The role of analogies in discovering interactions in inquiry learning tasks: a comparison between students from low, middle and high level of secondary school

Masterthese

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Universiteit Twente
ENSCHEDE
05 Januari, 2014

Abstract

The aim of this study was to investigate to which extent the uninstructed use of analogies fosters the discovery of finding interactions in concrete inquiry learning (IL) tasks. Participants were from three different academic secondary school levels, which engaged in a counterbalanced design, in two IL tasks where they could investigate the influence of five independent variables on a dependent one. The students from each level were divided over three conditions. The first is the single analogy condition, where students had to read a short analogy before performing the IL tasks. The students in the second conditions read two analogies before performing the same IL tasks. The used analogies share the same variable structure as the two IL tasks. And finally a control condition, where participants performed both tasks without an intervention. The cognitive ability of students was measured through a cognitive ability test (CAT), to investigate to which extent cognitive ability mediated students performances and to explore to which extent higher cognitive ability students benefit more from the analogy or analogies as an instructional approach. It was expected that the use of two analogies would result in more frequent discovery of the interaction effects and in higher learning outcomes than the use of a single analogy. In addition, it was expected that higher scores of the CAT will correlate with learning performances and mediate discovering the interactions in the IL tasks. Result showed that analogies foster the discovery of interaction effects to some extent. No differences were found between the use of a single analogy and the use of a double analogy. As expected, higher scores on the CAT correlated with IL performances, but higher cognitive ability students did not benefit more from the instructional approaches as was expected.

Introduction

The present study explores the use of analogies in discovering interaction effects in inquiry learning (IL) tasks. The analogies used have the same underlying variable structure as two IL tasks that a group of secondary school students will perform. In addition, performance of students on a cognitive ability test (CAT) will be used to explore the relation between cognitive ability and IL and between cognitive ability and the effectiveness of the instructional approach.

Reading, writing and arithmetics are the fundamental skills to be taught in school. Besides learning these fundamental skills, researchers agree that education should focus on the development of skills and strategies that enable students to become lifelong learners, and which are necessary to compete in the worldwide economy (Bulgren, Marquis, Lenz, Deshler & Schumaker, 2011). Students need to become creative problem solvers, applying acquired knowledge and skills in new situations. IL allows students to be actively engaged in the process of knowledge acquisition instead of being passive receivers of knowledge from an external agent (De Jong & Joolingen, 1998). Because IL and IL environments enable students to learn science by doing science (Mulder, Lazonder & Jong, 2011), it is an efficient method that enables students to become the creative problem solvers that are currently needed in education. IL is defined by the National Science Foundation (2000) as "an approach to learning that involves a process of exploring the natural or material world that leads to asking questions, making discoveries, and rigorously testing those discoveries in the search for new understanding" (p 2).

IL is considered highly constructivistic (Wilhelm, 2002). Constructivism proposes that learning is idiosyncratic and that providing learners with instructions or strategies during learning is ineffective. According to this approach, minimal guidance is required to give learners, when presented with goals and minimal information, the opportunity to construct their own knowledge with regard of their prior knowledge or experiences, which allows them to become creative problem solvers (Kirschner, Sweller & Clark, 2006). However, Clark, Kirschner and Sweller (2012) state that research in the past half century has revealed the weakness of minimally guided approaches. It seems that minimal guidance during instruction is only effective for experts, and that full guidance is more effective for novel learners. The ineffectiveness of minimally guided approaches for novel learners has to do with the structures of the human cognitive architecture (sensory memory, working memory and long term memory). It seems that unguided approaches do not take the characteristics of working memory and long term memory or the relation between them into account. Because IL imposes a heavy demand on working memory capacity needed for problem solutions, less capacity is available to the accumulation of knowledge in long term memory (Clark et al., 2012).

So, IL cannot be simply used as an effective learning approach without instruction and guidance. In fact, several cognitive skills and strategies need to be developed for IL to be effective. First, knowledge of the scientific reasoning skills, hypothesis generation, experimentation or observation, and evidence evaluation, are important for solving inquiry tasks (Zimmerman, 2007). For this purpose, several training models and programs are developed to support students in the acquisition of scientific reasoning skills. Examples can be found in De Jong and Joolingen (1998). In addition to learning and processing these cognitive skills, learners need guidance through the inquiry process, receiving explicit instruction, feedback and practice (Clark et al., 2012; Quintana et al., 2004). According to Clark et al. (2012) explicit instruction entails the full explanation of required concepts and skills that are necessary to learn. In an example of teaching students how to calculate a new mathematic problem, the teacher may begin by showing a step-by-step solution how to solve the problem, including the how (procedure) and why (concept) behind the procedure. After practice and feedback students should be able to solve the problem on their own. If students master the necessary inquiry skills and strategies, they will be able to transfer the acquired knowledge to new problems. In IL, if students do not receive guidance through the inquiry process they might get frustrated or draw the conclusion that the world cannot be known or is not worth trying to understand (Clark et al., 2012; Kirschner et al., 2006; Kuhn, Black, Keselman, & Kaplan, 2000). However, in a review of Dochy, Segers, Bossche and Gijbels (2003) including 43 studies on IL, it is concluded that in the long term, IL is more effective than direct instruction because students in the IL approaches retain more of the acquired knowledge in the long run. Students in other instructional approaches gained more knowledge than the students in the IL approaches at the time (during task performances), however they were less able to retrieve the acquired knowledge after a period of time. In addition, IL seems to have a positive effect on skill development of students.

Although IL methods are effective and foster learning, several studies have shown that learners have difficulties in performing IL tasks, even after training the required skills. Students have difficulties in choosing the correct variables to work with, they often are unable to generate relevant hypotheses and they often draw the wrong conclusions from experiments (De Jong, 2006; Lazonder, in press; Quintana et al, 2004; Zimmerman, 2000). In order to minimize these problems Quintana et al., (2004) note the importance of scaffolding, where an expert or a person with more knowledge provides assistance to a student to solve problems that otherwise would be too difficult for him or her. Thus, it has been shown that unguided IL or IL with minimal guidance is not very effective, but that learners effectively use processes and deploy strategies at a higher level when guided by an expert (Kirschner et al., 2006; Klahr & Nigam, 2004; Yelland & Masters, 2007). As said, IL is most effective when learners receive instructions for learning the necessary research skills and when IL environments integrate tools to scaffold and guide learners through the inquiry process (De Jong, 2006).

Klahr and Dunbar (1988) studied the core components (hypothesis generation, experimentation and evidence evaluation) of scientific inquiry with a computer- controlled robot tank, named BigTrak. Participant received training about how to use the function keys, except for the repeat (RPT) key. By programming the device, participant had to discover how this key worked. On the basis of this study and previous studies, the authors developed an integrated model of the scientific reasoning process, the SDDS model (Scientific Discovery as Dual Search).The SDDS model appoints that scientific discovery is accomplished by a dual search process. The search during inquiry takes place in two related problem spaces; the hypothesis space (theory) and the experiment space (evidence). The hypothesis space contains students' knowledge and assumptions about a given domain. The generated hypotheses in this space can be tested in the experiment space. The tested hypotheses can be rejected, accepted or refined. The search in these two spaces continues until the student draws his conclusions. Based on experimentation behavior, Klahr and Dunbar characterized learners as either Theorists or Experimenters. The Theorists keep searching in the hypothesis space, testing new hypotheses. The Experimenters, on the other hand, apply a data driven approach, they look for interpretable patterns and relation in their outcomes. A theory-driven approach, which requires prior knowledge, provides students the opportunity to generate testable hypotheses and is more effective and more efficient than an experiment-driven approach (Lazonder, Hagemans & De Jong, 2010; Lazonder, Wilhelm & Hagemans, 2008). The role of prior domain knowledge is important. Lazonder, Wilhelm and Lieburg (2009) state that domain knowledge facilitates IL processes and outcomes. In their study (see also Lazonder et al., 2008), students in a concrete task condition (in which variables were familiar) outperformed students in an isomorph abstract task condition (in which variables had no meaning). The experiments of the students in the concrete task condition more often tested hypotheses, which suggest that participants were able to infer hypotheses from the meaning of the variables.

Besides the importance of hypotheses generation and prior domain knowledge, Zohar (1995) states that variable control is necessary to differentiate between cases in which a variable has a causal effect on the outcome or has no effect. The CVS (Control-of-Variable strategy, Chen & Klahr, 1999) implicates that only the variable of interest should be manipulated while all other variables should be held constant, allowing for valid interferences about the effect of the independent variables on the dependent one. Although control of variables is an essential strategy for scientific reasoning, mastering this strategy does not automatically lead to drawing valid conclusion about e.g. interacting variables (Kuhn, Iordanou, Pease & Wirkala, 2008). Next to the value of variable control, thinking about interactions is also a crucial aspect for accurate scientific thinking. An interaction is present when the effect of one variable is dependent upon the level of another variable (Zohar, 1995). The author describes two strategic competencies that are required for valid interaction interferences. First, the execution of a double comparison, where the two interacting variables (A and B) that consist of two levels each in four ways have to be compared (A1-B1, A1- B2, A2-B1 and A2-B2) and second the control of all other relevant variables (which also have to be held constant during the first comparisons).

Identifying interacting variables is a difficult aspect of IL and the dynamic skill theory (Fischer, 1980) and the Relational complexity theory (Halfords, Wilson & Philips, 1998) acknowledge this complexity. According to both theories, cognitive development depends on relational processing capacity, which increases with age. Children form increasingly complex mental models to better understand the world. The dynamic skill theory predicts and explains changes in both development and variability in learning and problem solving. The theory is based on a step by step skill development through a structure of relational skills (single set, mapping, system, and system of systems), that emerge in cognitive development. A set of five transformation rules (intercoordination, compounding, focussing, substitution and differentiation, see Fischer, 1980) relate these structures to each other through a hierarchic cycle of three tiers (sensorimotor skills, representational skills and abstract skills). The four types of relations, which repeat in each tier, produces movement to higher order versions of relations (see figure 1). A (single) set is a (single) source of variation that can be controlled in each skill (tier). Mapping refers to the ability of relating between two sets in a single skill. System refers to the ability of relating two subsets of each of two sets in a single skill (two components of two actions, which allow a person to control two sources of variation in each set) and system of systems is the relation between two systems in a single skill (Fischer, 1980).

I	Single set	[W] or [X]
II	Mapping	[W — X]
III	System	$[W_{A,B} \leftrightarrow X_{C,D}]$
IV	System of systems	$\begin{bmatrix} W \leftrightarrow X \\ \updownarrow \\ Y \leftrightarrow Z \end{bmatrix}$ or [M]

Figure 1. The Cycle of Four Levels That Repeats in Each Tire (Fischer, 1980, p.486)

Similarly, the Relational Complexity theory proposes four types of relations that progressively increase in complexity. The unary relation is based on a single number of arguments (which correspond to a variable) that must be related to a single source of variety in the same cognitive representation. For example, the fact that Fido is a dog is expressed as: “dog (Fido)” (Andrews, Halford, Murphy & Knox, 2009, p.50-51). Children at the age of one year are able to process unary relations. The binary relation is based on two variables and can be processed at two years (Fido the dog is larger or smaller than another animal, Andrews et al., 2009). The ternary relation is based on three variables and can be processed at five years (Fido is larger than Spike and Sam is larger than Fido, Who is the largest dog?). The quaternary relation is based on four variables (“proportion, 2/3 = 6/9”, where each number is a variable and the answer is 0.67, Benson & Haith, 2010) and children at age of eleven years are able to process these (Andrews & Halfords, 2002; Andrews et al., 2009; Halfords et al., 1998). Interactions include four variables that have to be compared and Halfords, Baker, McCreden, and Bain (2005) state that quaternary relations are the upper limit of human processing capacity.

