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Marisa T. Cohen
The Graduate Center, City University of New York, Mcohen1@gc.cuny.edu

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Abstract

The relative effectiveness of discovery learning as compared with direct instruction is equivocal. This study examined the effectiveness of these two instructional styles in a diverse Queens classroom of 18 second grade students using a float or sink science lesson. An assessment test and transfer task was given to students to examine which method of teaching enabled the students to grasp the content of the lesson to a greater extent. Results demonstrated that the students in the direct instruction group scored higher on the assessment test and completed the transfer task at a faster pace; however, this was not statistically significant. There was no correlation observed between outcome on the assessment test and time on the transfer task. Overall, results suggest that a mixture of instructional styles would serve to effectively disseminate information, as well as motivate students to learn.

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Direct Instruction: a Definition

Direct instruction is a model for teaching that "…emphasizes well-developed and carefully planned lessons designed around small learning increments and clearly defined and prescribed teaching tasks" (National Institute, 2007). A major benefit of this form of teaching is that it provides a means of efficiently communicating large amounts of information in a short period of time. However, it is often criticized, as learners take on a passive, rather than an active role (Gagne & Berliner, as cited in King, 1995).

The direct instruction model was created by Engelmann and colleagues in the 1960s at the University of Illinois at Champagne-Urbana. The first implementation of the model was known as Direct Instruction System for Teaching and Remediation (DISTAR), which consisted of programs that addressed reading, language, and math (Magliaro, Lockee, & Burton, 2005). Elements of the direct-instruction model gained recognition in 1974 with a work addressing teacher behaviors and their relation to student performance by Brophy and Evertson (as cited in Ryder, Burton, & Silberg, 2006). These teacher behaviors include "…emphasizing seatwork, directing instruction, controlling pace, supervising seatwork, and working with students in small groups" (p. 181). It is rooted behavioral theory, specifically what Skinner labeled as radical or selectionist behaviorism, as it involves behaviors selected by the consequences which follow them (Magliaro, Lockee, & Burton, 2005). In 1986, Rosenshine elaborated on this model and encouraged teachers to present material in small incremental steps, pause to check for understanding, and aim to get active participation by all students (Ryder, Burton, & Silberg, 2006).

According to Rosenshine, there are six functions of each direct instruction lesson, which are: review, presentation, guided practice, corrections and feedback, independent practice, and weekly and monthly reviews (Magliaro, Lockee, and Burton, 2005). The idea behind this methodology is that direct instruction eliminates misconceptions which occur during the learning process, and allows for accelerated and more efficient learning. It is a highly organized, teacher directed approach, in which skills are divided into small units, ordered sequentially, and taught explicitly (Carnine 2000, as cited in Wisconsin Policy, 2001). Each component of the task associated with the target behavior is taught by the teacher. The teacher also models the behavior, provides practice and feedback, and assesses whether or not the skill needs to be re-taught (Ryder, Burton, & Silberg, 2006). It is not a lecture approach, but rather an instructional model that focuses on the interaction between teachers and students. The fundamental principle that connects the components of DI is that "…learners are actively engaged in the relevant curriculum in order to build knowledge, skills, and dispositions related to the goals and objectives of the lesson (Magliaro, Lockee, and Burton, 2005, p. 44).

Teacher-centered methods of instruction are often necessary to educate students on difficult material that requires multiple steps, and for procedures which are unlikely for students to discover on their own. Stahl et al. (1998, as cited in Ryder, Burton, & Silberg, 2006) stated that direct instruction approaches can be tied to three principles; language is broken down into components taught in isolation; learning is teacher directed; and students have little input.

Discovery Learning: a Definition

Discovery learning is when a student obtains knowledge by him/herself. It involves constructing and testing hypotheses rather than passively reading or listening to teacher presentations (Schunk, 2008). Discovery learning can also be referred to as problem-based, inquiry, experiential, or constructivist learning. It involves inductive reasoning because students move from a specific topic to formulating rules and principles (Kirschner, Sweller, & Clark, 2006). Over the past decade, research on this form of learning has moved from concept discovery learning towards authentic discovery learning, which is characterized by designing scientific experiments (Reid, Zhang, & Chen, 2003).

In its current conception and practice, discovery learning is a minimally guided instructional approach. Contrary to what many believe, students are not permitted to do anything they want, but rather are guided by teachers. Instructors will typically arrange activities, and then allow students to work with the materials provided to figure out concepts. They will also present questions or problems to encourage learners to make intuitive guesses (Schunk, 2008).

Discovery learning is thought to increase the ability of students to transfer information they construct to other areas, as it allows the students to independently explore broader issues (Klahr & Nigam, 2004). Despite the benefits of this method of instruction, it is important to note that discovery can impede learning when students have no prior knowledge or background information about the topic being studied (Tuovinen & Sweller, as cited in Schunk, 2008). In the classroom, discovery learning is often implemented as role playing, group projects, and computer simulations.

There are two main assumptions which underlie this type of instructional program. The first is that it challenges students to solve authentic problems in information rich settings. This assumption is based on the idea that encouraging a learner to construct his/her own solution leads to the most effective learning experience. The second assumption is that knowledge can best be acquired though experience (Kirschner, Sweller, & Clark, 2006).

The Argument

The dispute regarding the amount of guidance that should be provided during instruction has been ongoing for the last half century. On one side of the argument, supported by researchers such as Bruner (1961), Papert (1980), and Steffe & Gale (1995), is the idea that people learn best in an unguided or minimally guided environment, in which learners must discover or construct essential information for themselves. On the other side, researchers such as Cronbach & Snow (1977), Klahr & Nigam (2004), Mayer (2004), and Sweller (2003), suggest that learners should be provided with direct guidance on concepts required by a discipline and should not have to discover ideas or knowledge on their own (Kirschner, Sweller, & Clark, 2006).

