team members' contributions in terms of project components and activities required to complete the project. **(2 points)**

APPENDIX B

WORKING MEMORY TEST

Welcome to the working memory capacity test. Plan for about 15 minutes to focus on this test. First let's get some basic information about you.

Your Name (first and last)

Your @uga.edu email address

Your Gender

Your Age (in years)

What time is your Biology 1103 class? (NOT your lab)

Your Class Level

Your Current GPA

Okay, let's get started. Essentially, your job in this test is to memorize the words you see on the screen while you also solve math problems. Be sure to answer the math problems correctly, but DO NOT write down the words you see. Here is an example of what the math problems are going to look like. You will only have 6 seconds to answer yes or no and then you will be advanced to the next page. Or you can click ">>" to continue.

Is $(2 \times 1) + 1 = 2$ n Dog

Read the equation, then verify if the answer is correct or not by clicking YES or NO. You will only have 6 seconds to answer or you can click ">>" to continue. When you move on, you will be presented with a word. Say the word out loud and then wait to be continued to the next question. When you see a question like this one, your job is to type in all of the words that you saw in that set. Type the words in the same order that you saw them in, one word in each space. If you can't remember all of the words, leave the space for the word(s) you can't remember blank.

Type in all of the words that you saw in the set (leave an empty space for words that you can't remember)

Let's begin with some practice. Answer this practice question, then click ">>" Say the word on the next page and wait to be continued. Continue on until you type in all of the words.

IS $(7 \times 1) - 3 = 3$ n cheek

IS $(8 / 2) + 4 = 2$ n chalk

Type in all of the words that you saw in the set (leave an empty space for words that you can't remember). Nice work, here are some more practice questions before we get into the actual test.

IS $(6 \times 3) + 2 = 17$ n plant

IS $(3 / 1) - 2 = 3$ n foot

Type in all of the words that you saw in the set (leave an empty space for words that you can't remember). Do you think you are now ready to begin the real test or do you need some more practice?

Here is some more practice for you:

IS $(8 / 2) - 1 = 3$ y bike

IS $(10 / 10) - 1 = 2$ n ball

Type in all of the words that you saw in the set (leave an empty space for words that you can't remember).

Now it is time to start the test. The real test is going to work just like in practice, but there are going to be a different number of math problems and words in each set (up to six). Just like in practice, if you can't remember a word, please leave a space blank for it. Remember, be sure to solve the math problems correctly and DO NOT write down the words. (click ">>" to begin the test)

IS $(10 \times 1) - 7 = 3$ y clouds

IS $(10 / 1) + 1 = 10$ n baby

IS $(9 \times 3) + 2 = 27$ n sand

Type in all of the words that you saw in the set (leave an empty space for words that you can't remember).

IS $(10 \times 2) - 1 = 19$ y chance

IS $(4 / 1) - 3 = 1$ y end

IS $(5 \times 2) + 2 = 12$ y course

IS $(8 \times 1) + 2 = 10$ y floor

IS $(7 \times 1) + 6 = 13$ y soil

Type in all of the words that you saw in the set (leave an empty space for words that you can't remember).

IS $(7 / 7) + 5 = 6$ y hair

IS $(10 / 2) + 4 = 3$ n state

IS $(9 / 3) - 2 = 1$ y bush

Type in all of the words that you saw in the set (leave an empty space for words that you can't remember).

IS $(4 / 1) + 1 = 4$ n mind

IS $(7 \times 2) - 1 = 14$ n fact

Type in all of the words that you saw in the set (leave an empty space for words that you can't remember).

IS $(2 \times 3) + 1 = 4$ n cot

IS $(4 / 2) + 1 = 6$ n mold

IS $(6 / 2) - 1 = 1$ n class

IS $(9 / 1) + 8 = 18$ n hill

IS $(6 / 2) - 2 = 2$ n jar

Type in all of the words that you saw in the set (leave an empty space for words that you can't remember).

IS $(7 / 1) + 2 = 7$ n map

IS $(6 / 6) + 2 = 4$ n pipe

IS $(10 \times 1) - 5 = 10$ n side

IS $(5 \times 1) - 1 = 4$ y heart

IS $(2 \times 1) - 1 = 1$ y ears

IS $(9 / 3) + 3 = 6$ y world

Type in all of the words that you saw in the set (leave an empty space for words that you can't remember).

IS $(10 / 1) + 3 = 13$ y face

IS $(10 \times 2) + 2 = 21$ n jail

IS $(9 \times 3) - 2 = 25$ y point

IS $(2 / 1) - 1 = 1$ y lamp

Type in all of the words that you saw in the set (leave an empty space for words that you can't remember).

IS $(9 \times 1) - 5 = 5$ n drill

IS $(10 / 2) + 4 = 9$ y flute

IS $(3 \times 2) + 1 = 6$ n rain

IS $(5 / 5) + 4 = 5$ y town

IS $(2 \times 4) + 1 = 8$ n sea

IS $(8 / 8) + 1 = 2$ y hat

Type in all of the words that you saw in the set (leave an empty space for words that you can't remember).

IS $(10 / 5) - 1 = 1$ y beach

IS $(10 / 1) - 5 = 4$ n rat

Type in all of the words that you saw in the set (leave an empty space for words that you can't remember).

IS $(4 \times 4) + 1 = 17$ y lot
IS $(9 / 1) + 4 = 14$ n cone
IS $(6 / 2) - 2 = 2$ n kid
IS $(9 \times 1) + 9 = 1$ n tin

Type in all of the words that you saw in the set (leave an empty space for words that you can't remember).

APPENDIX C

QUANTITATIVE AND PROCESS SKILLS INSTRUMENT – FORM A

Quantitative and Process Skills Instrument

Directions: There are 19 questions. You will have about 25 minutes to work on the questions. Be sure to answer as many of the questions as you can in the time allotted. You will receive 0.5 points for completing the entire assignment today. Your grade will depend on completeness and thoroughness, not on correct answers. Your honest answers will help us better prepare the materials for the remainder of the semester.

Mark your answers on the scantron sheet, indicate your form in the lettered space provided.