Although both theories state that even young children can relate the effects of several variables, reasoning about interactions still remains complex (see e.g. Halfords et al., 2005). In the study of Zohar (1995) that focused on characterizing reasoning patterns about interactions, she included experts and novices. The experts (two university professors in physics and philosophy) in the study both showed an operational and a metastrategic thinking level about interactions. The novices on the other hand, were able to draw many limited inferences, which were theory based and theory driven instead being based on the necessary double comparisons that had to be made. Even when finding contradictions between evidence and their prior beliefs, novices stuck to their beliefs by describing their theory in terms of their own experiments and therefore encountered substantial difficulties in drawing valid conclusions. The author identified four types of novices' strategic difficulties in reasoning about interacting factors. The first factor is the lack of a strategy that is necessary for making valid inferences about interacting variables. Typically, participants were aware of the comparisons between the variables that they had to make (the goal), but were unable to use a strategy to separate the causal influence of each factor in relation to the other. The second factor is the lack of the conceptual framework for interacting factors. Participants showed difficulties in generating evidence for interactions between variables, without a conceptual framework in which findings could be interpreted, leading to confusion and many repeated experiments. The third factor concerned a coordination problem. Participants lost their focus by conducting a comparison to estimate an inference regarding one variable but their attention diverted to another variable before an inference regarding the first one was made. Finally, the participants had strategic difficulty in maintaining the necessary control of all other variables, which is necessary for making controlled interaction inferences. The participants showed a similar problem with the difficulty in controlling variables as in the first factor, but at a more complex level. Participants were only able to perform one of the two strategic competencies (the execution of a double comparison and the control of all other variables) that are required for valid interaction interferences.

Learners need explicit training and practice in indentifying interacting variables (Beishuizen, Wilhelm, & Schimmel, 2004). The authors compared the effect of explicit training and practice on IL. The practice approach provided the opportunity to experiment in a computerized IL environment (in two practice sessions), without an instructional approach on IL skills. The training approach focused on teaching students how to validly interpret results of conducted experiments to identify main, irrelevant and especially interaction effects. Both approaches showed positive effects on learning outcomes. Non significant differences were found between learning performance of the students in the second practice sessions and the students in the training group. With respect to the interaction effects no significant differences were found between and within all group comparisons, however students in the training group showed a better understanding of the interaction effects. The number of complete statements that relates the value of the independent variable to the interacting variable was significant higher in the training group (where 26 statements were given) than in the practice group (where four statements were given in each practice session). Although both interventions seemed to be effective in a familiar domain task, students from both groups did not show learning gains in a less familiar domain task. The authors stated that both interventions did not lead to transfer to an unfamiliar domain, probably because prior knowledge could not be activated.

Thus, finding interactions is a difficult aspect of IL for which some form of guidance is probably needed. Perhaps analogies can serve as a tool to enlarge the conceptual framework about interacting variables. If students are presented with interaction effects in an analogy they might be able to recognize and find the interactions in IL tasks. Analogical reasoning is widely used in educational settings. Learning by analogical reasoning has positive effects on the acquisition and restructuring of knowledge (Judy, Alexander, Kulikowich & Wilson, 1988) and leads to creative discovery, problem-solving, categorization, and learning and transfer (Gentner & Smith, 2012). Analogical reasoning is one of the most pervasive cognitive strategies and occurs when a concept or experience parallels another (Judy et al., 1988). An analogy contains a target and a base, where the target relates to an unfamiliar domain and the base to a familiar domain (Dagher, 1995). The familiar domain serves as a model one can understand and use to draw new inferences about a less familiar domain (Gentner & Smith, 2012).

Juthe (2005) makes a distinction between two types of analogies; the same-domain-analogy, where not only the elements of the different objects in target and base are the same but are also from the same domain, and the different-domain-analogy, where the elements are from a different domain and needs to be transferred to the required domain. An example of a same domain and a different-domain analogy is given in Gick and Holyoak (1980), Holyoak (2012) and Ruiz and Luciano (2011). A problem concerning a stomach tumor (Duncker, 1945), where a high intensity of X-rays will not only destroy the tumor but also the healthy tissue around it, and low intensity of X-rays which will have no effect on both, can be solved with a same domain analogy, when compared to a successful treatment of a cardiologist of a cardiopathy. The analogical relations between both diseases would be recognized by the doctor by studying their common elements. In a different domain analogy, the stomach tumor problem could be solved by comparing it to the source analogy that was used in a study of Gick and Holyoak (1980). In this study, a story was given about a general who tried to capture a fortress but could not send his army across the same road. Therefore, he sends his men in several small groups on different roads to arrive at the same time and capture the fortress. The elements in this analogy are not related to the medical domain and the common elements need to be generalized and transferred to the medical domain to be functionally equivalent to the medical treatment, and to see that several low intensity rays should be more effective to destroy the tumor instead of the high intensity rays which would destroy also the healthy tissue. The distance between the base and the target features in analogies determines the use of the analogies. Analogies based on superficial features are easier to transfer to a new situation, especially in the same domain, and are often used by children and novices. Experts on the other hand, base their analogies more on structural and relational similarities (Dunbar & Blanchette, 2001). Gentner and Smith (2012) state that reasoning by analogy involves identifying a common relational system between two situations and generating further inferences driven by these commonalities. These commonalities may include concrete property matches between the situations, but more importantly, there must be an overlap in relational structure. This relational mapping (which involves a process of aligning the two situations based on their commonalities) is the essence of analogy use.

Tunteler and Resing (2007a) compared the effect of explicit instruction and practice, with regard to the use of analogies. They found that teaching young children how to use analogies is more effective with analogical problem solving than the uninstructed use of analogies, although they also found some effect on analogical problem solving of the use of analogies in absence of instruction In an earlier study, they found that even four year old children were able to spontaneously apply analogical solutions from story problems to physical tasks (Tunteler & Resing, 2002) and several years later they concluded that regardless of age, children's use of analogies improves with practice, even without an explicit instruction (Tunteler & Resing, 2007b).

In another study where the use of analogy was examined, Judy et al. (1988) tested the effects of two instructional approaches in analogy training in gifted and non-gifted sixth- grade students. The students were assigned to three conditions; direct instruction treatment, inquiry approach treatment and a control treatment. The students in the treatment conditions received analogy training via either direct instruction or an inquiry approach. The students who received a direct instruction, which was based on Sternberg's (1977) component processes of analogical reasoning (encoding, inferring, mapping and applying), outperformed the student in the inquiry approach. In the inquiry approach, students received questions that led them through the tasks. Both treatment groups performed better than the students in the control group. The authors hypothesized that the gifted students would perform better under an inquiry approach, because they would have more freedom to question, explore and speculate about the content. This hypothesis could not be confirmed, the authors stressed that this may due to the novelty of the analogical reasoning in the elementary school curriculum. However, the gifted students outperformed the non-gifted student in all three conditions.

The aim of the current study is to examine the role that analogies have on finding interaction effects in IL tasks. In addition, the role that cognitive ability has on finding the interactions with regard of the used analogy or analogies will also be explored. The cognitive ability of students will be tested with a cognitive ability test (CAT), which is also used in a study of Wilhelm (2002). In this study he tested the influence of domain knowledge and cognitive ability on IL performances in different age groups. Four IL tasks were performed, two in the Biology domain and two in the Geography domain. Participants were tested on cognitive ability and domain knowledge (for each domain), before performing the IL tasks. The author found that higher scores of the CAT mediated IL outcomes. The correlations between cognitive ability and comprehension score of each task (.59 and .61) were larger than the correlations between domain knowledge and comprehension sores of the tasks in the current domain (.46 and .41). The correlations between domain knowledge and cognitive ability were .78 and .75. In line with findings of Halfords et al., (1998) he also found that learners were not able to discover interactions before the age of twelve.

Many studies have been conducted that explored the relation between different abilities and IL performances. For example, Howard, McGee, Shin and Shia (2001) conducted a study that evaluated Sternberg's (1985) triarchic theory of intelligence in context of an IL environment. According to this theory, there are three types of interdependent abilities. The first is the analytic ability, which is needed for analyzing, evaluating, explaining and comparing (the ability to learn from context and reason inductively). The second is the creative ability, which is needed for designing, discovering and inventing and thus for problem solving in unfamiliar situations (the ability to cope with novelty). The last ability is practical ability, which is needed to utilize, implement and apply problem solving processes in everyday situations (the ability to solve realistic problems). The authors tested the students and classified them as analytic, creative or practical. All students performed the same IL tasks. The authors found that high practical students were more capable in solving IL tasks. These students showed larger content understanding and greater transfer effects of problem solving skills. The high analytical students showed, as expected, substansive content understanding. However, they did not seem able to transfer problem solving skills. The high creative students were able to construct a strategy on problem solving skills, but showed no performance and thus no content understanding. According to Sternberg (1990) practical intelligence and general intelligence correlates only low, whereas practical intelligence and analytical intelligence show high correlations. There are multiple different conceptions about general intelligence, but it seems that intelligence test scores do predict school and job performances to some extent (Neisser et al., 1997). Overall, as Stel and Veenman (2007) describe, researchers diverge in their conceptions about intelligence but all agree that intelligence and learning are closely related.

In another study where ability level was included as an independent variable, Zohar and Peled (2008) found that explicit teaching of metastrategic knowledge had positive effects on student's strategic and metastrategic thinking regarding the CVS. Metacognition implies the presence of general knowledge about cognitive procedures that constitute higher-order thinking skills and strategies (which are comparable to the scientific reasoning skills), such as formulating and testing hypotheses, identifying hidden assumptions and drawing valid conclusions, (Zohar & Peled, 2008). The authors made a comparison between high and low achieving fifth grade elementary school students (school achievement scores of three subjects; Arithmetic, Science and Language were used to classify students achievement level). Students from each level were assigned to an experimental group (which received a metastrategic knowledge intervention) or a control group (which were taught about the domain of the task). Both groups performed the same two IL tasks, where students could conduct experiments to find out the causal effect of five independent variables on a dependent one. The authors hypothesized that the intervention would affect students from both achievement levels, but lower achieving students would make more progress. Result showed that the high achieving students from both conditions outperformed the low achieving students on the pre-test. The post-test scores of the low achieving students from the experimental group were almost equivalent to the scores of the high achieving experimental group students (although high achieving students from the experimental group faster and more often reached the maximum frequency of valid interferences) and higher than the high achieving control group students. So, only the first part of the hypothesis could be confirmed, explicit teaching had a positive effect in both achievement level groups. Furthermore, metastrategic knowledge instruction seems to be a valuable teaching strategy, especially for low achieving students.

Besides the importance of metacognitive skillfulness, there is evidence that also intellectual ability, especially general and spatial reasoning abilities and IL performance are related (Prince & Felder, 2006; Stel & Veenman, 2010; Veenman & Spaans, 2005; Veenman, Wilhelm & Beishuizen, 2004; Wilhelm, 2002). Although intellectual ability and learning performances are related, several authors found a larger impact of metacognitive skillfulness on IL performances than intellectual ability and that metacognitive skillfulness develops parallel with intelligence and increases with age (Stel & Veenman, 2010; Veenman & Spaans. 2005; Veenman, et al., 2004). The threshold of the problematicity theory (Elshout, 1987) suggests that task complexity causes changes in patterns of correlation between intellectual ability, metacognitive skillfulness and learning outcomes. Prins, Veenman and Elshout (2006) examined these patterns within a computerized IL environment with three different task complexity phases (easy, intermediate and complex). They distinguished between novice and advanced learners with low and high levels of intellectual abilities. The intellectual ability of the students was evaluated by six tests which characterize five primary intelligence factors; inductive reasoning, sequential reasoning, quantitative reasoning, verbal ability and closure flexibility. Participant performed a pre-test, an IL task and a post-test. Both test included three types of question, two qualitative (WHAT-IF) questions and one quantitative. The qualitative questions contained conditions (a depicted situation), action (value change of an independent variable) and predictions (value change of a dependent variable). Participants had to discover the effect of the independent variables on the dependent one. The findings showed that advanced and novice learners' metacognitive skillfulness was the most important determinant for learning outcomes. In the easy phase this was the case for novice learners and in the intermediate phase for advanced learners. The intellectual ability of advanced learners was modestly correlated with learning outcomes in the easy phase and high in the complex phase. Their prior knowledge was the strongest determinant for learning outcomes in the easy phase. The authors concluded that metacognitive skillfulness is essential for learning when learners are at the boundary level of their knowledge. While intellectual ability and metacognitive skillfulness are related to some extent, they have an independent impact on qualitative learning outcomes at an adequate level of task complexity. Further, the difference between pre-test and post-test scores showed that novice learners had larger learning gains than the advanced learners, which can be explained by lack of prior knowledge before experimenting in the IL task.