Some researchers (Gagne, 1985, as cited in Magliaro, Lockee, & Burton, 2005) posit that DI should not be used for higher level learning or performance, but in situations where motor skills or prerequisite intellectual skills are being instructed. This would include: mathematical procedures, grammar rules, scientific equations, etc. Basic skills must be mastered before moving on to more complex topics, which DI allows the students to do.

The constructivist idea of instruction has long dominated teaching methods in the scientific and mathematics communities. The belief is that the knowledge students construct on their own is more valuable than that which is presented to them by a teacher (Loveless, 1998, as cited in Klahr & Nigam, 2004). The Piagetian notion of discovery learning also contends that when a child is taught something which he/she could have discovered on his/her own, the child will not understand it as completely, as compared with discovering the idea. Advocates of the discovery learning approach also contend that instructional guidance, which provides strategies, interferes with the natural processes that the learner would have intended to use on his/her own (Kirschner, Sweller, & Clark, 2006).

Despite the ideas presented in favor of discovery learning, a great deal of empirical research has been presented against it. Researchers have found it to be ineffective in teaching students new concepts. The idea behind instructional methodology is constantly shifting.

In Support of Direct Instruction

Minimally-guided instructional approaches are very popular; however these approaches ignore the structures that constitute human cognitive architecture. A meta analysis conducted by Kirschner, Sweller, and Clark (2006) examined minimally-guided instructional approaches and found, based upon knowledge of human cognitive structure, discovery learning is ineffective. They believe that "[m]inimally guided instruction appears to proceed with no reference to the characteristics of working memory, long-term memory, or the intricate relations between them" (p. 75). One of the goals of instruction is to give learners specific guidance about how to manipulate information in ways that are consistent with a goal, and enable the students to store this knowledge in long-term memory. Discovery learning does not serve these purposes.

Results of studies conducted on novice and expert chess players in 1972 by Chase and Simon (as cited in Kirschner, Sweller, & Clark, 2006) demonstrate that expert problem solvers derive their skills by drawing on the experiences they have stored in their long-term memory and select and apply the best procedures when it comes to solving problems. It is our long-term memory which allows us to assess the characteristics of a situation and generate a procedure to handle it effectively. Because of this, instruction must alter long-term memory.

Methods of effective instruction must also be sensitive to the limits imposed on working memory, and how those limits disappear when working with familiar information. A great deal of discovery learning ignores the limits of working memory, as problem-based searching makes heavy demands on it. This form of instruction also does not enable information to get stored in long-term memory, because while working memory is being used to search for solutions, it is not available to be used to learn and store. Finally, discovery learning may even hinder students learning. A 1994 study by Brown and Campione (as cited in Kirschner, Sweller, & Clark, 2006), demonstrated that when students learn in pure-discovery science classrooms they often become lost and frustrated. De Jong and van Joolingen (1998) have stated that learners may encounter difficulties in four categories when using discovery learning methodology; difficulties in generating and adapting hypotheses, poorly designed experiments, difficulties in data interpretations, and problems regarding the regulation of discovery learning (as cited in Reid, Zhang, & Chen, 2003).

The authors of this article also argue with the constructivist notion that presenting students with partial information enhances their ability to construct a representation to a greater extent than when given full information. Instead, they contend that complete information results in a more accurate representation of the knowledge (Kirschner, Sweller, & Clark, 2006). Another problem inherent in the discovery based method of teaching is the failure to distinguish between learning as a discipline and practicing a discipline. While the idea that learning can best be accomplished through experience seems positive, it fails to take into account that the methods and behaviors of an expert in a profession are entirely different than those of students new to a field. Students first need to learn and understand the basic skills and facts before taking on more complex roles. Kirschner, Sweller, and Clark strengthened the idea that when learners are presented with novel information, they should be explicitly instructed on what to do and how to do it.

The advantages of direct instruction and limits of discovery learning do not only apply to elementary education, but also have a strong case in higher education. For example, the problem-based learning approach (PBL), which was introduced at the McMaster University School of Medicine, is aimed at having medical students work in groups to diagnose and suggest treatments for common patient symptoms. When students are taught problem solving skills and are given problems in which to practice those skills, they will learn in a more meaningful way. Review of this methodology in 1993 by Patel, Groen, and Norman (as cited in Kirschner, Sweller, & Clark, 2006), showed that it gave the students a disadvantage in that they could not separate the basic science knowledge from the cases it was embedded in. This led to more errors on novel cases and lower basic science exam scores. This further supports the idea that students need to first acquire basic knowledge by being directly instructed in their domain.

A study conducted by David Klahr and Milena Nigam (2004), which is in support of direct instruction, assessed the relative effectiveness of direct instruction and discovery learning. One hundred twelve third and fourth grade students were used for the purpose of this study, and were assessed at two different points in the learning process. The goal of the research was to explore the effectiveness of both discovery learning and direct instruction in teaching students about the control-of-variables strategy, a method for creating simple, unconfounded experiments. The students were instructed to set up experiments using ramps to determine the effect of steepness, and run lengths on how fast a ball rolls down them. Children in the discovery condition experimented by themselves, whereas those in the direct instruction condition were given explanations of experiments, provided with examples, shown demonstrations, and received feedback from a teacher. On a separate day, students evaluated science fair posters created by sixth graders.