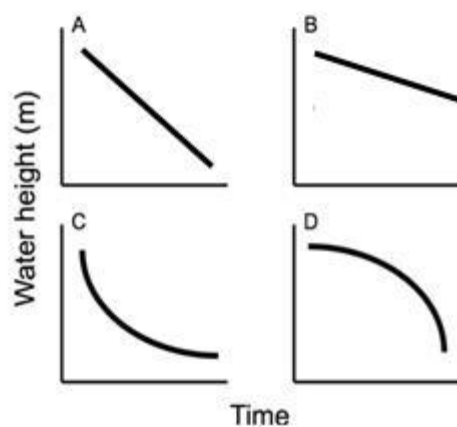
Bubble in your #810 on your scantron.

Do NOT use a calculator. Thank you for your participation in this project!

1. Which of the following is a valid scientific argument?
 - a. Run-off of fertilizers used exclusively for agriculture can pollute lakes. Alligators in a lake in Florida affected by fertilizer run-off develop abnormally and are unable to reproduce. When the lake was cleared of fertilizer run-off, alligators developed normally and were able to reproduce. Therefore, the fertilizer affected alligator development.
 - b. A large percentage of the US population believes that species were created and do not change. This widespread belief is appropriate evidence to support the claim that species do not evolve over time.
 - c. Measurements of sea level on the Gulf Coast taken this year are lower than normal, and the average monthly measurements were almost 0.1 cm lower than normal in some areas. These facts prove that sea level rise is not a problem.
 - d. Aristotle was one of the greatest thinkers of all time. He believed that all organisms were composed of some combination of four elements: earth, wind, air, and fire. Aristotle was able to convince many other very famous scientists that this was the case. Thus he was right.

2. A scientist is studying the growth of a bacterial population over time. She counts the number of bacterial colonies growing in a petri dish over time. Given the data below, what graph best fits the pattern of bacterial growth over time in the petri dish?

Time (Hrs)	Number of colonies
2	330
4	329
8	310
11	222
14	160
16	20



Use this data table showing a study of several coastal locations to answer questions 3-

4. The data links fishing by humans to a marine food chain off the east coast of the U.S. In this marine food chain, sharks feed on sea stars, controlling the size of the population.

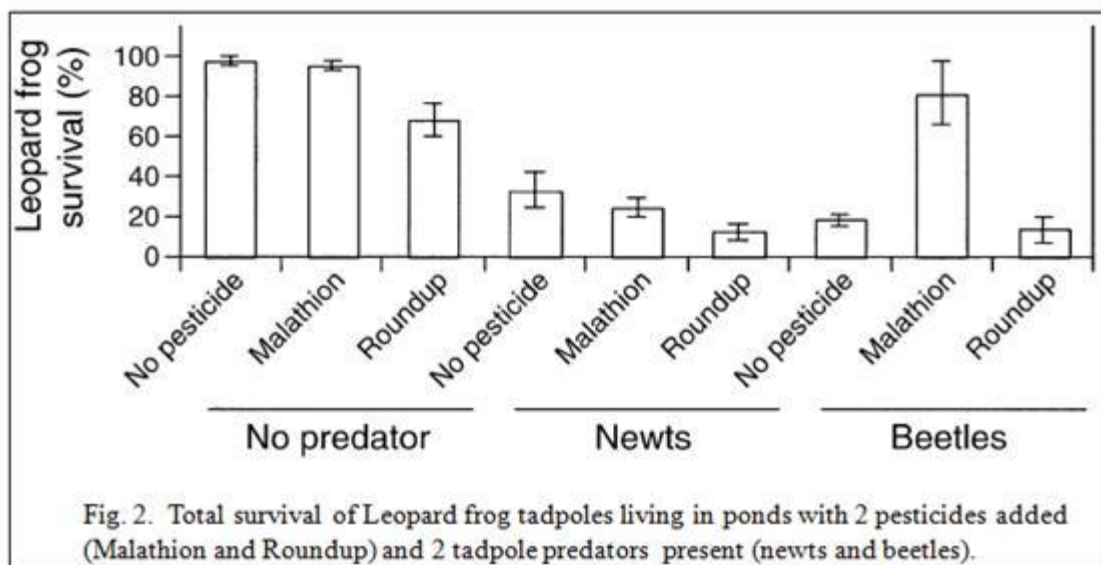
	Site 1 (in NC)	Site 2 (in GA)	Site 3 (in SC)	Site 4 (in AL)
Mass of sharks harvested per year in shark seafood fishery (kg)	248,617	86,245	398,356	95,487
Number of sea stars observed (per m ² of oyster reef)	12	1	18	2
Number of oysters killed by sea stars	150	17	170	21

3. Scientists wonder if harvesting sharks is impacting the food web. What testable hypothesis could you derive from this data?
 - a. There is not enough information to make a hypothesis.
 - b. As the number of harvested sharks increases oyster numbers will increase because a larger population of oysters are eaten by sea stars.
 - c. As the number of harvested sharks increases oyster numbers will increase because a larger population of sea stars are eaten by sharks.
 - d. As the number of harvested sharks increases oyster numbers will decrease because a larger population of sea stars are eaten by sharks.
4. For the data in the table, how could you be certain that there was a difference when harvesting of sharks was increased?
 - a. There is no way to be certain that there is a difference since the numbers in the table are so vastly different.

- b. To be certain that there is no difference, a statistical analysis should be conducted to determine if the numbers of oysters differ between sites.
 - c. It is possible to be certain that there is a difference by comparing the numbers of oysters and sharks between sites.
 - d. It is certain that there is a difference because the numbers of oysters and sharks in each site differ depending on the harvesting rates.
5. Which of the following actions is a valid scientific course of action?
- a. A government agency relies heavily on two industry-funded studies in declaring a common chemical found in plastics safe for humans, while ignoring of scientific studies linking the chemical with adverse health affects.
 - b. Journalists give equal credibility to both sides of a scientific story, even though one side has been disproven by many experiments.
 - c. A government agency decides to alter public health messages about breast-feeding in response to pressure from a council of businesses involved in manufacturing infant formula.
 - d. A scientific research journal, where articles are reviewed by scientific experts, chooses not to publish a paper because it ignores past research findings that disagree with claims made in the paper.

The following graph appeared in a scientific article¹ about the effects of pesticides on tadpoles in their natural environment.