The focus in this study is on the instructional effect that analogies may have on finding interaction effects in IL tasks for students from different cognitive ability levels. For example, descriptive analogies in the form of a story may serve as guidance for choosing the right target variables and provide a strategy to find the causal influence of each factor in relation to another. A distinction will be made between the role of a single analogy and the role of two comparable analogies. The usage of two analogies is to provide a deeper understanding of the connection between the two situations. This analogical connection occurs at a level of similarities when the relations in the first analogy are compared with the relations in the second analogy (Biela, 1991).There are several types of analogies that communicate science concepts in a powerful way. Examples can be found in Dagher (1995).The two created analogies are presented in the form of a story and can be classified as procedural, different domain analogies because they refer to procedures in the way that science should be performed (Dagher, 1995). They include a step by step explanation of how to investigate and familiarize students with interacting factors. Perhaps, if familiarizing students with interactions in a particular domain, they probably will be able to transfer these to a different domain in the IL computer tasks.

To investigate to which extent the uninstructed use of analogies foster the discovery of interaction effects in concrete IL tasks, participants were assigned to two experimental conditions and one control condition. In the first experimental condition students received an analogy to study before performing two IL tasks. The second experimental group received two analogies before performing the two IL tasks. Finally, the control condition performed the IL task without an intervention. It is hypothesized that the use of a single analogy and the use of a double analogy will foster the discovery of the interaction effects. Further, connecting the similarities of the two analogies is hypothesized in more frequent discovery of the interaction effects and in higher learning outcomes than the use of a single analogy.

To create a representative group and to distinguish between academic achievements levels, students from three different academic school levels participated in the study. The students were from T (VMBO Theoretische leerweg[1]), TH (VMBO-Theoretisch /HAVO)[2] and HV (HAVO-VWO)[3], which will be respectively classified as low, intermediate and intermediate/high ability. CAT scores will be used as a measure for intellectual ability. First, the cognitive ability of students will be used for comparison between the three conditions, to test if cognitive ability level of students is equally divided across conditions. Second, CAT scores will be used to explore to which extent higher cognitive ability students benefit more from the analogy or analogies as an instructional approach. It is expected that higher scores on the CAT correlate with IL performances. Because discovering the

[1] Vocational Theoretical program of secondary school.
[2] A combination of the vocational theoretical program and a High level of secondary school program.
[3] A high level of secondary school program.

interaction effects is the most difficult aspect of the tasks it is hypothesized that higher CAT scores mediate discovering the interactions in the IL tasks.

Method

Participants

Eighty-three first grade secondary school students participated in this study (42 boys and 41 girls). The students were from three different academic achievement levels, T (low), TH (intermediate) and HV (Intermediate/high) and came from three different schools from a middle large city in the Netherlands. The sample consisted of 21 students from T (M=12.48 years, SD: .60), 32 students from TH (M=12.44 years. SD=.50) and 30 students from HV (M= 12.33 years, SD=.48). To create homogenous groups, participants were stratified by gender and class level and were assigned to two experimental conditions and one control condition. There were 29 students in the single analogy condition (1A), 28 students in the double analogy condition (2A) and 26 students in the control condition, performing the computer tasks in a counterbalanced design. This results in eighteen groups. The 1A condition consisted of 4 boys and 3 girls from T, 5 boys and 7 girls from TH and 4 boys and 6 girls from HV. The 2A condition consisted of 5 boys and 2 girls from T, 6 boys and 4 girls from TH and 5 boys and 6 girls from HV. Finally, the control condition consisted of 3 boys and 4 girls from T, 5 boys and 5 girls from TH and 5 boys and 4 girls from HV (see Table 1).

Table 1

Frequencies of Participants in Experimental and Control Condition

Class level	Computer task sequence	2 Analogies group	1 Analogy group	Control group	Total
T	Peter-Plant	4	3	4	11
	Plant-Peter	3	4	3	10
TH	Peter-Plant	5	6	5	16
	Plant-Peter	5	6	5	16
HV	Peter-Plant	5	5	4	14
	Plant-Peter	6	5	5	16
Total		28	29	26	83

Note; T refers to VMBO Theoretische leerweg (low), TH refers to VMBO-Theoretisch /HAVO (intermediate) and HV refers to HAVO-VWO (intermediate/high).

Materials

Cognitive ability test (CAT)

The cognitive ability of participants was assessed with aid of a test battery consisting of four subtests: Word Analogies, Number Series, Abstract Syllogism and Hidden Figures.

Since inquiry tasks call upon induction, they therefore rely on general and spatial reasoning abilities (Prince & Felder, 2006). For both factors tests were included (Veenman et al., 2004). The subtests Word analogies, Number series (Elshout, 1976) and Abstract syllogisms (Conclusions, Elshout, 1976) assess general reasoning ability. The subtest Hidden Figures (Flanagan, 1951) measures spatial reasoning and deductive reasoning ability (Carroll. 1993).Word analogies and Number series assess the ability of inductive reasoning (Carroll, 1993). Wilhelm (2001) and Veenman et al. (2004) have shown that performance on these tests correlates with performance on IL tasks.

Word Analogies exists of 40 statements. In each statement three words are given, where the first two words have a certain relationship. Between the third word and one of five possible answers the same relationship exists. For example: hand: finger = foot: .. . Which word belongs on the dotted line? Wrist, toe, ankle, arm or leg? (toe) Participants have six minutes to complete this test.

The Number Series test consists of 45 rows. In each row, five numbers are given and their order follows a specific rule. Applying this rule produces a sixth number that should be picked from five possible answers. For example: 2 4 6 8 10? Which of the following numbers is correct? 11 12 13 14 15 (12). Participants receive 12 minutes to complete this test.

In the Abstract Syllogisms test the relations between symbols A, B and C are given and participants need to pick a correct statement that can be inferred from these relations. The test consists of 50 items and the relations are represented by the symbols $<$, $>$, $\leq$, $\geq$ and $=$. For example: $A = B > C$. Which is correct? 1) A is smaller than C, 2) A is larger than C, 3) A is smaller than or equal to C, 4) A is larger than or equal to C and 5) There is too little information (2). Participants receive nine minutes to fill in this test.

Finally, the Hidden Figures test consists of two parts of sixteen items. Participants are given five simple figures, one of these five figures fits in a more complex figure. The simple figures are indicated with the letters A to E and participants need to pick the correct one (see Figure 2). For each part of the test participants receive ten minutes. Due to time constraints, only the first part of this subtest was administered.

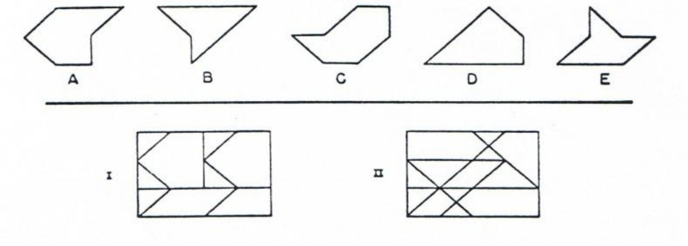

Figure 2. Two Example Items of the Subtest Hidden Figures.

Computer tasks

The computer tasks were configured in FILE (Flexible Inquiry Learning Environment; Hulshof, Wilhelm, Beishuizen & Van Rijn, 2005). In FILE, students can conduct experiments to discover the effect of five independent variables on a dependent one. All participants performed two tasks, the Plant growing task and Peter bikes to school task (Hulshof et al., 2004; Wilhelm et al, 2005). In the Plant growing task, participants can determine the effects that variables have on the height of the plant. The height of the plant is the dependent variable and can reach the following values; 5, 10, 15, 20 or 25 centimeters. This growth can be influenced by five given independent variables; 1) the use of water, either once or twice per week; 2) using insecticides or not; 3) putting dead leaves in the flower pot or not; 4) the location of the plant, inside the house, on the balcony or in a greenhouse, and 5) the size of the flower pot, small or large. The variables 1 and 5 interact. Giving water once a week in a small flower pot has a positive influence on the height of the plant. When the plant is watered twice a week, it will drown. In the large flower pot, watering the plant once or twice water per week does not influence the height of the plant. Variable 4 has a main effect, placing the plant inside the house has a negative influence on the growth and placing the plant on the balcony and in the greenhouse has an equally positive effect. Finally, the variables 2 and 3 are irrelevant.

In the second task, Peter bikes to school, the participants need to discover the effects that five variables have on the time that Peter arrives at school. The number of minutes that Peter arrives to late at school is the dependent variable. This can take the following values, 0 minutes (in time), 5, 10, 15 and 20 minutes. The time that Peter arrives at school may depend on five variables: 1) type of bicycle, a normal bicycle or a race-bike; 2) eating breakfast at home or on the bike; 3) riding with his friends, alone at his own pace or alone as fast as he can; 4) taking only the books he needs for that day or some extra just in case and 5) the type of shoes, ordinary ones or sneakers. The variables 1 and 2 interact. Eating breakfast on the race-bike has a negative effect, whereas eating breakfast at home and taking his race-bike is his best option. On the normal bicycle, eating breakfast at home or on the bike does not make a difference. Variable 3 has a main effect, riding with friends has a negative influence on the time, while riding alone in own pace or as fast as he can makes no difference. Finally, the variables 4 and 5 are irrelevant.

Participants received a task instruction that they had to read carefully before performing the computer tasks. A summary of the goal of the task and the instruction of how to conduct the experiments in the learning environment were given. In the task instructions the students were informed that they had to discover the effect that five independent variables had on the dependent one. An example of one conducted experiment was provided for each task. After reading the task instruction, students were able to ask questions if necessary.

Pre-test and Post-test

To assess prior beliefs, a pre-test was administered (see Appendix 1). A paper and pencil response form including six open questions was made for each computer task. The first five questions referred to beliefs about the effects that the independent variables had on the dependent one. For instance, the first question on the plant growing was: “You can choose between either giving the plant once or twice water per week. What effect do you think watering the plant either once or twice per week has on the height of the plant?” The sixth question asks for any additional beliefs that students might have about the mentioned factors. This question was used to check if any participant proposed interactions. In the post-test (see Appendix 2) participants wrote down their findings, it was identical to the pre-test.

Analogies

In the analogy stories, a character investigates the effect of three input variables on one output variable, where he defines a problem, generates hypotheses, conducts experiments and draws conclusions from these results. The character systematically conducts experiments, by changing one variable at a time. By chance he discovers a contradiction with previous findings. After further investigation he discovers an interaction effect between two variables. The first analogy is about a swimmer, named Leo who attempts to figure out how to win his weekly swimming competitions by investigating three factors; location of swimming competition, either away or at home, extra training, either two or three times per week and encouragement or not of his girlfriend (see Appendix 3). The second analogy is about a little girl who is afraid to sleep alone in her bedroom. Her mother tries to figure out the effect of three factors (door open or closed, using a night light with two different modes and the company of a “super bear” for protection) that would help the girl to lose her fear of sleeping alone in her bedroom (see Appendix 4). Both analogies share the same variable structure as the inquiry tasks and provide an implicit step by step research model of how to investigate, but will not be explicitly discussed with participants. This to investigate the uninstructed use of analogies on finding the interaction effects in the IL tasks. Before reading the analogy or analogies participants will receive a hint that the story or stories will be helpful in performing the IL tasks. Gick and Holyoak (1980) found that when students receive a hint that the story will be helpful in generating a correct solution to the problem solving task is more effective than reading the same story without a hint. After reading the story or stories participants will receive a short verbal summary that emphasize the main and interaction effect in the analogy. For the two comparable analogies the similarities of the interaction effects of both analogies will also be emphasized to make sure that an analogical connection occurs (Biela, 1991). In contrast to the computer tasks, the analogies do not include irrelevant variables. Participants will not be familiarized with the irrelevant effects and need to discover these on their own. This, to maintain the characteristics of IL to some extent.