The hypotheses tested were that direct instruction is more effective, children who have mastered the procedure being taught in the lesson should outperform others when evaluating science-fair posters, and what is learned, is more important than how it is taught. The last of the hypotheses is aimed at testing the prediction that if children are able to master a new procedure, transfer will not be affected by the way they reached that mastery. This was to test the idea that discovery learning helps with transfer, of which the researchers were dubious. Data was collected during the initial acquisition of the objective, which was designing and interpreting experiments, and during transfer and application of this skill in evaluating science fair posters.

When compared to discovery learners, results demonstrated that more children were able to learn from direct instruction. The ability of children to create additional unconfounded experiments in the direct instruction condition increased from exploration to assessment from 1.0 to 3.1 ($p < .0001$). Those in the discovery learning condition also increased, but not to such a large extent. A greater proportion of direct instruction students became “masters,” at designing unconfounded experiments, 77% as compared with 23% of discovery children. Masters were operationally defined as creating at least three unconfounded experiments. Masters of direct instruction were also able to perform just as well, as the few master students who learned from discovery learning when skills were transferred to making scientific judgments about the science fair posters. Also, those who became masters were able to succeed in transferring the knowledge to the new task, irrespective of the method in which they were instructed. Further study should aim at assessing whether these proportions are stable across different learners and whether there are specific features of some learners that make discovery learning effective.

In Support of Discovery Learning

According to Zhang (2000), effective scientific discovery learning involves three main interlocking spheres; problem representation and hypothesis generation, which relies on the activating and mapping of prior knowledge; testing hypotheses with valid experiments; and reflective abstraction and integration of the discovery experiences (Reid, Zhang, & Chen, 2003). Taking this into account, the effectiveness of discovery learning is also determined by three interrelated conditions. The first is the meaningfulness of the discovery processes, in that learners need to activate prior knowledge to help them understand the problem and generate appropriate hypotheses. Second, the logicality of the discovery activities must be determined, as effective discovery learning involves proper scientific reasoning and manipulations of the variables. Finally, there must be reflective generalization over the discovery processes, which means the rules and principles should be learned from the situation and can be applied to other settings (Reid, Zhang, & Chen, 2003).

A study conducted by Saab, van Joolingen, and van Hout-Wolters (2005) examined the effectiveness and interrelatedness of discovery and collaborative learning. Collaborative learning occurs when students construct knowledge through communication and the joint use of instruments, and is thought to have a positive effect on discovery learning. This is because collaboration is a promoter of elaboration and explication. Externalizing thoughts also enables students to be aware of their metacognitive thinking processes, and influences planning and decision making (Dekker & Elshout-Mohr, 1998, as cited in Saab, van Joolingen, and van Hout-

Wolters, 2005). Okada and Simon (1997) showed that due to peer interaction, pairs performed better than single students when forming hypotheses. Saab, van Joolingen, and van Hout-Wolters hypothesized that as students engage in collaborative learning, they search for a common way of working, which makes the discovery learning process explicit. This communicative support is used to strengthen the idea behind discovery learning. It was predicted that argumentative, elicitative, and acceptance collaborative learning activities would correlate with discovery activities.

Twenty-one pairs of 10^{th} grade students enrolled in pre-university education in Amsterdam used a computer-based learning environment to study particle collisions. A computer simulation was utilized to represent a learning domain, as this engages the students in active investigation while they are constructing knowledge. Students worked in dyads at separate computer screens, communicating via chat boxes. Two learning outcome measures were used, one related to performance within the environment, and the other to what was learned from working with the learning environment determined by pre- and post-tests.

Results showed that communicative activities naturally co-occur with discovery learning and can lead to positive learning outcomes. There were significant relationships between both argumentative and elicitative activities and discovery processes, as these activities helped students establish agreement on their conclusions. Students also demonstrated improvement between pre-test and post-test. Correlational analysis demonstrated that part of the progress accomplished was explained by prior knowledge, and the rest of the progress could be attributed to the processes of communication and discovery which took place in the collaboration environment.

A limitation of this study is that only correlations were shown, which does not establish causation. A further caution regarding this study, is that the researchers note that students have to build common ground before they can work constructively together, which includes synchronizing background knowledge and agreeing on the definitions of variables. In diverse classrooms with younger students, such as the one proposed in the current study, a common ground may be impossible to achieve. Also, students may not be able to articulate what it is they know about a subject.

A study by Reid, Zhang, and Chen (2003) used a computer simulated learning environment dealing with the floating and sinking of objects in water to examine instructional support in discovery learning. This scientific principle was also investigated in the present study. The researchers examined three spheres of support: interpretative support (IS), which helps learners with the generation of hypotheses and construction of coherent understandings; experimental support (ES), which scaffolds learning in the scientific design of experiments, prediction and observation of outcomes, and drawing of conclusions; and reflective support (RS), which increases learners' self-awareness of the learning processes and prompts reflection on discoveries. It was hypothesized that ES should enhance the learners' experimental activities and manifest prominent effects on the discovery of rules. IS should increase the meaningfulness of the discovery processes and promote application of the discovered rules. Participants consisted of 78 boys between 12 and 13 years of age from a comprehensive school in the UK. There were four groups compared, ES but not IS, IS but no ES, ES and IS, and no support.

The ES in the experiment included four specific treatments to assist learners in conducting the experiments: explanations about the scientific experimental design, identification of the objectives of each trial, and predictions and comparison, which helped students compare the conclusions of their new discovery against an experiment structure table showing the comparisons of variables between two objects in a pair of experiments. The IS consisted of activating prior knowledge through the use of multiple choice questions on the subject, general analysis of the problem, which required students to select factors relevant to the experiment, and access to the knowledge base through a reference book containing useful descriptions and definitions. The posttest consisted of multiple choice items assessing principle knowledge, intuitive understanding, flexible application, and integration of knowledge, which required written responses.