¹ Modified from Relyea, R.A., N.M. Schoepner, J.T. Hoveman. 2005. Pesticides and amphibians: the importance of community context. *Ecological Applications* 15: 1125-1134



6. When beetles were introduced as predators to the Leopard frog tadpoles, and the pesticide Malathion was added, the results were unusual. Which of the following is a plausible hypothesis to explain these results?
 - a. The Malathion killed the tadpoles, causing the beetles to be hungrier and eat more tadpoles.
 - b. The Malathion killed the tadpoles, so the beetles had more food and their population increased.
 - c. The Malathion killed the beetles, causing fewer tadpoles to be eaten.
 - d. The Malathion killed the beetles, causing the tadpole population to turn to cannibalism.

7. Which of the following is(are) an example(s) of scientific fields of study?

- i. studies of planets and stars to interpret past and present events to predict human behavior
- ii. studies of the motion and relationships of and between the planets and stars
- iii. studies of the change of inherited traits of a group of organisms

- a. i.
- b. ii.
- c. iii.
- d. ii. and iii.
- e. all of the above

8. Your interest is piqued by a story about human pheromones on the news. A Google search leads you to the following website²:

² <http://www.athenainstitute.com/science.html>

<h1 style="text-align: center;">ATHENA INSTITUTE</h1>				
HOME	ATHENA SCIENCE	PHONEHOME DISCOVERY	MEDIA ARTICLES	BOOKS AND PRODUCTS
			CONTACT US	VIDEO LINKS
<p>...from the work of Dr. Winifred Cutler, research biologist:</p> <h2 style="text-align: center;">Books and Products Available from the Athena Institute</h2> <p>Our Products are Shipped in Plain Packages to Protect Your Privacy</p> <p><i>Since we began offering our intellectual products in 1988 we have never sold, rented or otherwise shared the identities of our customers to telemarketers, advertisers etc.</i></p> <p style="text-align: center;">Warning: Avoid Counterfeit Athena Products</p> <p>Within North America unless you buy directly from Athena, you risk buying a fake.</p> <p>Outside the USA click here for a list of our authorized resellers.</p> <p style="text-align: center;">Click on any Athena product to learn more about it</p> <p style="text-align: center;">Athena Pharmaceuticals—fragrance additives to enhance your sex-appeal.</p>				
<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>Athena Pharmaceuticals 10 (13th) for women</p> </div> <div style="text-align: center;"> <p>Increase the feminine attention you get from men.</p> </div> </div>				

For this website, which of the following characteristics are most important in your confidence that the resource is accurate or not.

- The resource may not be accurate, because appropriate references are not provided.
- The resource may not be accurate, because the purpose of the site is to advertise a product.
- The resource may not be accurate, because the author(s) of the website do not have the appropriate credentials.
- Yes, the resource is likely to be accurate, because appropriate references are provided.
- Yes, the resource is likely to be accurate, because the author(s) of the website is(are) reputable.



Background for Question 9: Merck Pharmaceuticals is a company that develops drugs for treating osteoporosis (a condition of bone thinning that often occurs in the elderly). Two of the drugs that Merck developed are called Fosamax and Vioxx. Elsevier is a company that publishes peer-reviewed scientific journals. Peer review

involves asking unaffiliated, unbiased scientists to read and evaluate research to determine its validity before it is accepted for publication. Merck paid Elsevier an undisclosed amount of money to publish several volumes of a publication that appeared to be a peer-reviewed medical journal, called the *Australasian Journal of Bone and Joint Medicine*. The final volumes mostly contained data and studies funded by Merck that showed the effectiveness of drugs Merck produced. Most advertisements in the volumes were for Fosamax and Vioxx. These published data and findings were reprinted or summarized from previously published articles (some were originally peer reviewed).

9. What steps could be taken to **best** improve the contents of the *Australasian Journal of Bone and Joint Medicine*?
- “Merck” should be included in the journal title and the journal’s financial records should be disclosed
 - the journal should include studies from a variety of researchers
 - the journal should pay scientists unaffiliated with Merck to conduct unbiased research on the drugs and publish the results
 - the entire publication should be original, peer-reviewed articles
 - contents should be regulated by an independent, publicly funded third party organization such as the FDA.

Consider the following facts for questions 10-11:

- Pet owners have released exotic snakes, Burmese Pythons, into the Everglades when the snakes have grown too large.
- Pythons feed on a wide variety of native birds and mammals.
- Some species of native birds are scarce and likely to go extinct due to predation by snakes.
- Snakes can be trapped and removed to protect native species from predation but traps are expensive to install and monitor.

10. Which of the following would **best** describe the role of science for determining whether there should be a financial investment to install and monitor traps?
- Science will be the primary or exclusive approach used.
 - Science must be used in conjunction with other approaches.
 - Science is not an appropriate approach.
11. Which of the following would **best** describe the role of science for monitoring changes in populations of native species after the installation of the snake traps?
- Science will be the primary or exclusive approach used.
 - Science must be used in conjunction with other approaches.
 - Science is not an appropriate approach.
12. You are doing experiments to test whether a specific traditional herbal homeopathic remedy works. According to proponents of this remedy, individuals who take Valerian root supplements will be able to treat insomnia. As part of your experiments on the scientific validity of this homeopathic remedy, it would be important to:
- test only people who believe in homeopathic remedies.
 - test only people without opinions, pro or con, about homeopathic remedies.
 - have the study performed by researchers who believe in this homeopathic remedy.
 - determine whether Valerian root versus other treatments produce different results.