Procedure

The study consisted of two individual or group sessions and took place in a period of five weeks, mainly during school hours. The students received a brief explanation of the purpose of the study and participated voluntarily, with prior consent of their parents or guardians. In the first week, all students performed the CAT in one session. The second session was performed in a period of three weeks, where students from each class level and each condition participated separately, which led to nine separate sub-sessions. In the second week the control group performed the second session, which contained the pre-test, computer tasks and the post-test. In the third week the 1A group performed the second session and the 2A group did so in the fourth week. The fifth week contained catch-up sessions for students who were absent at one of the sessions in the weeks before. The second session took place during homework hours. To prevent that student would inform each other about the used analogy or analogies between sessions this order was chosen. Students were asked not to share their findings with their peers that still had to perform the tasks. Eight students were tested individually in a home environment. These participants fitted the target groups but came from the informal network of the researcher.

In the first session, students were given a few minutes to read the instruction per CAT subtest. After reading the instructions they could ask questions. The researcher kept time and made sure that students did not collaborate. The CAT took an hour to complete.

In the second session students in the experimental groups received one or two analogies. In the *single analogy (1A) condition* participant first studied the instruction of the computer tasks (see Appendix 5) and filled in the pre-test. After the pre-test they received an analogy to read. They were told that the analogy would be helpful in performing the computer tasks. After students finished reading the analogy the researcher gave a summary of the analogy which emphasized the interaction effect, to be certain that students understood the interaction. In this summary, the effects of the three independent variables (location of swimming competition, either away or at home, extra training, either two or three times per week and encouragement or not of his girlfriend) on the dependent one were explained. At first, location of swimming competition appeared to make no difference. The effect of additional training has a positive effect on Leo's average swim time with no difference between two or three time's trainings a week. Finally, the encouragement of his girlfriend has a positive effect. However, when the story tells about Leo's girlfriend getting sick and forced to stay at home the effects change. After further investigation there seems to be a connection between encouragement of his girlfriend and the location of the swimming competition. Leo can win home matches without encouragement but in out matches this encouragement seems to be needed. Perhaps he feels at ease at his own location where he knows most spectators, whereas in a strange location he does not feel at ease and therefore he needs the encouragement of his girlfriend. Finally, the students were told that during task performance, they could reread the analogy story if needed. Then students performed the two computer tasks. Half of the students first performed the Plant Growing task, followed by the Peter

Bikes to School task and the other half did this the other way round. During the tasks, students could note their findings on the post-test response form. They were instructed to perform at least fifteen experiments, to increase the chance of finding the interaction effect. Students received one hour to complete the computer tasks and the post-test.

In the *double analogy (2A) condition* students received two analogies to read before performing the computer tasks. The two analogies had the same variable structure. The analogy that was used in the 1A condition was also used in this condition. The researcher provided the students with a summary of both analogies and emphasized the similarities of the interaction effects in both analogies. The effects of the three variables in the second analogy seemed at first that keeping the door open or close makes no difference. The night light works, with no difference between normal or bright light and super bear has a positive influence. However, when the story tells about the night light breaking down, these effects appear to be different. After further investigation there seems to be a connection between super bear and an open or closed door. The door open alone does not have a positive influence, unless super bear is present. This since super bear needs a bit of light to be able to protect. The interaction between the encouragement of Leo's girlfriend and the location was isomorph to the interaction between an open or closed door with the presence of super bear. Finally, the students received a comment that during performance on the computer task they could read the stories again if needed. In the control condition students only performed the computer tasks without an intervention.

Scoring and Data analyses

For the CAT participants received one point for each correct answer. Missing answers were coded as wrong. Participant could gain 40 points for Word Analogies, 45 points for Number series, 50 point for Abstract Syllogisms and 16 points for Hidden Figures.

Participants could gain a total of nine points for each computer task. One point for each correct answer to the questions about the effects of the irrelevant variables, three points for the effect of the independent variable with a main effect and four points for the interaction effect. For the main effect, three statements represent full comprehension of the main effect (three points, one point for each statement). For instance, the components in the plant growing task are: 1) Placing the plant inside the house has a negative influence on the growth, compared with the greenhouse; 2) Placing the plant inside the house has a negative influence on the growth, compared with the balcony and 3) The greenhouse and the balcony have an equal positive effect. The intermediate comprehension score may consist of either of one or two of these correct statements.

In each task two irrelevant variables are present, participants received one point for each if answered correctly. In the plant growing task the usage of insecticides and putting dead leaves in the flower pot have no influence on the growth of the plant. Because these questions only could be answered right or wrong, no distinction will be made between full and intermediate comprehension, but only in finding one, two or no irrelevant variables.

In each computer task, an interaction effect is present between two variables. There are four statements that describe the interaction effect (see Wilhelm & Beishuizen, 2003). For instance, these statements in the Plant growing task are; 1) watering the plant once a week has a positive influence on the height of the plant in a small flower pot, 2) watering the plant once a week has a large positive effect on the height of the plant in a small flower pot compared to a large flower pot, 3) giving the plant twice water per week in a small flower pot has a large negative effect on the height of the plant and 4) the use of water either once or twice water per week in a large flower pot has no influence on the height. If students described these four statements correctly a full comprehension score of four points was given. An intermediate comprehension score of two points was given for the presence of three of these statements. When students described only two of these statements or less, their responses were classified as no identification. This was for instance the case if students described the effect of water (either once or twice a week) in a small flower pot correctly without mentioning the effect of water in a large flower pot or without comparing the effect of a small flower pot with a large one. No distinction was be made between wrong and missing answers.

Interrater reliability measures using Cohen's Kappa statistics showed a mean agreement percentage of 82 % for the total post-test scores (both computer tasks combined) and a mean agreement percentage of 88% for the total pre-test scores. Measures on the different effects that could be found showed a Kappa of .87 for the irrelevant effects, .91 for the main effects and 1.00 for the interaction effects on the post-test. For the pre-test Kappa's statistics showed a kappa of .91 for the irrelevant effects and .92 for the main effects. Because no interaction effects were proposed in the pretest no Cohen's Kappa statistics were computed.

First, total CAT scores (the four subtest combined into one scores) were used for comparison across the three conditions. An alpha level of .05 was used for all statistical tests. The Shapiro-Wilk test showed that total CAT scores were normally distributed in each condition. The maximum total CAT score is 151 points and the total mean was 60.95 (SD = 13.7) with a minimum of 33 and a maximum of 100 points. ANOVA was used to test for any differences between conditions on cognitive ability. Total CAT score, did not differ significantly between the three conditions (F (2, 80) = 0.35, p = 0.71. The mean scores of the three conditions were 61.04 (SD=11.45) for the control group, 59.41 (SD=14.36) for the 1A treatment group and 60.95 (SD=15.00) for the 2A treatment group.

Second, correlations between CAT scores were analyzed, the Pearson correlation coefficient between the subtests showed a positive correlation between the four subtest scores. A positive, significant correlation was found between Word Analogies and Number series $r(83) = .38$, $p < 0.001$, Word Analogies and Abstract Syllogisms, $r(83) = .55$, $p < 0.001$ and Word Analogies and Hidden Figures, $r(83) = .23$, $p < 0.05$. Also a positive significant correlation was found between Abstract Syllogisms and Number series, $r(83) = .41$, $p < 0.001$ and Abstract Syllogisms and Hidden Figures, $r(83) = .33$, $p < 0.001$. A positive but non-significant correlation was found between Number series and

Hidden Figures, *r*(83) = .09, p = 0.44. Because not the complete test of Hidden Figures was taken and the correlations between Hidden figures and the other subtest are marginal, the scores of Hidden Figures will not be included in further analysis.

Results

To test if learners showed learning gains, irrespective of the three different conditions, pre-test and post-test scores were analyzed for each computer task individually. The difference between the post-test scores and the pre-test scores is the learning gain score. Results revealed learning gains during task performance for both tasks. The mean scores for the Plant task were 1.04 (SD = .83) for the pre-test and 2.82 (SD = 2.12) for the post-test. The mean scores for Peter task were 1.45 (SD = .89) for the pre-test and 3.14 (SD = 2.08) for the post-test. Shapiro-Wilk test showed that the pre- and post-test scores of both computer tasks were non- normally distributed. Therefore a Wilcoxon Signed Ranks test was performed. Test statistics showed learning gains (post-test minus pre-test scores), on both tasks, $z = -6.110$, $p < .001$ for the Plant task and $z = -6.113$, $p < .001$ for the Peter task.

To explore the effect that analogies had on student's performance, pre-test, post-test and learning gain scores, for each task were analyzed. Statistics of the pre-test, post-test and learning gain scores for each condition are depicted in Table 2. Further analyses will be performed with learning gain scores. Shapiro-Wilk-tests showed that learning gain scores on both computer tasks were normally distributed, except for the Plant growing task in the 1A group, $S\text{-}W = 0.921$, $df = 29$, p= 0.03 and for Peter Bikes to school task in the 2A group $S\text{-}W = 0.894$, $df = 28$, p < 0.01. Levene's statistics showed a non-normal distribution of learning gain scores for the Plant Growing task (p = 0.03) and a normal distribution for the Peter task (p = 0.51). The non-parametric Kruskal-Wallis test showed that learning gains on the Plant Growing task (χ^2 (2, N = 83) = 1.85, p= 0.40) did not differ between the three conditions. ANOVA was performed to test for differences on learning gains between conditions for the Peter task. Test statistics (F (2, 80) = 1.28 p = .28) also revealed no differences in learning gains between conditions

It was expected that higher scores on the CAT correlate with IL performances. To test to which extent cognitive ability and IL performance are related, learning gain scores were correlated with CAT scores. Pearson correlation analysis showed a positive significant correlation for Peter bikes to school task $r = .41$, p < 0.001 and a positive significant correlation for the Plant growing task $r = .23$, p = 0.04. As expected, cognitive ability and IL performance are related to some extent. To test which subtest of the CAT is mostly related to learning gains, learning gains of both computer task were combined into one score. The correlations between learning gains and the subtests, in descending order were: $r = .43$, p <0.001 for Abstract Syllogisms, $r = .31$, p < 0.01 for Number series and $r = .28$, p < 0.01 for Word Analogies.

To test if cognitive ability mediates the effect of the analogical instruction, the student group was split in two. The maximum total CAT score, without Hidden Figures is 135 points and the total mean was 57.47 (SD = 12.9) with a minimum of 29 and a maximum of 93 points. Students with a score above 60 points on the CAT were classified as high cognitive ability students (N = 42) and students with a score of 60 or below as low cognitive ability students (N = 41). In Table 3 the means, standard deviations for learning gains scores are depicted for high and low cognitive ability students for both tasks. An independent sample T-test was used to test for differences between learning gain scores of high and low cognitive ability students. High cognitive ability students had significant larger learning gain scores (M= 2.24, SD= 2.19) than the low cognitive ability (M = 1.32, SD = 1.94) students $t(81) = -2.03$, $p < 0.05$ for the Plant Growing task and $t(81) = -3.49$, $p < 0.01$ for the Peter bikes to school task (M= 2.45, SD= 2.39 for high and M= 0.93, SD= 1.47 for low cognitive ability students).

ANCOVA was performed to test for differences in learning gains between conditions, where CAT scores were used as a covariate. For the Plant Growing task, a marginal significant main effect was found for cognitive ability and learning gains ($F(1,82) = 3.78$, $p = 0.06$. No main effect was found for condition ($F(2,80) = 0.05$, $p = 0.95$ and no interaction effect was found between cognitive ability and condition ($F(2,80) = 0.07$, $p = 0.93$. For the Peter tasks, a significant main effect was found for cognitive ability and learning gains ($F(1,82) = 14.40$, $p < 0.001$. No main effect was found for condition ($F(2,80) = .07$ $p = 0.94$ and no interaction effect was found between cognitive ability and condition ($F(2,80) = 0.04$ $p = 0.96$. So, although learning gain scores of high cognitive ability students are larger than learning gain scores of their lower cognitive ability counterparts, these students did not seem to profit more from the analogical instruction.