Results showed that students with the ES scored higher on the principle knowledge test than those without, and the same trend existed for IS, but results did not reach significance. On intuitive understanding outcome measures, there was a significant main effect of IS ($p < .05$). For flexible application, there was a significant main effect of IS ($p < .01$), but no significant effect of ES. For the integration of knowledge, IS showed a significant positive main effect ($p < .01$), but again no significant effect for ES was found. Using data from the logfiles, analyses could be conducted to examine how the students interacted with the simulation environment and used the supports. It was found that there was no significant difference between the ES and no-ES groups when comparing experimental quality. However, a significant interaction did arise when students' scores on a recent examination were entered into the equation. It was shown that ES had a marginally significant effect among the high science achievement students ($p = .05$). Overall, learners from all four groups had benefited significantly from the simulation-based learning processes, demonstrating the usefulness of this approach to instruction.

IS was shown to be highly significant in this study. It activated relevant knowledge, enhanced problem representation and hypothesis generation, and elicited more explanation activities from the experiment. This enabled the students to construct a more elaborate understanding of the experiment. Implications from this experiment are that learning depends on the meaningfulness of the discovery experience and instructional support should be considered. Also, instructors must focus on the meaningfulness and logicality of the discovery learning process. The outcome of an experiment depends on the learners' ability to reason and experiment within the learning environment.

Mixed Results Regarding Instructional Methodology

Not all studies come to a clear consensus regarding the validity of direct instruction and discovery learning; some show mixed results. A study by Demant and Yates (2003) examined the attitudes of primary school teachers, working in the mainly lower SES northern suburbs of Southern Australia, towards direct instruction as a viable teaching method using a questionnaire. Very often people's conceptions of this term are in direct contradiction with one another. Whereas, some use the term direct instruction to refer to instructional procedures correlated with learning gains, others view it as a term referring to instances where teacher centered activity is in direct conflict with student centered needs (Rosenshine & Meister, as cited in Demant & Yates, 2003).

Out of 150 questionnaires that were distributed, 58 were returned via mail. Of the respondents, 20 were male and 38 female, with a median length of teaching experience of 15 years. The questionnaire consisted of 11 statements, rated on a 7-point Likert-type scale, which was used to assess the teachers' attitudes. Five of the statements reflected positive views, and six reflected negative views. To assess knowledge, a 20-item checklist was used, in which teachers were asked to check items they considered key components of direct instruction. Out of the 20 items presented, only 17 were items of direct instruction as described by Rosenshine and Stevens (1986), the remaining three items were used as tricks. Teachers were also asked to name the occupations of 20 people, seven of which were direct instruction researchers, to assess their knowledge of researchers.

Nineteen percent of the respondents exhibited varying degrees of negative attitude, and 81% exhibited varying degrees of positive attitude. The one item in which answers dropped below the mean for all teachers was the statement "Direct instruction is an effective method with all students." It was shown that attitudes to direct instruction positively correlated with teachers' years of experience ($p < .01$) and with a checklist which measured knowledge of the components of direct instruction ($p = .001$). Chi-square analysis was used to identify the items on the checklist which discriminated teachers with positive attitudes, which were: teacher states lesson objective; teacher asks many questions; teacher monitors closely to see if students understand; teacher explains things in detail; and teacher uses a good deal of modeling and demonstrating. An analysis of the effects of gender showed that females reported more positive attitudes than males ($p = .01$). No significant relationships were found between awareness of researchers and attitudes or knowledge scores. Out of all of the participants, 70% did not identify any of the researchers, 10% identified one, and 10% identified two or more.

This study indicates that direct instruction is an area of divergent attitudes. The results also garner support for direct instruction, especially with teachers who are aware of what the term refers to. Also, the finding that teachers with positive attitudes are those who are more aware of the research meaning of the term direct instruction, suggests that negative images may be due to misconceptions regarding this term. A limitation is the small sample used. Future research should aim at determining why it appears that male teachers were less positive in their ratings than female teachers on the issue of direct instruction.

Other studies have also shown mixed results, especially with regards to the types of students DI works for. Ryder, Burton, and Silberg (2006) conducted a longitudinal study on the effects of direct instruction on first through third grade students from Milwaukee (MPS) and Franklin Public schools (FPS), which are respectively an urban and a suburban school district. Their study addressed the renewed interest in direct instruction for enhancing reading achievement, as the Department of Education is focusing on systematic and uniform reading instruction, and showed mixed results for this method.

The researchers examined the effects of this form of instruction on students' reading achievement, teacher perceptions, nature of the classroom, and special education referral rate. Of the three MPS schools, one used a DI approach, the second used a mixed-method approach, and the third used the Houghton Mifflin basal reading series. Students in the four FPS schools received DI as well as primary reading curricula. Gates-MacGinitie Reading Tests (GMRT) were used to assess the students in all three grades. In-class observations were conducted by graduate students who assessed classroom variables such as teaching, planning and organization, materials and achievement, student participation, classroom atmosphere, and classroom management/control. All observational data were based on a 5-point Likert-type scale. Teachers were rated as to their activity planning, emphasis on skill development, expectations for high achievement, instructional pace, building on students' prior knowledge, and disciplinary methods. Students were rated on their affect, interest, and level of challenge that the instructional materials provided. Teachers were also interviewed as to their thoughts on the instructional techniques used in the classroom, and filled out questionnaires dealing with components of instruction, special education referrals, and their teaching philosophy.