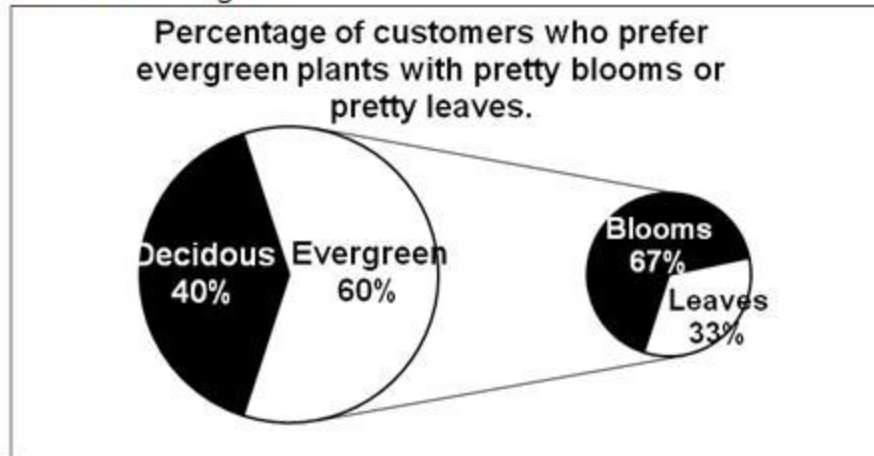
13. An oil spill killed 30% of a population of pelicans. Later, 20% of the pelicans that survived the oil spill died because no food was available. What percentage of the original population of pelicans is left after these 2 events?
- 20%
 - 30%
 - 56%
 - 60%
 - Cannot be calculated without knowing the original number of pelicans.
14. Two studies estimate the mean sugar content in a brand of cereal. Each study does the same tests on a random sample of boxes of cereal. Study 1 uses 10 boxes of cereal, and Study 2 uses 100 boxes of cereal. Which statement is true?
- The uncertainty in the estimate of the actual mean sugar content will be smaller in Study 1 than in Study 2.
 - The uncertainty in the estimate of the actual mean sugar content will be larger in Study 1 than in Study 2.
 - The estimates of the actual mean sugar content from each study will be equally uncertain.
15. What is the main difference between science and pseudoscience?
- Pseudoscience has a preconceived idea that leads to a research study, whereas science has a hypothesis that leads to a research study.
 - Pseudoscience bases conclusions on unverifiable sources or studies, whereas science bases conclusions on controlled, repeatable studies.
 - Pseudoscience has to employ more basic studies due to lack of funds, whereas science uses high tech equipment, machinery, and protocols to perform their experiments.
 - Pseudoscience uses surveys to collect data from practitioners, whereas science sets up experiments to determine conclusive facts about nature.

16. For one month, 300 people tracked their daily exercise. The average number of hours of a week exercising was 2. Most people who exercised less than 2 hours a week reported a higher-than-average number of headaches. Based on these 300 people, which of the following is the most appropriate conclusion to draw?
- People should exercise 2 or more hours a week if they want fewer headaches.
 - If people exercise more, their number of headaches will decrease.
 - Exercising does not necessarily cause a decrease in the number of headaches.
 - If you report high numbers of headaches and exercise less than 2 hours a week, your exercising habits likely caused the high number of headaches.

Background for Question 17: Dr. Hwang Woo-Suk published ground-breaking findings on stem cell research in the peer-reviewed scientific journal, *Science*. The research involved creating stem cells by cloning them from donated human eggs. Many of the eggs were donated by female researchers from Dr. Hwang's lab. Dr. Hwang knew the origin of the eggs and unknowingly violated the bioethics of human experimentation by allowing the eggs of his collaborators to be used in his research. Further bioethical probes uncovered that all published stem cell lines were fabricated, which lead to *Science* retracting both of Dr. Hwang's articles that it had previously published. Dr. Hwang alleges that at least two of the stem cell lines were legitimately cloned and they were later switched in a conspiracy to sabotage his research. In 2006, Dr. Hwang said he would be able to re-create the stem cell lines to prove his findings. To date no one has been able to re-create the cloned stem cell lines.

17. Pick the **best** answer that describes the research performed in Dr. Hwang's lab.
- is a credible source of scientific research that used eggs knowingly donated by researchers from the lab in which the research was performed.
 - is a credible source of scientific research because it was peer-reviewed and published by a scientific journal, *Science*.
 - is not a credible source of scientific research because another expert in the field wrote an article criticizing Dr. Hwang's work in a reputable journal.

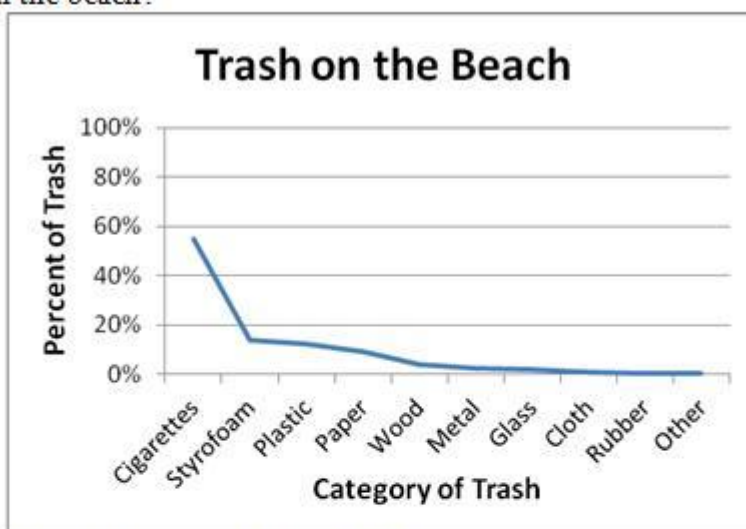
- d. is not a credible source of scientific research because the studies did not contain data that was verifiable or repeatable.
 - e. is not a credible source of scientific research because the stem cell lines were not able to be recovered after being sabotaged during the conspiracy to frame Dr. Hwang.
18. You want to open a plant nursery in your town. You surveyed your potential clients about their plant preferences (results shown below) and only those that were interested in evergreens, your specialty, were asked if they preferred blooms or leaves on their evergreens.



What proportion of your potential clients want you to breed blooming evergreen plants?

- a. 20%
- b. 40%
- c. 60%
- d. 67%
- e. Cannot be calculated without knowing the original number of survey participants.

19. This graph³ was created by a community organization. What is the BEST change you could make to this graph to better the argument that smoking should be banned on the beach?



- a. The area under the line should be shaded.
- b. The y-axis should be re-calculated to show number of items found on the beach.
- c. The scale of the y-axis should be adjusted to show values between 0 and 60%.
- d. The data should be displayed in a bar graph.
- e. All of the above changes need to be made in order to make an accurate evaluation of the graph

³ <http://kids.nceas.ucsb.edu/DataandScience/beachline.html>

APPENDIX D

QUANTITATIVE AND PROCESS SKILLS INSTRUMENT – FORM B

Quantitative and Process Skills Instrument

Directions: There are 19 questions. You will have about 25 minutes to work on the questions. Be sure to answer as many of the questions as you can in the time allotted. You will receive 0.5 points for completing the entire assignment today. Your grade will depend on completeness and thoroughness, not on correct answers. Your honest answers will help us better prepare the materials for the remainder of the semester.