Table 2

Means and Standard Deviations of Pre-test, Post Test and Learning Gain Scores

	Control Group	1 Analogy Group	2 Analogies Group
Plant task			
Pre-test scores	0.96 (0.77)	1.03 (0.68)	1.11 (1.03)
Post-test scores	2.65 (1.67)	2.66 (2.32)	3.14 (2.31)
Learning gains	1.69 (1.44)	1.62 (2.38)	2.04 (2.38)
Peter task			
Pre-test scores	1.58 (0.81)	1.45 (1.06)	1.32 (0.77)
Post-test scores	2.77 (1.68)	3.21 (2.04)	3.43 (2.44)
Learning gains	1.19 (1.90)	1.76 (1.79)	2.11 (2.57)

Table 3

Means and Standard Deviations of High and Low Cognitive Ability Students on Total Scores on Learning Gains

	LG of high cognitive ability students						LG of low cognitive ability students					
Plant task	N	M	S.D	Min	Max	Range	N	M	S.D	Min	Max	Range
2A	16	2.56	2.85	-3	8	12	12	1.33	1.37	-1	3	4
1A	14	1.93	2.02	-1	4	5	15	1.33	2.72	-2	8	10
Control	12	2.17	1.34	0	4	4	14	1.29	1.44	-1	4	5
Total	42	2.24	2.20	-3	8	12	41	1.32	1.93	-2	8	10
Peter task	N	M	S.D	Min	Max	Range	N	M	S.D	Min	Max	Range
2A	16	2.88	3.01	-2	9	11	15	1.08	1.38	-1	3	4
1A	14	2.34	1.91	-1	6	7	12	1.13	1.46	-1	4	5
Control	12	1.92	2.02	-1	5	6	14	0.57	1.60	-2	3	5
Total	42	2.45	2.39	-2	9	11	41	0.93	1.47	-2	4	6

To explore the role of analogies in finding interactions in IL environments, comprehension scores of finding the interaction effects of both computer tasks were analyzed. Four points were given for full comprehension and two points for intermediate comprehension in either one of the tasks. To test if interactions were found in general, not considering the three different conditions, an interaction comprehension score (ICS) for each computer task was analyzed. The mean ICS for the Plant task was 0.00 for the pre-test and 0.19 (SD = 0.80) for the post-test and. The mean ICS for the Peter task was 0.00 for the pre-test and 0.24 (SD = 0.85) for the post-test. This indicates small learning gains on ICS's on both tasks.

Descriptive statistics showed that only participants from the treatment groups had an intermediate or a full interaction comprehension score. Four students had a full comprehension score in either one of the tasks and one student had a full comprehension score in both tasks. Besides the student who found the interaction effect in both tasks, all other students found the interaction effect in the second task. In Table 4, number of students, intermediate and full interaction comprehension scores for each task are depicted. In Appendix 6, the correct statements of the full and intermediate comprehension of the interaction effect are depicted.

To explore the effect that the manipulation had on finding the interaction effects, ICS's for each condition were analyzed. Levene's test ($p < 0.001$) indicated unequal variances on total ICS's (ICS's of both tasks combined, not distinguish between full or intermediate comprehension) between conditions. Therefore, a nonparametric Kruskal-Wallis test was performed to test for differences in ICS's between conditions. Although only participants from the treatment groups found the interaction effects, marginally significant differences χ^2 (2, N = 83) = 4.88, p= 0.09 were found between conditions. To compare the differences in total ICS between the three groups a Mann Whitney U test was performed. The test statistics indicated a greater ICS for the 2A treatment group compared with the control group $U = 299.0$ (N = 54), $p < 0.05$, r=0.04, also a greater ICS for the 1A treatment group compared with the control group $U = 325.0$ (N = 55), $p < 0.05$, $r = 0.04$. Although the 2A group had a greater ICS than the 1A group, no significant effects were found between both groups $U = 384.05$ (N = 57), p = 0.59, $r = 0.01$.

To test if these effects are the same for each computer task separately, ICS of each computer task were analyzed. Statistics of the ICS's for each task are depicted in Table 5. Levene's test showed unequal variances between conditions (F = 6.24, $p < 0.01$ for the Plant task and F = 12.83, $p < 0.001$ for the Peter task). Kruskal- Wallis test did not reveal significant differences on ICS for both task, χ^2 (2, N = 83) = 2.77, p= 0.25 for the Plant Growing task and χ^2 (2, N = 83) = 3.84, p= 0.15 for Peter Bikes to School task.

To explore the effect that the manipulations had on finding the full interactions, full comprehensions scores were analyzed. Kruskal-Wallis analysis showed only a significant effect for full comprehension χ^2 (2, N = 83) = 6.04, p< 0.05 and condition for the Peter task (the mean rank for the 2A treatment group was 44.95 and 40.50 for the other two conditions). To compare the differences in full comprehension score for the Peter task between the three groups a Mann Whitney U test was performed. The test statistics indicated marginally greater full comprehension scores for the 2A treatment group compared with the control group $U = 325.0$ (N = 54), p = 0.09, r=0.03 and also marginally greater full comprehension scores for the 2A treatment group compared with the 1A treatment group $U = 362.0$ (N = 57), p = 0.07, $r = 0.03$.

Table 4

Number of Students who found the Interaction Effects

	C (N = 26)	1A (N = 29)	2A (N = 28)	Total (N = 83)
Plant task				
No identification	26	27	25	78
Intermediate comprehension	-	1	1	2
Full comprehension	-	1	2	3
Peter task				
No identification	26	26	24	76
Intermediate comprehension	-	3	1	4
Full comprehension	-	-	3	3

Note. Four students had a full interaction scores in either one of the tasks and one student had a full interaction scores in both tasks.

Table 5

Means and Standard Deviations of Interaction Comprehension Scores

Condition		Plant Growing task						Peter Bikes to School task					
	N	M	SD	Sum	Min	Max	Range	M	SD	Sum	Min	Max	Range
2A	28	0.36	1.10	10	0	4	4	0.50	1.29	14	0	4	4
1A	29	0.21	0.82	6	0	4	4	0.21	0.62	6	0	2	2
Control	26	-	-	-	-	-	-	-	-	-	-	-	-
Total	83	0.19	0.80	16	0	4	4	0.24	0.85	20	0	4	4

To test if cognitive ability was related to the discovery of the interaction effects, correlations between total CAT scores and ICS in each task were analyzed. Pearson correlation analyses revealed that there was only a weak positive significant correlation $r(83) = .24$, p = 0.03 between CAT and ICS for Peter Bikes to school task. Because ICS include both full and intermediate comprehension, a Pearson correlation analysis was also performed with the full comprehension scores. Also a weak positive significant correlation $r(83) = .27$, p = 0.01 was found between CAT and full comprehension score for Peter Bikes to school task. The CAT scores of the two students that found the interaction effect in the Peter task were, 69 and 93 points. The student who found the interactions in both tasks had a CAT score of 64 points (mean total CAT score was 57.47).

To test if high cognitive ability students did profit more from the analogical instruction in finding the interaction effects, ICS's of high and low cognitive ability students were analyzed. An independent sample T-test was used to test for differences on ICS's between high and low cognitive ability students. High cognitive ability students had marginally significant larger ICS's (M= .38, SD= 1.10) than the low cognitive ability (M = .10, SD = .43) students t (53.8) = -1.55, p = 0.08 for the Peter task. No significant differences on ICS were found between high and low cognitive ability students for the Plant task (t (81) = -.52, p = 0.26).

To explore the effect that class level had on finding the interaction effects, ICS's were analyzed. The number of students who found the interaction effects and class level are depicted in Table 6. Levene's test indicated unequal variances for ICS for both tasks. Therefore Kuskal-Wallis test was performed to test for any differences in ICS between the three different class levels. Although only students from the highest class levels found the interactions, test statistics showed no significant differences on ICS and class level χ^2 (2, N = 83) = 2.17, p= 0.34 for the Plant task and marginally significant differences χ^2 (2, N = 83) = 4.90, p= 0.09 for the Peter task.

Table 6

Number of students who found the interaction effects in each class level

	T (N = 21)	TH (N = 32)	HV (N =30)	Total (N = 83)
Plant task				
No identification	21	30	27	78
Intermediate comprehension	-	1	1	2
Full comprehension	-	1	2	3
Peter task				
No identification	21	30	25	76
Intermediate comprehension	-	2	2	4
Full comprehension	-	-	3	3

Conclusions and discussion

The aim of this study was to investigate to which extent the uninstructed use of analogies foster the discovery of interaction effects in concrete IL tasks. Students from three different academic school levels participated in this study and were assigned to three different conditions. The first condition was the single analogy (1A) condition, where students had to read one analogy before performing two computer tasks. The second condition was the double analogy (2A) condition where students had two read two analogies before performing the same computer tasks. Finally, a control condition, where students performed the computer tasks without an intervention.

This study shows that analogies foster the discovery of interaction effect to some extent. It was hypothesized that the use of a single analogy and the use of a double analogy would foster the discovery of the interaction effects. Further, it was hypothesized that connecting the similarities of two analogies would result in higher learning outcomes than the use of a single analogy and more extensive discovery of the interaction effects. The first hypothesis can be confirmed based on the total ICS's (sum of full and intermediate interaction comprehension scores for both computer tasks). Results showed that students from both treatment groups had significant higher ICS's compared with students from the control group. The second hypothesis could not be confirmed, because no differences were found between total ICS's in both treatment groups. Further, both hypotheses could not be confirmed with regard of ICS for each computer task separately. Although only students from the treatment groups, especially from the 2A group found the interaction effects, no significant differences were found between conditions for the Plant Growing task and marginally significant differences for Peter bikes to school task.

Based on full interaction comprehension scores both hypotheses were confirmed for the Peter task. Results showed that the 2A treatment group outperformed the control group and also outperformed the 1A treatment group. Perhaps this can be explained by the fact that the Peter task relies more on general knowledge of an everyday situation and the Plant Growing task requires specific domain knowledge and the analogical instruction may have confused students to make valid interferences, because no same-domain analogy was provided. Perhaps the students who found the interaction effect in the Plant Growing task had prior knowledge in that domain, which was activated during task performances. Another explanation may be that one of the used analogies (Leo the swimmer) was more closely related to Peter bikes to school task, because both characters try to decrease a time variable. Where Leo tries to decrease his time to win his swimming competition and Peter tries to decrease his time to be on time in school. Remarkably, where students from both treatment groups received this analogy, only students from the 2A group found the interaction effect in the Peter bikes to school task. Perhaps the second analogy provided a deeper understanding of the similarities between the two analogies and the similarities with the Peter bikes to school task.

The hypothesis that cognitive ability mediates finding the interaction effects could also be partly confirmed. Results show that cognitive ability and finding the interaction effect in the Peter task had a weak, but significant correlation. These results are similar for the ICS and for the full comprehension score. No significant correlations were found between cognitive ability and finding the interaction effect in the Plant growing task. To explore the effect that the instructional approach had on low and high cognitive ability students the students group was split in two. No significant differences were found in finding the interaction effects between the cognitive ability groups, although for Peter bikes to school task marginally significant differences were found in the expected direction. It seems that higher cognitive ability students did not benefit more from the instructional approaches as was expected.

The dynamic skill theory (Fischer, 1980) and the Relational complexity theory (Halfords, Wilson & Philips, 1998) acknowledge the complexity of identifying interacting variables. Both theories also state that children from the age of eleven are able to process these variables. This study shows that only five students found the interaction effect in either one of the tasks. Besides the student who found the interaction effect in both task, the other students found the interaction effect in the second task. Perhaps this can be explained by the importance of practice in the IL environment that enables students to draw valid conclusions from the data (Beishuizen et al., 2004).

An important limitation of this study which may explain why only a few students found the interaction effects may be the motivation of students. Students did not receive a grade for their performances. Perhaps if students would have received a grade, they would have had better performances. Another limitation may have been the amount of time and the place where students performed the tasks. Students performed the tasks in groups, which sometimes were tumultuous and noisy. Further, students had to catch up their own (home) work that stayed unfinished because they participated in the study. This may have caused rushing through the tasks and tests to resume their own work as quick as possible.