Results of this study showed that low-skilled suburban readers benefited from a combination of DI and non-DI instruction, while urban students benefited from non-DI instruction. Non-DI students significantly outperformed DI students at grades 1, 2, and 3. This demonstrates that students who received DI during grade 1 exhibited less growth in reading achievement from year to year. Data were then analyzed in terms of the interaction between district and method of instruction. Results showed that DI students in FPS outperformed all groups, including the FPS non-DI students, whereas MPS non-DI students outperformed MPS DI students. This leads to the conclusion that a DI method of instruction may benefit suburban students, but the non-DI method benefits urban students when they are learning how to read. Overall, FPS DI students outperformed all groups in terms of their comprehension skills. Also, DI did not decrease special education referral rates. Analysis of the observation results of the classrooms showed that teachers who demonstrated effective classroom behaviors taught classes that scored higher on the GMRT than did teachers who did not evidence as many of the effective behaviors.

Results of the interview showed that teachers felt that they would have trouble meeting the needs of the children due to the scripted nature of the DI curriculum and the wide variability of their students' abilities in reading. However, many teachers, especially those in suburban areas, felt that DI was a good corrective tool if used in conjunction with other programs. Urban teachers were concerned with DI's lack of sensitivity to issues of poverty, culture, and race, and felt that this mode of instruction disregarded urban student's lack of exposure to life experiences. When the nature of the teachers' lessons was analyzed, it was shown that although DI and non-

DI teachers began instruction in reading very similarly, there was a break between grades 2 and 3. Non-DI teachers focused more on comprehension building during this period of time, whereas DI teachers maintained similar instruction, probably due to the highly scripted nature of the program.

Limitations of the study included the high attrition rate, the small number of comparison classrooms within MPS, as well as the use of a scripted DI curriculum. Many schools have adopted DI methods because they believe it will yield higher reading scores than other methods; however it is the characteristics of the teachers rather than the instruction method which impacts the achievement of students in the classroom. This study also raises issue with the scripted nature of the DI curriculum. The explicitness of the teachers and the ability of them to engage students may be more important than the type of instruction they use.

Swaak, de Jong, and van Joolingen (2004) conducted a study to compare discovery learning with expository instruction using 112 high school physics students. Expository teaching is a teacher-centered approach to learning that parallels the goals and features of DI (Jacobsen et al., 1993, as cited in Magliaro, Lockee, & Burton, 2005). In this study, the discovery learning environment was created in the form of a simulation-based environment, and the expository environment consisted of the presentation of hypertext. It was hypothesized that learners in the simulation condition would acquire knowledge in a way that would allow them to score higher on an intuitive knowledge test. The learners in the hypertext condition would score higher on the recognition of factual knowledge, as measured by an explicit knowledge test. It was also expected that the learners in the simulation condition would have more problems explaining the relations between variables than those in the hypertext condition, as simulations lead directly to intuitive knowledge that is hard to verbalize.

The learning environment contained models of moving and colliding particles, in which the participants could control a number of input variables. The hypertext environment contained graphical displays and pictures. Both environments had the same information and support measures, which consisted of model progression, assignments, feedback, and explanations with equations. The assignments in the simulation environment encouraged learners to perform experiments, whereas those in the hypertext environment encouraged them to have a close look at the equations. The assessments included a definitional knowledge test which consisted of multiple-choice questions aimed to measure recognition of facts, definitions, and equations. A "what-if" multiple-choice test was used to measure intuitive knowledge about the relationships between the variables. A "what-if-why" test was also used to have students explain why an action resulted in a predicted situation. A log of process measures was also kept to record the number of simulation runs in the simulation condition and the number of graph pages viewed in the hypertext condition.

Results demonstrated that the participants in the hypertext condition outperformed those in the simulation on the definition knowledge test, which showed support for one hypothesis. Learners from the hypertext also had an overall higher correctness score in the "what-if" test, which looked at intuitive knowledge, which is contrary to what the researchers initially expected. It was also shown that learning from simulations resulted in quicker response times on this test. Finally, there was an advantage for those students in the hypertext condition on the "what-if-why" test as they had higher correctness scores on the prediction part of the items.

A major limitation of this study is that students appeared to make the hypertext environment active and as perceptually rich as those in the simulation condition, by the frequency use of assignments and feedback explanations. Also, both conditions used directive phrasing in the assignments, which is a feature of DI instruction. The distinctive features of the simulation and hypertext environments were blurred, as the learners made the two environments very similar, turning them into instances of direct instruction. Learners in the discovery environment barely made use of the opportunity to design experiments themselves, and instead used the experiments to produce graphs, the same as the ones available in the hypertext environment. The support provided may have taken away from the discovery character of the assignment condition. Students in the hypertext environment may have outperformed those in the simulation condition because the graphs were already available to them, and they did not have to first generate them following the assignments.

Not only is there contention about the usefulness of direct instruction versus discovery learning, but also with regards to the type of discovery learning that is most effective. Richard Mayer (2004) assessed pure and minimally guided discovery learning and also addressed the constructivist teaching fallacy in his review. He notes that many people feel that constructivist teaching must be restricted to pure discovery methods in order to get active learning. He believes that active learning does not always require active teaching. Instructional methods that promote processing in learners can be enacted in which the learners do not need only hands-on activity or group discussion. He states that pure discovery is not effective, however, minimally guided discovery is. He notes a 1957 study by Kittel in which students were given logic problems. Participants were split up into a pure discovery group, in which they were given no hints; a guided discovery group, which was given the general rule; and an expository group, which was given the rule and the solutions to the problems. The pure discovery group performed the worst, and the guided discovery group performed the best.