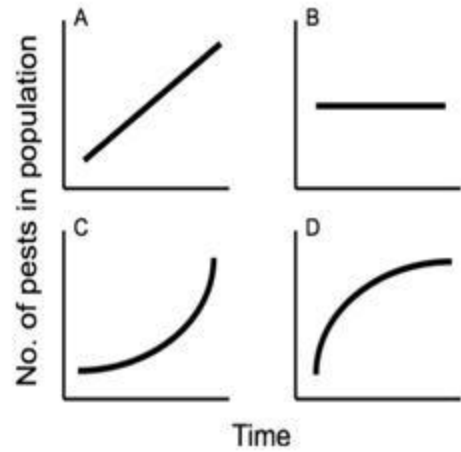
Mark your answers on the scantron sheet, indicate your form in the lettered space provided. Fill in your #810 on your scantron. Do NOT use a calculator. Thank you for your participation in this project!

1. Which of the following is a valid scientific argument?
 - a. A recent poll revealed that 34% of Americans believe that dinosaurs and early humans co-existed because fossil footprints of each species were found in the same location. This widespread belief is appropriate evidence to support the claim that humans did not evolve from ape ancestors.
 - b. A strain of mouse was genetically engineered to lack a certain gene, and the mice were unable to reproduce. Introduction of the gene back into the mutant mice restored their ability to reproduce. Therefore, the gene is essential for mouse reproduction.
 - c. This winter, the northeastern US received record amounts of snowfall, and the average monthly temperatures were more than 2°F lower than normal in some areas. These facts prove that climate change is occurring.
 - d. Stephen Hawking is widely known as a brilliant modern physicist. He has recently stated that he believes if aliens were ever to visit the Earth, they would be aggressive and seeking only to gain resources. Several prominent scientists have voiced their support of this idea as the most likely scenario. Therefore, he is correct.

2. You grow vegetables in your backyard and last summer you noticed a particular kind of insect eating your plants. You took a rough count (see data below) of the pest population over time. What would the number of individuals of this pest living in your backyard look like over time

Time (days)	Number of insects
2	7
4	16
8	60
10	123
14	487

if you took no action against them?



Background for Questions 3-4: There has recently been a human disease outbreak in several counties in your state and the Environmental Protection Agency (EPA) has gathered data shown in the table below. Use this table to answer the next 2 questions.

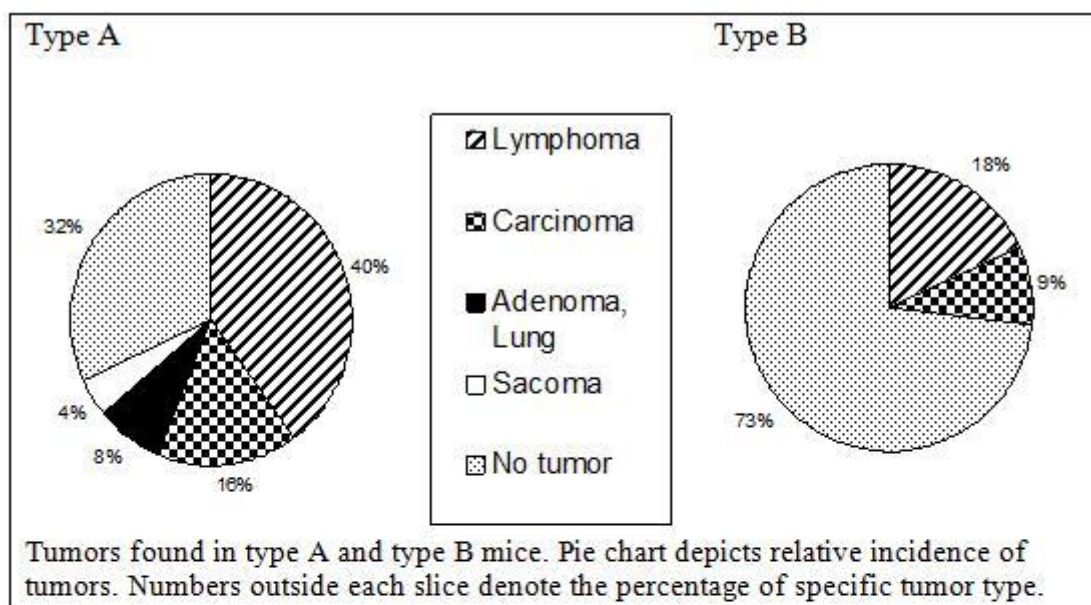
	County 1	County 2	County 3	County 4
Miles of rivers in county	9,462	578	8,672	954
Number of snails observed (per mile of river)	2,346	189	1,985	172
Number of ducks observed (per mile of river)	26	6	11	24
Number of human disease cases (per 100 people in county)	17	2	16	3

3. Scientists wonder if the disease may be spread through waterways. What testable hypothesis could you derive from this data?
 - a. There is not enough information to make a hypothesis
 - b. The disease is not spread through waterways- the number of disease cases is too low for this to be likely.
 - c. The disease is spread through waterways- snails possibly harbor the bacteria.
 - d. The disease is spread through waterways- the bacteria possibly originate from duck feces.

4. For the data in the table, how could you be certain that there was a difference between the number of human cases per 100 people in county 1 and 3?
 - a. There is no way to be certain that there was a difference between the number of human cases per 100 people in county 1 and 3 because the number of cases is too similar.

- b. The EPA can be certain that there was a difference between the number of human cases per 100 people in county 1 and 3 because the two counties differ in terms of their surroundings; that is, county 1 has more miles of rivers, and greater numbers of snails and ducks.
 - c. The EPA can be certain that there was a difference between the number of human disease cases in county 1 and 3 by determining whether number is statistically different between counties.
 - d. The EPA can be certain that there was a difference between the number of human cases per 100 people in county 1 and 3 because the number is calculated as cases per 100 people, so there is a large difference between county 3 and county 1.
5. Which of the following actions is a valid scientific course of action?
- a. A government continues to fund a sex-education program based on two studies that have shown only limited short-term effectiveness while ignoring studies that find the program ineffective.
 - b. A group of scientists asked to review research proposals from peer scientists base their funding decisions on the credentials, project plans and preliminary data from the research proposals.
 - c. A panel of scientists for a government-supported study on global climate change is selected based on their expertise and secondarily on their political beliefs.
 - d. A scientific journal rejects a rigorous study because the results provide evidence against a widely accepted model.
6. Which of the following is the **best** interpretation of the graph below⁴?