Another issue has to do with the rigorous scoring of the interaction effects. Students received only points for correct statements. Almost correct statements were not rewarded with points. For example, if a student mentioned that there is no difference between watering the plant once or twice per week (which is only correct in a large flowerpot, because watering the plant twice per week in a small flowerpot has a negative effect), without mentioning the size of the flowerpot, they received no points. In Beishuizen et al. (2003), participants received one point for such statements. Because of this rigorous scoring, students who perhaps were close to discovering the interactions or almost found a correct statement were not included in the results. The reason of not using these statements was to make sure that the scored statements showed some understanding of the interaction effect. This to validly interpret the effect of the manipulations and the role of cognitive ability in finding the interactions.

The results showed that overall learning occurred for students from all conditions for both computer tasks. As expected, higher scores on the CAT correlated with IL performances. Although learning gains were the lowest in the control group, no significant differences were found between conditions. Thus, it seems that the uninstructed use of analogies did not affected overall learning in IL environments. In addition, results showed that higher cognitive ability students had significant larger learning gains than their lower cognitive ability counterparts. Thus, IL performances and cognitive ability seem to be related. In accordance with findings of Carroll (1993) it is shown that IL performances are mostly related with the subtest Abstract syllogisms and Number series, which assess general reasoning ability.

Although learning gains occurred, results also showed negative scores on learning gains. The learning gains were calculated by subtracting the post-test scores from the pre-test scores. With regard to the pre-test, students were able to note their assumptions and generate hypotheses, which could be tested in the IL environment to draw valid conclusions. Results showed that students from all three conditions were not always able to draw valid conclusions after experimenting in the IL environment. Students who had correct assumption in the pre-test seemed not always able to confirm these assumptions, which lead to negative scores. This is in conformation with previous research (De Jong, 2006; Lazonder, in press; Quintana et al, 2004; Zimmerman, 2000) that states that students have difficulties with IL tasks. Observations showed that students had difficulties in choosing the correct variables to work with and draw the right conclusion from experimenting in the IL environments, which probably had to do with lack of the required IL skills. The interactions also may have confused these students, causing contradictions in the IL environment that students could not comprehend. In addition, the used analogies, which also provide an implicit model of how to investigate, did not have an effect. Therefore, an explicit training of the scientific reasoning skills is needed. The use of analogies could also be more effective in IL if students receive training in scientific research skills. If students are familiar with these skills and are able to experiment in the way that science should be carried out, they would be more able to identify the common relational system between the two situations (analogy and IL task) and generate further inferences driven by these commonalities (Gentner & Smith, 2012). In this case, students can focus on the information that an analogy provides to connect the similarities in the analogy to the similarities in the IL task instead of searching for a method to test their hypothesis, which imposes heavily demand on their working memory (Kirschner et al., 2006).

So, perhaps explicit instruction in scientific reasoning skills, followed by analogies would provide a solution to this problem. Although previous research did show the use of analogies without explicit instruction to be effective (Tunteler & Resing, 2002; 2007b), it is shown that the instructional use of analogies and the explicit instruction of the scientific reasoning skills and practice in IL environments are more effective in solving IL tasks (De Jong, 2006; Kirschner et al., 2006; Tunteler and Resing, 2007a; Zimmerman, 2007). A recommendation for further research on the use of analogies in IL environment is to be sure that students master the scientific reasoning skills. The current study shows that analogies do not serve well as an instruction method to train these skills, even if the analogy describes and teaches the needed skills implicitly.

This study shows that discovering the interactions is a most difficult aspect of IL and that the used analogy or analogies did not seem to have a great effect on discovering the interactions. Perhaps if students received more guidance and questions that triggered the finding of the interactions, they would have had better performances. A recommendation for further investigation is to modify the questions in the tests that enables student in finding the interactions. For example, a step by step questioning procedure where several aspects of the effects of interacting independent variables on the dependent variables are questioned. To maintain the characteristic of IL learning, these questions can be used in practice tasks, where learners in the second task have to find these on their own.

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Appendix 1: Pre-test

Naam: .... Klas: ....M/V leeftijd:.................

Antwoordformulier 1: Het groeien van een plant

Je mag nu een zestal vragen beantwoorden over hoe de vijf factoren (die je net in de handleiding hebt gelezen), volgens jou invloed hebben op de groei van een plant.

1. Je kunt kiezen tussen één en twee keer per week water geven. Welke invloed denk je dat het aantal keer per week water geven heeft op de groei van de plant?

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2. Je kunt kiezen tussen het gebruiken van een middel tegen bladluizen of het niet gebruiken van een middel tegen bladluizen. Welke invloed denk je dat dit heeft op de groei van de plant?

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3. Je kunt kiezen uit het plaatsen van dode bladeren in de bloempot of het niet plaatsen van dode bladeren in de bloempot. Welke invloed heeft het plaatsen van dode bladeren of het niet plaatsen van dode bladeren op de groei van de plant?

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4. De plant kan in een kas, in het huis of op het balkon geplaatst worden. Welke invloed heeft de locatie van de plant op de groei van de plant?

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5. Je kunt kiezen uit een kleine of een grote bloempot. Welke invloed denk je dat dit heeft op de groei van de plant?

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6. Als je nog meer weet over deze factoren, dan kun je dat hieronder opschrijven.

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Naam: .... Klas: ....M/V leeftijd:.................

Antwoordformulier 1: Peter fietst naar school.

Je mag nu een zestal vragen beantwoorden over hoe de vijf factoren (die je net in de handleiding hebt gelezen), volgens jou de tijd waarop Peter te laat op school komt zullen beïnvloeden.

1. Je kunt kiezen tussen een normale fiets en een racefiets. Welke invloed denk je dat deze twee soorten fietsen hebben op Peter's fietssnelheid?

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2. Je kunt kiezen tussen thuis ontbijten of een boterham meenemen op de fiets. Welke invloed denk je dat dit heeft op het aantal minuten dat Peter te laat op school komt?

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3. Peter heeft drie mogelijke manieren om naar school te fietsen. Hij kan samen met twee vrienden fietsen, alleen in zijn eigen tempo of alleen flink doortrappen. Welke invloed hebben deze drie manieren op het aantal minuten dat Peter te laat op school komt?

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4. Welke invloed heeft volgens jou het meenemen van alleen de benodigde boeken of het meenemen van een aantal extra boeken op de tijd waarop Peter te laat op school komt?

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5. Welke invloed heeft volgens jou het aantrekken van normale schoenen of het aantrekken van sportschoenen op het aantal minuten dat Peter te laat op school komt?

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6. Als je nog meer weet over deze factoren, dan kun je dat hieronder opschrijven.

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Appendix 2: Post-test

Naam: .... Klas: ....M/V   leeftijd:.................

Antwoordformulier 2: Het groeien van een plant

De volgende vragen gaan over je bevindingen in de leertaak.

1. Welke invloed heeft het één keer per week en het twee keer per week water geven op de groei van de plant?

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2. Welke invloed heeft het gebruiken van een middel tegen bladluizen en het niet gebruiken van een middel tegen bladluizen op de groei van de plant?

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3. Welke invloed heeft het plaatsen van dode bladeren en het niet plaatsen van dode bladeren in de bloempot op de groei van de plant?

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4. Welke invloed heeft de locatie van de bloempot, in een broeikas, in het huis en op het balkon op de groei van de plant?

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5. Welke invloed heeft een kleine bloempot en een grote bloempot op de groei van de plant?

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6. Heb je nog andere invloeden ontdekt van de factoren op de groei van de plant?

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Naam: .... Klas: ....M/V leeftijd:.................

Antwoordformulier 2: Peter fietst naar school.

De volgende vragen gaan over je bevindingen in de leertaak.

1. Welke invloed heeft een gewone fiets en een racefiets op het aantal minuten waarop Peter te laat op school komt?

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2. Welke invloed heeft het thuis ontbijten en een boterham meenemen op de fiets op de tijd waarop Peter te laat op school komt?

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3. Welke invloed heeft het fietsen met zijn vrienden, alleen fietsen en alleen flink doortrappen op de tijd waarop Peter te laat op school komt?

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4. Welke invloed heeft het meenemen van de benodigde boeken en het meenemen van een aantal extra boeken op de tijd waarop Peter te laat op school komt?

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5. Welke invloed heeft het aantrekken van gewone schoenen en het aantrekken van sportschoenen op de tijd waarop Peter te laat op school komt?

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6. Heb je nog andere invloeden ontdekt van de factoren op de tijd waarop Peter op school komt?

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Appendix 3: Analogy 1

Analogie 1: Leo de zwemmer

Leo is een ervaren zwemmer. Hij traint 1 keer per week en zwemt elke zaterdag wedstrijden. Soms zijn de wedstrijden thuis (bij zijn eigen zwemclub) maar het komt vaker voor dat hij uitwedstrijden heeft (bij een andere zwemclub). Leo wint bijna nooit een wedstrijd, terwijl zijn vrienden wel regelmatig winnen. Hij besluit te onderzoeken waarom zijn vrienden (Pieter, Johan en Evert) wel regelmatig winnen en hij niet. Hij vraagt ze wat ze anders doen om te weten te komen waar het aan ligt.

Locatie zwemwedstrijd	Pieter wint vaak als hij thuis zwemt. Uitwedstrijden verliest hij vaak.
Training	Johan traint 2x en soms wel 3x per week.
Aanmoediging	Evert neemt altijd zijn vriendin mee om hem aan te moedigen.

Locatie zwemwedstrijd

Leo besluit om eerst te kijken of hij bij zijn eigen zwemclub sneller zwemt dan bij een andere zwemclub. Hij houdt acht wedstrijden lang zijn tijden bij. Leo zwemt de baan in gemiddeld 40 seconden. Dit gemiddelde is hetzelfde bij zijn eigen zwemclub als bij een andere zwemclub.

Locatie zwemwedstrijd maakt geen verschil

Training

Leo besluit eerst 2x per week te trainen. Dit doet hij 2 maanden lang waarna hij zijn tijden weer acht wedstrijden bijhoudt. Hij zwemt nu de baan over in gemiddeld 35 seconden. Hierdoor wint hij nu ook wat vaker. Twee maanden later besluit hij 3x per week te trainen en houdt weer acht wedstrijden zijn tijd bij. Zijn tijd verandert hierdoor echter niet.

Training heeft effect op Leo's gemiddelde tijd, 2x of 3x per week maakt echter geen verschil

Aanmoediging

Nu heeft Leo de smaak te pakken en wil hij eigenlijk vaker winnen. Hij vraagt of zijn vriendin mee wil naar de zwemwedstrijden om hem aan te moedigen. Zijn vriendin wil hem wel steunen en gaat nu elke zaterdag mee. Hierdoor presteert Leo veel beter en zwemt de baan over in minder dan 35 seconden.
Hij wint nu bijna elke wedstrijd.

Aanmoediging heeft ook effect.

Twee of drie keer per week training en zijn vriendin mee zorgen er dus voor dat Leo vaker wedstrijden wint.

Op een zaterdag is de vriendin van Leo ziek. Hierdoor kon ze niet mee gaan naar de wedstrijd. Met tegenzin stapte Leo op de fiets voor een thuiswedstrijd. Tot zijn verbazing wint hij! Nu begint hij zich af te vragen of de zwemlocatie misschien toch verschil maakt, zoals Pieter had aangegeven. Hij besluit om zijn vriendin niet mee te nemen naar de volgende twee uitwedstrijden. Deze verliest hij allebei. Bij de derde uitwedstrijd is zijn vriendin wel weer aanwezig en hij wint! De volgende thuiswedstrijd, maar dan weer zonder zijn vriendin, wint hij ook weer.

Leo is tot de volgende conclusie gekomen: hij wint vaak een wedstrijd in de volgende gevallen:

- Uitwedstrijd, met 2x of 3x per week trainen, met aanmoediging van zijn vriendin.
- Thuiswedstrijd, met 2x of 3x per week trainen, zonder of met aanmoediging van zijn vriendin.