Under pure discovery methods some students never learn the rule or find the solution; some guidance is needed. Students may fail to come into contact with the "to be learned" material due to the excessive amount of freedom they are given. Mayer states that students need enough freedom to be active in the learning process, but enough guidance so they can construct useful knowledge. Pure discovery, according to his literature review, fails as a method of instruction; however, this does not mean that constructivism is wrong as a theory of learning. It is useful to have students use hands on activities as long as they are guided in the right direction.

Mayer also asserts that it is difficult to create an effective educational intervention based on constructivism, as it is not an evidence-based or research-based theory. Mayer states that instead of behavioral activities such as hand-on learning, discussion, and free exploration; cognitive activity, such as selecting, organizing, and integrating knowledge should be implemented in the classroom. In these instances the students would be constructing knowledge and learning by thinking (Mayer, 2004).

Present Study

The relative effectiveness of discovery learning as compared to direct instruction is equivocal. Whereas some researchers believe that discovery learning will enable a student to find a deeper understanding (Loveless, 1998, as cited in Klahr & Nigam, 2004), others believe that direct instruction is the only effective method in educating students. Critics contend that discovery learning will often lead to inconsistent or misleading feedback, causal misattributions, and inadequate practice and elaboration (Klahr & Nigam, 2004). Thus the benefits associated with figuring out a problem independently are far outweighed by the roadblocks to learning experienced by those constructing their own knowledge. The research proposed examined the effectiveness of these two instructional styles in a diverse Queens classroom. A science lesson on displacement, taught through the concepts of floating and sinking, was presented to second grade learners using both a direct instruction and minimally guided discovery method approach. An assessment test, as well as a transfer task, was given to students after the interventions to examine which method of teaching enables the students to grasp the content of the lesson to a greater extent.

Previous studies comparing the two methods of instruction have not been generalizable to different populations. This study allows us to determine the effects of instruction on a diverse group of second grade learners who each have different amounts of prior knowledge. This study also addresses the shortcomings of previous studies which either only examined one form of instruction or those which compared the extremes of both forms of instruction. Many studies of discovery learning have no teacher intervention, and thus provide no guiding questions or feedback, which is not the case in most classrooms. Finally, most studies use highly scripted DI curricula when disseminating information to the students. Rather than using a set DI program, the methodology behind this form of teaching, providing explicit guidance and instruction, was implemented as a general approach to classroom instruction. The teacher was provided with a script, which was adapted to meet the needs of her students as she saw fit.

Hypotheses

It was hypothesized that the direct instruction approach would enable students to grasp the science lesson to a greater extent, which would be shown by higher test scores on the science assessment presented after the lesson. Though discovery learning is good in that it involves a "hands-on" approach to learning, which is especially useful in content areas such as science;

guidance is needed. It was expected that in a diverse, multi-lingual, Queens classroom it would be difficult for discovery learning to work. Students would simply fall off task. Furthermore, with such diverse levels of prior knowledge, those less experienced may become lost, frustrated, and prone to adopting misconceptions in a discovery learning environment. The students need explicit instruction that instills basic information within them. The second hypothesis was that these students would be able to complete the transfer task faster, as they understood the concepts better. Finally, the third hypothesis was that as the scores on the float or sink test increase, the time needed to create the boat should decrease.

Method

Participants

Nineteen second-grade New York City public school students participated in this study. Participants were both male and female, from diverse backgrounds and ethnicities. The data of one student was incomplete, and thus omitted from the present study.

Measures

Understanding of float and sink concepts. To measure whether or not students understood the concepts presented, they were given a Float or Sink Test. Students were shown 10 objects and asked to write on a piece of paper "F" for float or "S" for sink. The objects were a key, small rubber ball with a radius of 2", ½" bolt, empty tennis ball can with plastic lid, small glue stick, 2 "eraser, rubber band, thumbtack, 2" toy dinosaur, and a pen.

Transfer task. To measure whether or not students could transfer what they learned from the lesson to another task, they were presented with a 5" x 5" piece of aluminum foil and five pennies in a film container. They were instructed to create a boat that would hold and enable the canister with pennies to float above the water. Students were given a maximum of 90 seconds to figure out how to create the boat, and the time they used was recorded. If a student did not create a boat that floated within 90 seconds, the task was considered incomplete.

This transfer task required students to take the concept of displacement already learned to realize that it affects the ability of the boat to float. They also had to realize that shape can affect the boat. A ball of aluminum foil with pennies will sink, but a canoe shape constructed from the same amount of aluminum foil can float and support the pennies, as it displaces more water. It allows more fluid to be pushed out of the way in relation to its weight. The student should not have curled the edges too much, because the boat would be too small to support the weight. The larger the boat shape, the more water is displaced. If just the flat aluminum foil was used without curling up the edges, the weight of the film container with the pennies would push the foil down slightly, allowing the water onto it, which would enable it to sink. Water must be displaced without getting into the boat. Students were prompted by being told that they were going to build boats out of foil and to think about what they already learned about floating and sinking when constructing their boats.