⁴ Modified from Wang, Y., S. Klumpp, H.M. Amin, H. Liang, J. Li, Z. Estrov, P. Zweidler-McKay, S.J.Brandt, A. Agulnick, L. Nagarajan. 2010. SSBP2 is an *in vivo* tumor suppressor and regulator of LDB1 stability. *Oncogene* 29: 3044-3053.



- a. Type "A" mice with Lymphoma were more common than type "A" mice with no tumors.
 - b. Type "B" mice were more likely to have tumors than type "A" mice.
 - c. Lymphoma was equally common among type "A" and type "B" mice.
 - d. Carcinoma was less common than Lymphoma only in type "B" mice.
7. Which of the following is (are) an example(s) of what a scientist studies?
- i. Traditional (without randomized controlled studies) uses of plants and their extracts for remedies
 - ii. Manipulations of cells to uncover the structure and function in living organisms
 - iii. Effects of movement on the human body during physical activity

- a. i.
- b. ii.
- c. iii.
- d. ii. and iii.
- e. all of the above

8. Your interest is piqued by a story about the status of new innovations in male contraceptives on the news. A search of the American Association for the Advancement of Science's Science Sources site leads you to the following website⁵:

⁵ <http://www.newmalecontraception.org/index.htm>

Home

Press resources

In the news

Limitations of current
contraceptives for women

*Frontiers in Nonhormonal Male
Contraception: The Next Step*

Abstract

Introduction

Why new contraceptives?

Would men use one?

Why nonhormonal?

Vas-based methods

Heat methods

Ultrasound

Oral methods

Other nonhormonal methods

Why do we need new contraceptives?

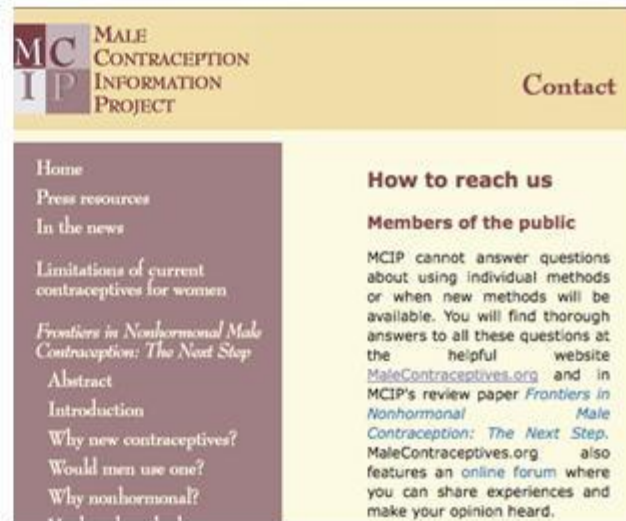
Abortion rates are still high.

In the United States, about 2% of women get an abortion each year, and more than 20% of total pregnancies end in abortion ([Elam-Evans et al., 2002 p. 1, 3; The Alan Guttmacher Institute, 2005](#)). Furthermore, the United States has the highest adolescent birth rate in the industrialized world — about four times the European Union average, and more than 10 times the rate in Japan and Korea. In fact, one in five girls has a child by the time she turns 20 ([UNICEF International Child Development Centre, 2001](#)). Nearly one million teenage girls become pregnant in the U.S. each year, and 78% of these pregnancies are unintended ([The National Campaign to Prevent Teen Pregnancy, 2001](#)).

With the United States disgraced with a teenage pregnancy rate more than twice that of its neighbor to the north, clearly the state of contraceptive technology is not the only problem. Politics, pricing and culture have also limited access to contraceptives that already on the market. A 2004 report calls contraceptive availability in the United States an "unfinished revolution" ([Reproductive Health Technologies Project, 2004](#)). Still, even with universal health coverage and consistent support for contraception, other prosperous nations have not completely eliminated the need for abortion — a sign that the search must continue for reliable, foolproof, long-term

For this website, which of the following characteristics are most important in your confidence that the resource is accurate or not.

- The resource may not be accurate, because appropriate references are not provided.
- The resource may not be accurate, because the purpose of the site is to advertise a product.
- The resource may not be accurate, because the author(s) of the website do not have the appropriate credentials.
- Yes, the resource is likely to be accurate, because appropriate references are provided.
- Yes, the resource is likely to be accurate, because the author(s) of the website is(are) reputable.



Background for Question 9: Dr. Hwang Woo-Suk published ground-breaking findings on stem cell research in the peer-reviewed scientific journal, *Science*. The research involved creating stem cells by cloning them from donated human eggs.

Many of the eggs were donated by female researchers from Dr. Hwang's lab. Dr. Hwang knew the origin of the eggs and unknowingly violated the bioethics of human experimentation by allowing the eggs of his collaborators to be used in his research. Further bioethical probes uncovered that all published stem cell lines were fabricated, which lead to *Science* retracting both of Dr. Hwang's articles that it had previously published. Dr. Hwang alleges that at least two of the stem cell lines were legitimately cloned and they were later switched in a conspiracy to sabotage his research. In 2006, Dr. Hwang said he would be able to re-create the stem cell lines to prove his findings. To date no one has been able to re-create the cloned stem cell lines.

9. In the above scenario, what are the best steps to take in order to provide new support for the retracted publications resulting from Dr. Hwang's lab:
 - a. Dr. Hwang's lab should replicate the experiment with a witness present.
 - b. Dr. Hwang's lab should replicate the experiment using ethically obtained eggs to generate the stem cell lines, with a witness present.
 - c. Dr. Hwang's lab should obtain permission from the donors, which should be included as a formal statement in a peer-reviewed publication.
 - d. A third-party bioethics investigation should be conducted, which should include interviews of Hwang lab members and collaborators, as well as a thorough audit and review of laboratory documentation such as laboratory notebooks and records.
 - e. Another unrelated research team should replicate the Hwang experiment using ethically obtained eggs.