Er lijkt dus een verband te zijn tussen de wedstrijdlocatie en de aanmoediging. Thuiswedstrijden kan hij zonder zijn vriendin winnen maar bij uitwedstrijden heeft hij wel haar aanmoediging nodig. Misschien voelt hij zich in zijn eigen zwemclub meer op zijn gemak omdat hij veel toeschouwers al kent. Maar op een vreemde locatie voelt hij zich niet op zijn gemak en heeft hij zijn vriendin nodig om hem aan te moedigen.

Appendix 4: Analogy 2

Analogie 2 Maartje

Maartje is een kind van 3 jaar en durft niet te gaan slapen omdat ze bang is voor de monsters in haar kamer. De moeder van Maartje is radeloos en weet niet meer wat ze moet doen. Ze besluit om naar de kinderarts te gaan voor consultatie. De kinderarts raadt drie veelvoorkomende oplossingen aan.

Deur open	Houd de deur op een kier met de lamp van de gang aan.
Nachtlampje	Laat een nachtlampje op de kinderkamer aan
Superbeer	Verzin een superbeer die het kind tegen monsters beschermt.

Deur open

Dezelfde avond ligt Maartje in bed met de deur op een kier, hierdoor heeft ze wat licht in de kamer en weet Maartje dat mama in de buurt is. Maartje houdt het toch geen minuut vol, ze begint te huilen omdat de monsters er weer zijn. Maartje's moeder probeert dit een week lang maar het heeft geen zin.

Deur open of dicht maakt geen verschil

Nachtlampje

Een week later mag Maartje met een nachtlampje aan slapen. Het nachtlampje heeft drie standen: uit, normaal en fel licht. Maartje's moeder probeert een week de nachtlamp op normaal licht en dit lijkt te werken. Maartje huilt minder vaak en het lijkt of de monsters niet meer elke dag komen. Een week later probeert de moeder van Maartje het met fel licht van de nachtlamp. Dit maakt echter geen verschil.

Nachtlamp aan werkt wel, normaal of fel licht werken even goed

Superbeer

Aangezien Maartje nog wel af en toe last heeft van monsters besluit de moeder ook de derde tip te proberen. De superbeer lijkt heel goed te werken. Maartje voelt zich goed beschermd door hem en is niet meer bang voor de monsters.

Superbeer heeft ook effect

Na een aantal weken was het nachtlampje kapot. Omdat Maartje al een aantal weken niet in het donker heeft geslapen besluit moeder de deur op een kier te laten met het licht van de gang aan. Tot moeders verbazing gaat het goed. Maartje heeft niet geklaagd over de monsters.

Maartje's moeder bedenkt dat Maartje misschien alleen de beer nodig heeft. De volgende dag laat ze haar met de deur dicht slapen. Het helpt niet, Maartje krijst van angst. De monsters zijn weer teruggekeerd. Volgens Maartje heeft superbeer wel licht nodig om de monsters te zien.

Maartje's moeder is tot de volgende conclusie gekomen. Maartje is minder vaak bang in de volgende gevallen:

- Deur dicht, nachtlamp aan met normaal of fel licht, met of zonder superbeer.
- Deur open, nachtlamp uit, met superbeer.

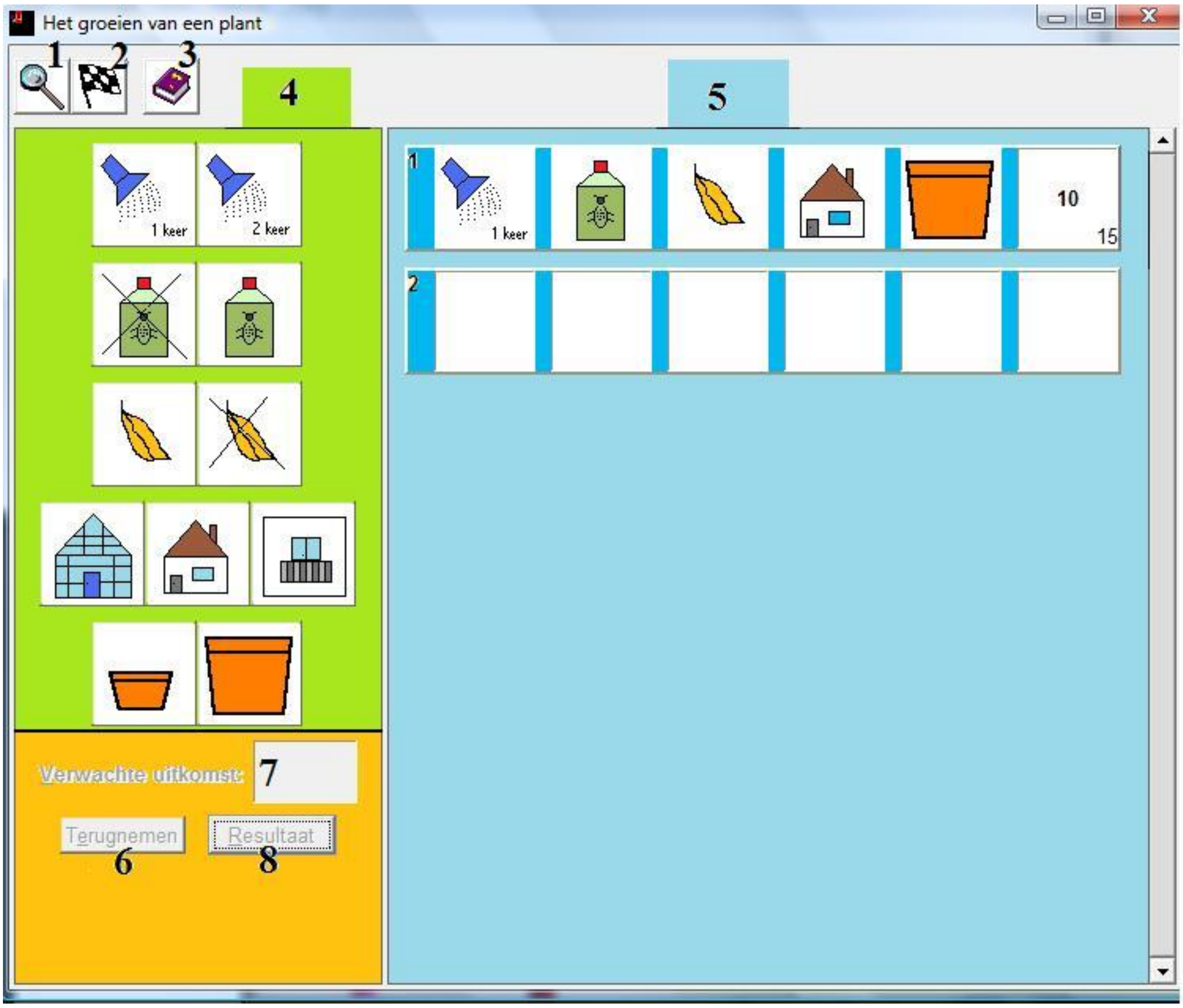
Dus alleen de deur op een kier met licht in de gang aan helpt niet. De nachtlamp in de kamer aan helpt wel. Superbeer help in alle gevallen, behalve in het donker. Er lijkt dus een verband te zijn tussen superbeer en de deur op een kier of niet. Alleen de deur op een kier helpt niet, tenzij super beer aanwezig is.

Appendix 5: Instruction Computer Tasks

Het groeien van een plant

Een plantje groeit meestal uit tot een grote, sterke plant, maar het is niet zo dat plantjes van dezelfde soort allemaal even groot worden. Hoe zou dat kunnen komen? Hoe vaak je water geeft kan een rol spelen. Je kunt bijvoorbeeld één of twee keer per week water geven. Het wel of niet gebruiken van een middel tegen bladluizen zou ook belangrijk kunnen zijn. Misschien maakt het ook wel wat uit voor de groei van een plantje als je wat dode bladeren in de pot legt. De plek waar je het plantje laat groeien kan ook belangrijk zijn. Je kunt straks kiezen uit: in een kas, in huis of op het balkon. Ook de grootte van de pot waar het plantje in staat kan belangrijk zijn. Je kunt straks kiezen uit een kleine of een grote pot. Je ziet dat je bij het laten groeien van een plantje verschillende keuzen kunt maken. De bedoeling is dat jij gaat uitzoeken wat die keuzen te maken hebben met de grootte van het plantje als het is uitgegroeid. Het plantje kan **5, 10, 15, 20 of 25 cm** groot worden. Klaar met lezen? Dan gaan we door ....

Handleiding voor computeropdracht: Het groeien van een plant



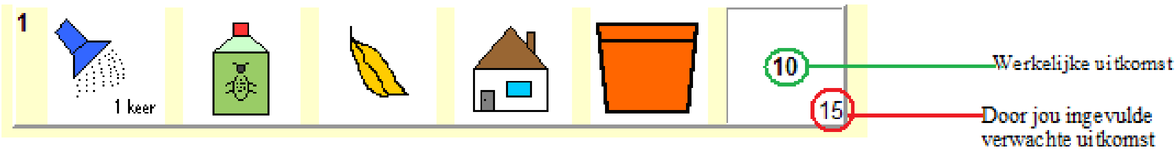
Je ziet hierboven een screenshot van de computeropdracht waar je zo mee gaat werken. Hieronder zal beschreven worden hoe de computeropdracht werkt.

Open nu eerst de plant computertaak. Vul je voornaam en achternaam in en klik daarna op doorgaan. Je krijgt een scherm met introductie. Lees deze aandachtig door en ga verder met het lezen van deze instructie.

- In de opdracht waar je zo mee aan de slag gaat moet je door het uitvoeren van experimenten er achter zien te komen wat de invloed is van vijf factoren op de groei van de plant. Deze factoren staan hieronder en vind je in het groene vak, nummer 4:
    - Water: één of twee keer per week water geven.
    - Insecticide: het wel of niet geven van een middel tegen bladluizen.
    - Dode bladeren: wel of geen dode bladeren in de bloempot leggen.
    - Locatie van de plant: in een kas, in huis of op het balkon
    - Bloempot: grote of kleine bloempot

  De lengte van de plant kan de volgende waarden aannemen: 5, 10, 15, 20 en 25 cm

- Door met de muis op een plaatje te klikken verschijnt één van de mogelijkheden per factor (bijv. bij de eerste factor water, in de screenshot 1 keer per week water geven) rechts in het blauwe experimentvak (5). Als je dat voor alle factoren hebt gedaan heb je een experiment ingericht. In de screenshot gaat het om 1 keer per week water geven, wel insecticide, wel plaatsen van dode bladeren in de bloempot, in het huis en in een grote bloempot.
- Mocht je je keuze nog willen wijzigen, kan dat met “terugnemen” (6).
  Als je je keuze gemaakt hebt kan je bij “Verwachte uitkomst” (7) een getal invullen. Dat getal staat voor de hoogte die de plant volgens jou aanneemt gegeven de mogelijkheden die je hebt aangeklikt in dit experiment.
- Als je nu op “Resultaat” (8) klikt verschijnt de werkelijke tijd in het midden en je verwachte tijd rechts onder in het vakje rechts van het experiment (zie afbeelding hieronder).



- Je hebt nu een experiment uitgevoerd!
  Als je meer dan vier experimenten hebt gedaan, dan verdwijnen er experimenten van het scherm. Met de scrollbar aan de rechterkant kun je deze experimenten weer op het scherm krijgen.
  Om experimenten met elkaar te kunnen vergelijken is het handig ze onder elkaar te kunnen zetten in een volgorde die je zelf kiest in plaats van heen en weer te scrollen.
  Dat kan door experimenten aan te klikken (ze kleuren dan oranje) en vervolgens op het “loepje” (knop 1) te klikken. De door jouw geselecteerde experimenten verschijnen dan onder elkaar in een nieuw window.
- De “finish-vlag” (knop 2) is om de opdracht af te sluiten. DRUK DEZE NIET ZELF IN! Maar meld het de proefleider als je klaar bent.
- Als je de introductie-tekst nogmaals wilt lezen druk je op het “boekje” (knop 3).