Interventions

Direct Instruction Group. Students in the direct instruction group first heard background information on how objects sink or float, making sure to stress that it is not the weight of the object, but rather displacement which enables an object to float. The teacher made sure to emphasize the idea that an object will float if it displaces more water than its own weight. (BrainPOP jr., 2007). Students were then presented with a tub filled with water for floating small objects (as an adapted version of the Can It Carry Cargo? Lesson plan (Bonneville Power Association, n.d.). They were given a bag with 10 objects to use for a floating test (large paper clip, pencil, ¾” cube of wood, plastic cup with a height of 2 ½ ”, marker, 1”screw, 5” x 5” piece of aluminum foil rolled into a ball, penny, ping pong ball, and rubber ducky). The teacher went through each of the objects in front of the class, putting them in water, and explaining to the students why they either sank or floated, making sure to stress that weight does not matter, but rather how much water each object displaces. See Appendix A for script used.

Discovery Learning Group. Students in this group were presented with the same tub filled with water and objects as the direct instruction group. Students were given 15 minutes to experiment with the objects and place them into the container. They were instructed to determine which items floated, which items sank, and what they thought made an object float or sink. During this time, the teacher stood over them and reinforced the action of the object. For example, if it floats, she said “Look! That object floated. Why do you think this happened?” This provided the group with some guidance and direction in case they were not familiar with the idea of floating and sinking. See Appendix B for script used.

Procedure

The teacher entered the classroom and explained to students that they were going to learn a science lesson on whether objects sink or float. The teacher divided the class in half by having students go around the room and call out letters A and B in succession. Group A was the direct instruction group and went to the back of the classroom to go through the lesson plan with the teacher’s guidance for 15 minutes with the water and bag of objects. At this time, group B was taken into another corner of the room and read a story by a teacher’s assistant, so as not to interfere with the other group or see what they were doing. The story used in this experiment was "Cloudy With a Chance of Meatballs," by Judi Barrett. After 15 minutes, the groups switched stations. Group A was read the story, while group B experimented with the objects on their own. After both groups finished, the teacher presented a short math lesson, as to have some period of time pass before the assessment phase of the experiment. After this, the float or sink test was administered to the students. They recorded their answers, as well as, their group letter on their paper, which was handed in to be graded and assessed by the researcher. After the sink or float test, students were taken four at a time, to complete the transfer task. They were given 90 seconds in which to construct the boat, and the amount of time it took them to figure it out was recorded. If the child did not figure out how to make the boat float within this time, 90 seconds was recorded as their time. The total time spent in the classroom was approximately 90 minutes.

Statistical Analyses

The two groups outcome scores on the float or sink test, as well as, the time needed to create the boat were compared using two T tests for independent samples. The time needed to create the boat was also correlated, using a Pearson correlation coefficient, to the outcome score on the float or sink test.

Results

Results of the float or sink test showed that the mean of group A, the direct instruction group was 74.44 points, with a standard deviation of 8.819 points. Group B, the discovery learning group had a mean percent correct on the outcome test of 68.89 points, with a standard deviation of 16.159 points. Though the direct instruction group scored higher overall, this result did not reach significance ($p = .157$).

The mean time that group A, the direct instruction group spent on creating the floating boat in the transfer task was 29.44 seconds, with a standard deviation of 25.055 seconds. The mean time that group B spent on the task was 39.44 seconds, with a standard deviation of 29.733 seconds. Group A spent less time on the transfer task overall, however, this result also did not reach significance ($p = .462$).

The time spent on the transfer task was not correlated to the score on the float or sink test ($r = .03$)

Discussion

The results lend support to the first and second hypotheses. The students in the direct instruction group did score higher on the float or sink assessment test, and did perform the transfer task faster than the discovery learning group. However, the results did not reach significance. The third hypothesis, expecting a negative correlation between the float or sink score and time on transfer task, was not supported. This may be due to the fact that most students were able to solve the task in a timely fashion, and did not rely on the concepts learned from the lesson to create the boat. Also, many of the students appeared to copy off one another, which prevented the researcher from determining which student was the one who came up with the idea in the first place, and at what time.

It is important to note that one type of instruction does not fit all students, as individual differences moderate the impact of instruction. Rather than fitting the students to the instructional method, we should alter the teaching method to reach each individual student.

Literature on aptitude treatment interactions demonstrates that different instructional methods benefit different types of students. Findings in 1993 by Kyllonen and Lajoie (as cited in Kirschner, Sweller, & Clark, 2006), indicate that highly structured instructional presentations benefited less able learners and weaker treatments benefited more able learners. It is important to consider how direct instruction may be detrimental to students who have a great deal of knowledge and experience with the body of knowledge being presented. Direct instruction could serve to decrease their motivation for engaging in the task, which would negatively impact their performance. Instructional strategies to optimally reach all of the students should be devised and investigated.

Limitations

There are many factors which may limit the generalizability of the study presented. First, a convenience sample was used. These results may not apply to other geographic locations, or other schools within the district. Results may vary with the makeup of the class.

Second, individual differences confounded the results. Some students may have been taught the ideas behind this lesson at home. Some may also have been able to transfer the ideas from the intervention phase to the testing phase more easily than others, due to inherent individual differences, such as intelligence.

Third, being that the students could not be taken out during the course of the study, some may have learned the concepts being tested by observing the other groups intervention phase. We tried to limit this by reading a story to one group, while the other group was learning, in order to keep them busy with another task.

A fourth limitation is that even though that lesson was presented as one appropriate for a kindergarten classroom, the scientific principle behind it may have been too complex for students to simply discover on their own. The idea of displacement may not have guided the students' approach to answering the outcome task or solving the transfer task, as they still may have been influenced by the misconception that weight alone influences the ability of an object to float or sink.