Consider the following facts for Questions 10-11:

- Salt marsh habitats serve as nurseries for young fish, shellfish, and crustaceans, including some of commercial importance.
- Smooth cordgrass, the most common salt marsh plant, covers virtually the entire marsh.

- Since Fall 2001, many acres of cordgrass have died due to predation by snails, imperiling salt marsh habitats.
 - Exclusion cages can be used to protect grasses from snails in areas of concern, but they are expensive.
10. Which of the following would **best** describe the role of science for determining whether there should be a financial investment in the installation of exclusion cages?
- a. Science will be the primary or exclusive approach used.
 - b. Science must be used in conjunction with other approaches.
 - c. Science is not an appropriate approach.
11. Determine which of the following would **best** describe the role of science for monitoring environmental change after the installation of the exclusion cages:
- a. Science will be the primary or exclusive approach used.
 - b. Science must be used in conjunction with other approaches.
 - c. Science is not an appropriate approach.
12. You are doing experiments to test whether a specific type of acupuncture works. This type of acupuncture holds that specific needle insertion points influence specific parts of the body. As part of your experiments on the scientific validity of this particular type of acupuncture, it would be important to:
- a. test only people who believe in acupuncture.
 - b. test only people without opinions, pro or con, about acupuncture.
 - c. have the study performed by researchers who believe in this form of acupuncture.
 - d. determine whether acupuncture versus other treatments produce different results.

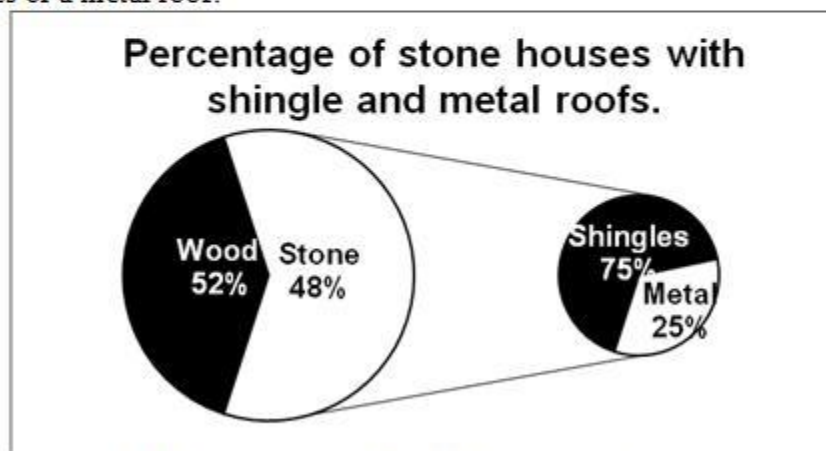
13. A hurricane wiped out 40% of the wild rats in a coastal city. Then, a disease spread through stagnant water killed 20% of the rats that survived the hurricane. What percentage of the original population of rats is left after these 2 events?
- 40%
 - 48%
 - 60%
 - 80%
 - Cannot be calculated without knowing the original number of rats.
14. Two studies estimate the mean caffeine content of a brand of energy drinks. Each study uses the same test on a random sample of the energy drinks. Study 1 uses 25 bottles of energy drink, and study 2 uses 100 bottles of energy drink. Which statement is true?
- The estimate of the actual mean caffeine content from each study will be equally uncertain.
 - The uncertainty in the estimate of the actual mean caffeine content will be smaller in study 1 than in study 2.
 - The uncertainty in the estimate of the actual mean caffeine content will be larger in study 1 than in study 2.
15. If you were to read an article in the media (either online or in print) about a new innovation, what is the **most** important factor influencing you to categorize it as science versus pseudoscience?
- the presence of data or graphs
 - the name of the media source
 - the article was peer-reviewed by unbiased third-party experts
 - the presence of references
 - the publisher of the media source

16. For one month, 500 pre-teens wrote down how many hours they spent playing video games. The average number of hours a week playing video games was 13. Most pre-teens who played video games more than 13 hours a week reported higher-than-average amounts of anxiety. Based on these 500 pre-teens, which of the following is the most appropriate conclusion to draw?
- Pre-teens should play video games less than 13 hours a week if they want to decrease their anxiety level.
 - If pre-teens play video games for fewer hours, their anxiety level will decrease.
 - Playing video games does not necessarily cause increased anxiety levels.
 - If you have high anxiety levels and play more than 13 hours of video games a week, your gaming habits likely caused your high anxiety levels.

Background for Question 17: Merck Pharmaceuticals is a company that develops drugs for treating osteoporosis (a condition of bone thinning that often occurs in the elderly). Two of the drugs that Merck developed are called Fosamax and Vioxx. Elsevier is a company that publishes peer-reviewed scientific journals. Peer review involves asking unaffiliated, unbiased scientists to read and evaluate research to determine its validity before it is accepted for publication. Merck paid Elsevier an undisclosed amount of money to publish several volumes of a publication that appeared to be a peer-reviewed medical journal, called the *Australasian Journal of Bone and Joint Medicine*. The final volumes mostly contained data and studies funded by Merck that showed the effectiveness of drugs Merck produced. Most advertisements in the volumes were for Fosamax and Vioxx. These published data and findings were reprinted or summarized from previously published articles (some were originally peer reviewed).

17. Pick the **best** answer that describes the *Australasian Journal of Bone and Joint Medicine*.
- It is a credible source of scientific research that happened to emphasize Merck products.

- b. It is a credible source of scientific research because it was published by a company, Elsevier, that has historically published peer-reviewed scientific journals.
 - c. It is not a credible source of scientific research because there were advertisements within the journal.
 - d. It is not a credible source of scientific research because the studies did not contain data.
 - e. It is not a credible source of scientific research because the original experiments were funded to support the efficacy of Merck drugs.
18. Different housing designs are best suited for different climates. You are moving to a new city where the county government keeps data on file about problem houses (results shown below). Because stone houses are rapidly growing in popularity, people with problematic stone houses were asked if their house had shingles or a metal roof.

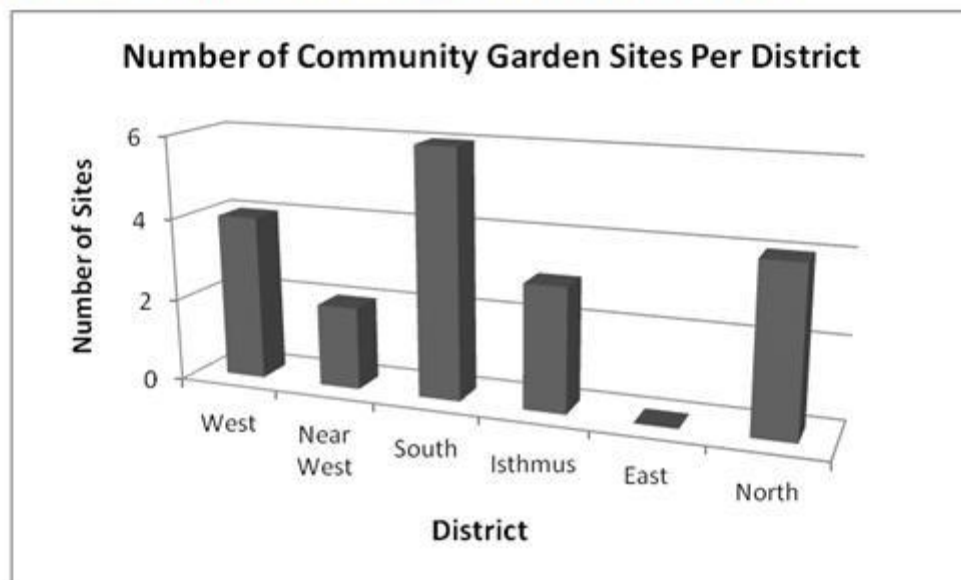


What proportion of homeowners with problem houses had a stone house with a shingled roof?

- a. 12%
- b. 25%

- c. 36%
- d. 48%
- e. Cannot be calculated without knowing the original number of survey participants.

Use this information to answer question 19: The following graph⁶ is being presented by a local community to argue that spending on planned gardens is not being evenly distributed based on size of the districts across sites in the district.



19. What is the BEST change you could make to this graph in order to make an accurate evaluation of the argument that garden sites per district are (or are not) evenly distributed across districts?
- a. The bars should not be 3D, because it makes the values deceptively larger than they actually are.

⁶ <http://www.thedailypage.com/forum/viewtopic.php?f=51&t=46890&start=225>

- b. The scale on the Y-axis should be adjusted to show percent of all the garden sites in the district.
- c. Instead of showing number of sites on the y-axis, the y-axis should be re-calculated as Percent Garden Area for each site out of the Total District Area.
- d. The scale of the y-axis should be adjusted to show numbers of sites between 0 and 10.
- e. All of the above changes need to be made in order to make an accurate evaluation of the graph.

APPENDIX E

THE PERSONAL RESPONSIBILITY ORIENTATION SELF-DIRECTED LEARNING SCALE

Name:_____ **Date:**_____ **ID#**_____

A Learning Experience Scale (PRO-SDLS)

Please check one answer for each statement. There are no “right” answers to these statements, which pertain to your recent learning experiences in college-not just those experiences from this class (although they may be the same).

ITEM	Strongly Disagree	Disagree	Sometimes	Agree	Strongly Agree
1. I am confident in my ability to consistently motivate myself.					
2. I frequently do extra work in a course just because I am interested.					
3. I don't see any connection between the work I do for my courses and my personal goals and interests.					
4. If I am not doing as well as I would like in a course, I always independently make the changes necessary for improvement.					
5. I always effectively take responsibility for my own learning.					
6. I often have a problem motivating myself to learn.					
7. I am very confident in my ability to independently prioritize my learning goals.					
8. I complete most of my college activities because I WANT to, not because I HAVE to.					
	Strongly Disagree	Disagree	Sometimes	Agree	Strongly Agree
9. I would rather take the initiative to learn new things in a course rather than wait for the instructor to foster new learning.					
10. I often use materials I've found on					

my own to help me in a course.					
11. For most of my classes, I really don't know why I complete the work I do.					
12. I am very convinced I have the ability to take personal control of my learning.					
13. I usually struggle in classes if the professor allows me to set my own timetable for work completion.					
14. Most of the work I do in my courses is personally enjoyable or seems relevant to my reasons for attending college.					
15. Even after a course is over, I continue to spend time learning about the topic.					
16. The primary reason I complete course requirements is to obtain the grade that is expected of me.					
ITEM	Strongly Disagree	Disagree	Sometimes	Agree	Strongly Agree
17. I often collect additional information about interesting topics even after the course has ended.					
18. The main reason I do the course activities is to avoid feeling guilty or getting a bad grade.					
19. I am very successful at prioritizing my learning goals.					
20. Most of the activities I complete for my college classes are NOT really personally useful or interesting.					
21. I am really uncertain about my capacity to take primary responsibility for my learning.					
22. I am unsure about my ability to independently find needed outside materials for my courses.					
23. I always effectively organize my study time.					
24. I don't have much confidence in my ability to independently carry out my student plans.					
25. I always rely on the instructor to tell me what I need to do in the course to succeed.					

APPENDIX F

TASK SURVEY

Please fill out this survey to help us understand your learning and improve class projects for other students. No individual response will be shared with the instructor, so please answer as honestly as you can.

Your First Name:

Your Last Name:

Your @uga.edu email address (example jdears@uga.edu):

Which project did you recently complete?

Please mark the extent to which you agree or disagree with each of the following statements about the project you recently completed.

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
This project was realistic, that is, it represented what I might do in real life.						
I will use the information that I learned in this project when this class is over.						
I found many of my own learning materials to complete this project.						
I did this project because I wanted to, not because I had to.						
During this project, I did more than what was required so that I could learn more about biology concepts.						
During this project, I had to take charge of my own learning.						
This project was easy for me to do.						
I made and followed a detailed plan to complete this project .						
I had to adjust my personal schedule in order to complete this project.						

I often thought about whether I was making adequate progress during this project.						
During this project, I had to determine if the information I used was accurate.						
During this project, I discovered new ways to improve my own learning.						
At the beginning of this project, I considered alternative ways to accomplish it.						
I often consulted the class project requirements as I completed this project.						
During this project, I thought about when to ask others to help me and when not to.						
I was in complete control of my own success during this project.						
I chose to do this project over the other possible projects in class because:						
The aspects of this project that were realistic were:						
The aspects of this project that made me take charge of my own learning (if any) were:						