The idea of the transfer task was that students needed to use the principles learned in the first task, dealing with water displacement, to construct a boat that would hold a container of pennies. If the students balled the aluminum foil closely together near the container, not enough water would be displaced, and the boat would sink. The students had to realize that the boat needed a lot of surface area, leaving only small upturned edges, in order to displace enough water. This would enable the boat to float. A problem with this task is that students may not have seen the connection between the two lessons. They may have just accomplished the task by trial and error. In the future, a think aloud protocol could be used to determine if the students were taking the ideas presented in the earlier lesson into account. However, there would still be a confounding variable as not all students are capable of articulating their thought processes to the same degree.

What was noticed during experimentation was that when the four students were taken to the back of the room to complete the transfer task, the other students tended to just copy the student who was successful first. Many students, who may have not had an accurate idea of how to create a boat on their own, simply followed the ideas of another student. In future studies, the students should be separated into different corners of the classroom.

Educational Implications

Despite the limitations, this study has a great deal of real world value. As shown by the results, direct instruction did indeed improve students' ability to learn from the float and sink lesson. This was probably due to the explicit nature of the lesson and presentation of the information. Such an approach should be used in classrooms when basic concepts are to be taught.

It is important to note that the teaching style used in the direct instruction intervention was not completely teacher-driven. The teacher did interact with the students, rather than just presenting the lesson in a lecture format. The discovery learning intervention allowed for minimal guidance. This is important, as most students learn from a mixture of approaches, and most teachers implement their lessons using a blend of pedagogical techniques.

With the current federal and state mandates related to standards based performance in the schools, it is likely that direct instruction will come back into favor with most curriculum developers. As shown by the research and this study, basic information must be directly and explicitly taught in order for students to master the material and transfer the ideas to other lessons.

Direct instruction can also be implemented on a wide scale, making it especially useful for distance learning with older students (Magliaro, Lockee, & Burton, 2005). As education expands to more areas and is disseminated to increasingly diverse learners, this method of instruction is likely to be used. It allows for students from all over to interact with an instructor and obtain valuable information.

Future Research

While this study did go beyond previous studies looking at realistic uses of both forms of instruction in a diverse classroom, there is still a great deal of work to be done. As already noted in the limitations section, the study should be repeated using a think aloud protocol to examine how the students are solving the transfer task, be it using the principles already learned or through trial and error. With a more accurate insight into their thought processes, the effectiveness of instructional techniques can be more clearly examined.

Also, as mentioned, the students should have been separated during the transfer task into different corners of the room so they would not copy the first successful student. The two intervention groups should not have been kept in the same room during experimentation. This would diminish the chance of one group learning the principles examined from the other group's intervention period. However, this was not possible in the scope of this project, as removing students from the classroom would have been atypical of the common teaching methodology practiced by the instructor, and would have required IRB approval.

Future research should also focus on learners of which English is a second language. Would English language learners need more explicit instruction to understand the principles, or would they be better off using discovery methods? Perhaps, since English is difficult for them, explicit teaching would not effectively reach them.

Research should also be directed at learning disabled populations. These groups of students tend to fall through the cracks in the classrooms when it comes to typical instruction, as they have special needs to be met. Discovery learning may not be sufficient to teach them the concepts behind the experiments they are presented with. Small groups with direct instruction from the teacher may be more beneficial.

The difference between cultures should also be examined. Perhaps, collectivist Asian cultures benefit more from the peer and group dynamics associated with discovery learning, whereas Westerners benefit more from direct instruction. Conversely, as Asian cultures tend to use a strict and direct instructional style, the students may not feel comfortable taking initiative and experimenting using discovery learning methods themselves.

Another issue to address would be to directly compare students from different socioeconomic statuses. Perhaps those who come from a lower socioeconomic status work with their siblings or other family members when completing their assignments, making discovery learning more familiar to them. On the other hand, wealthier students may have traditional tutors, so a direct instruction approach would be what they are more accustomed to.

Finally, different levels of guidance in discovery learning should be compared. Perhaps minimally guided discovery learning is more effective than direct instruction. What is the most appropriate level of intervention on the part of the teacher? The level of guidance which is most beneficial should be determined.

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Appendix A

Teacher Script for Direct Instruction

Today we are going to learn about what makes objects float or sink. It is not just how heavy something is that makes it float or sink. Real boats are extremely heavy, but they still float. Coins, which are light, sink. Floating and sinking has to do with the amount of water that is pushed out of the way or displaced. When you put an object in water, it pushes some of the water away which is known as displacement. The more water that is displaced, the harder the water pushes back at the object. This means than an object can float if it displaces more water than its own weight.

Any boat will sink if you put enough stuff inside it. For example, if you have a small heavy object such as a rock, it will not float because it does not displace enough water. The object needs to push away enough water to be at least the same weight as itself. This means that objects which cover a great deal of surface area, or are more spread out, have a better chance of floating. We are going to see how this works with the following objects: large paper clip, pencil, cube of wood, plastic cup, marker, screw, piece of aluminum foil rolled into a ball, penny, ping pong ball, and rubber ducky.

- For each item ask students; do you think this object will push or displace a lot of water? Does this mean the object will float or sink? After having the students answer this, demonstrate by placing the object in the tub.

Appendix B

Teacher Script for Discovery Learning

Today we are going to learn about what makes objects float or sink. You will be given 15 minutes in the back of the classroom to experiment with the following 10 objects: large paper clip, pencil, cube of wood, plastic cup, marker, screw, piece of aluminum foil rolled into a ball, penny, ping pong ball, and rubber ducky. Your task is to figure out why certain objects sink, and why certain objects float.

- Every time an object floats say, “Look! That object floated. Why do you think this happened?” Conversely, ask students why objects that sink do so. Make sure to point out that smaller objects may be floating, while larger objects may be sinking.