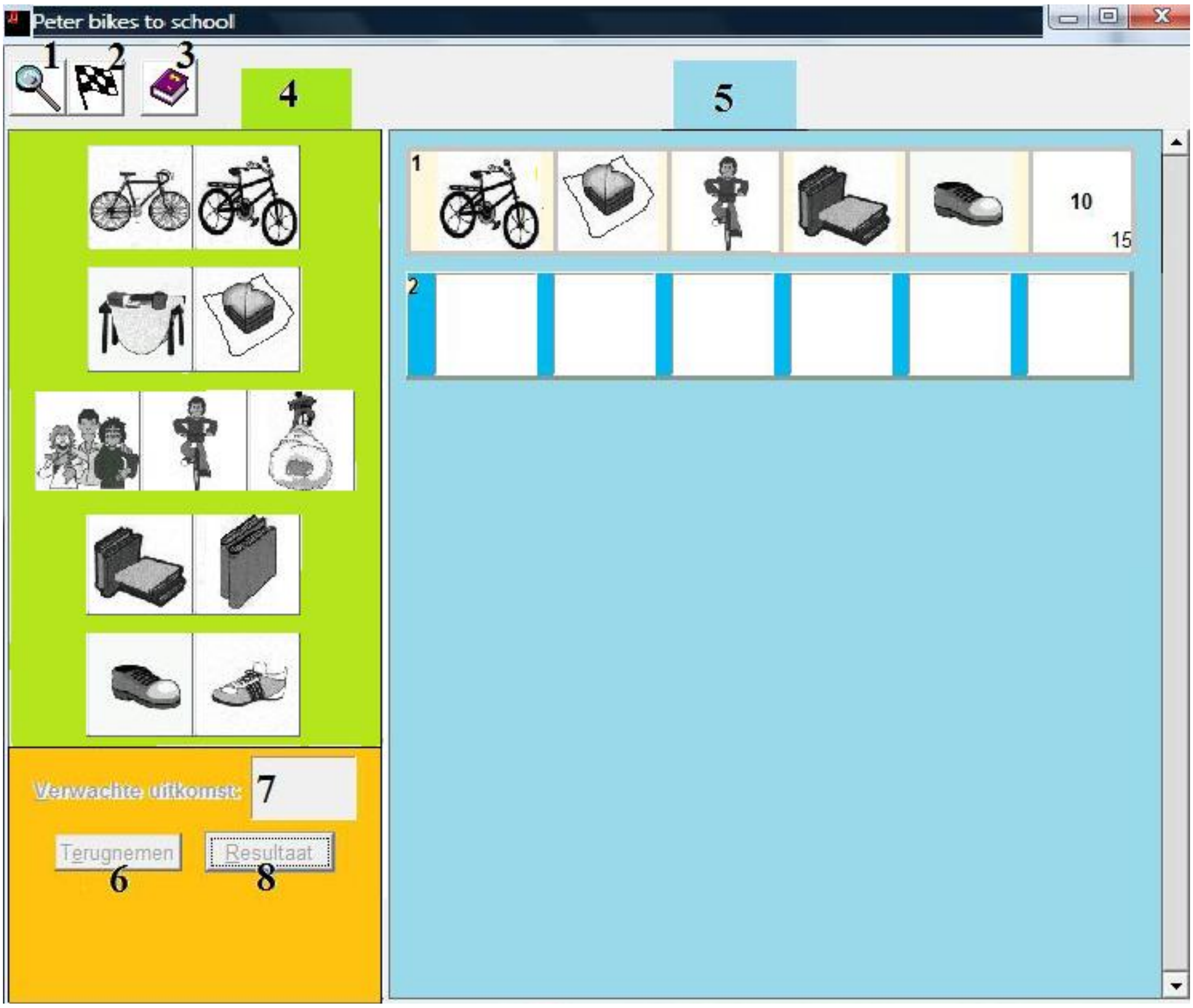
De opdracht is dus om door het uitvoeren van minimaal 15 experimenten er achter zien te komen wat de invloed is van de vijf factoren op de hoogte van de plant.

Ben je klaar met het lezen, steek dan je hand op en wacht op de proefleider voor verder instructie.

Peter Fietst naar school

Peter is 13 jaar en zit in de brugklas. Op school gaat het prima met hem, maar hij heeft één probleem: **hij komt regelmatig te laat op school**. Soms komt Peter **5 minuten** te laat, het kan ook **10 minuten**, **15 minuten** of **20 minuten** zijn. Gelukkig komt hij niet altijd te laat op school, soms komt hij **op tijd.** Te laat komen is natuurlijk niet handig. Het is al eens voorgekomen dat hij te laat was voor een belangrijk proefwerk. De directeur van de school heeft Peter daarom de opdracht gegeven om uit te zoeken hoe het komt dat hij vaak te laat op school komt **Peter heeft een paar dingen bedacht die misschien iets te maken hebben met het te laat op school komen.** Elke ochtend om acht uur maakt Peters moeder het ontbijt klaar. Zij weet dan dat Peter nog maar weinig tijd heeft om op school te komen en vraagt daarom altijd of Peter thuis ontbijt of dat ze zijn boterhammen moet inpakken voor op de fiets. Peter eet daarom soms zijn boterhammen op de fiets op en soms thuis. Als Peter zijn schoenen aantrekt kan hij kiezen: gewone schoenen of sportschoenen. Soms draagt hij het ene paar en soms het andere paar. Peter gaat op de fiets naar school. Hij heeft twee fietsen: een normale fiets en een racefiets. Soms pakt hij zijn gewone fiets en soms zijn racefiets. Veel schoolkinderen fietsen in groepjes naar school. Peter doet dat ook wel, maar niet altijd. Soms fietst hij in zijn eigen tempo in zijn eentje naar school. Het komt ook voor dat hij met zijn vrienden Fred en Jos meefietst, in andere gevallen probeert hij door zo hard te trappen als hij kan zo snel mogelijk op school te komen. Peter wil goed zijn best doen op school. Vaak doet hij daarom wat extra boeken in zijn tas, je weet maar nooit. Die extra boeken heeft hij lang niet altijd allemaal nodig. Daarom pakt hij soms alleen de boeken in waarvan hij zeker weet dat hij ze echt nodig heeft. **Je ziet dat Peter bij het naar school gaan altijd een paar keuzen maakt. Wat jij gaat proberen uit te zoeken is wat die keuzen te maken hebben met het aantal minuten dat Peter te laat op school komt. Dit ga je doen door Peter steeds op een andere manier naar school te laten fietsen.** Klaar met lezen? Dan gaan we door ....

Handleiding voor computeropdracht: Peter fietst naar school



Je ziet hierboven een screenshot van de computeropdracht waar je zo mee gaat werken. Hieronder zal beschreven worden hoe de computeropdracht werkt.

Open nu eerst de computeropdracht Peter fietst naar school school. Vul je voornaam en achternaam in en klik daarna op doorgaan. Je krijgt een scherm met introductie. Lees deze aandachtig door en ga verder met het lezen van deze instructie.

- In de opdracht waar je zo mee aan de slag gaat moet je door het uitvoeren van experimenten er achter zien te komen wat de invloed is van vijf factoren op het aantal minuten dat Peter te laat op school komt. Deze factoren staan hieronder en vind je in het groene vak, nummer 4:
    - Soort fiets, een normale fiets of een racefiets
    - Thuis ontbijten of tijdens de fietsrit.
    - Met zijn vrienden fietsen, alleen in zijn eigen tempo of snel doortrappen
    - Alleen de nodige boeken meenemen of een aantal extra voor de zekerheid.
    - Het aantrekken van gewone schoenen of sportschoenen.

  Het aantal minuten dat Peter te laat kan de volgende waarden aannemen, 0 minuten (op tijd), 5 minuten, 10 minuten, 15 minuten en 20 minuten.

- Door met de muis op een plaatje te klikken verschijnt één van de mogelijkheden per factor (bijv. bij de eerste factor het soort fiets, in de screenshot een normale fiets) rechts in het blauwe experimentvak (5). Als je dat voor alle factoren hebt gedaan heb je een experiment ingericht. In de screenshot gaat het om een normale fiets, een boterham meenemen op de fiets, alleen in eigen tempo fietsen, extra boeken mee en aantrekken van gewone schoenen.

- Mocht je je keuze nog willen wijzigen, kan dat met “terugnemen” (6).
  Als je je keuze gemaakt hebt kun je bij “Verwachte uitkomst” (7) een getal invullen. Dat getal staat voor het aantal minuten dat Peter volgens jou te laat op school aankomt, gegeven de mogelijkheden die je hebt aangeklikt in dit experiment.
- Als je nu op “Resultaat” (8) klikt verschijnt de werkelijke tijd in het midden en je verwachte tijd rechts onder in het rechter vakje van het experiment (zie afbeelding hieronder).

- Je hebt nu een experiment uitgevoerd!
  Als je meer dan vier experimenten hebt gedaan, dan verdwijnen er experimenten van het scherm. Met de scrollbar aan de rechterkant kun je deze experimenten weer op het scherm krijgen.
  Om experimenten met elkaar te kunnen vergelijken is het handig ze onder elkaar te kunnen zetten in een volgorde die je zelf kiest in plaats van heen en weer te scrollen. Dat kan door experimenten aan te klikken (ze kleuren dan oranje) en vervolgens op het “loepje” (knop 1) te klikken. De door jouw geselecteerde experimenten verschijnen dan onder elkaar in een nieuw window.
- De “finish-vlag” (knop 2) is om de opdracht af te sluiten. DRUK DEZE NIET ZELF IN! Maar meld het de proefleider als je klaar bent.
- Als je de introductie-tekst nogmaals wilt lezen druk je op het “boekje” (knop 3).

  De opdracht is dus om door het uitvoeren van minimaal 15 experimenten er achter zien te komen wat de invloed is van de vijf factoren op de tijd waarop Peter te laat op school komt.

Ben je klaar met het lezen, steek dan je hand op en wacht op de proefleider voor verder instructie.

Appendix 6: Interaction Statements

Citaten leerlingen voor de Plant taak.

Plant Growing Task	
Interactie effect (Full comprhension)	7. 'De kleine pot heeft weinig water nodig en de grote maakt niet uit. Water heeft geen invloed op de grote pot.' 8. '1/2 keer water maakt niet uit bij de grote bloempot en bij de kleine wel, dan moet 1 keer.' 9. '2 x water in een kleine pot is slecht dan wordt de plant kleiner. 2x water in de grote pot, dan groeit hij het zelfde als 1x water.'
Interactie 1e gedeelte (Intermediate comprehension) In een kleine pot groeit het plant het best als je deze 1 x per week water geeft. 2 x per week heeft een negatief effect.	10. 'In een kleine pot groeit de plant het best. Als je 2x water geeft groeit hij slechter dan als je hem 1x water geeft.' 11. 'In een kleine bloempot groeit de plant sneller. Als je de plant 2 x water geeft groeit hij slechter dan als je hem 1x water geeft.' 12. '1x per week water doen in een kleine potje is beter dan 2x water doen in een kleine potje.'
Interactie 2e gedeelte (Intermediate comprehension) In een grote pot heeft het aantal keer per week water geen invloed op de groei.	X
Bijna een correct statement	13. 'Kleine bloempot maakt ook iets uit maar de grote niet.' 14. 'Kleine pot beter, de besproeiing maakt heel veel uit.' 15. '1 x besproeien met een kleine bloempot is die langer dan 1x met grote.' 16. '1x water in een kleine pot, in kas of balkon zorgt voor de beste groei.'

Citaten leerlingen voor de Peter taak.

Peter bikes to school task	
Interactie effect (Full comprhension)	17. 'Als Peter met een normale fiets een boterham op de fiets eet of thuis ontbijt heeft geen effect. Als hij op zijn racefiets een boterham op de fiets eet is hij slomer.' 18. 'Als hij thuisontbijt is hij sneller. Een racefiets is sneller dan een normale fiets, maar met een boterham duurt het een kwartier langer terwijl het op een normale fiets niet uitmaakt waar je eet.' 19. 'Bij een racefiets en brood onderweg kom jet te laat en racefiets en ontbijt kom je niet te laat. Maar bij een fiets maakt het helemaal niks uit waar je eet.'
Interactie 1e gedeelte (Intermediate comprehension) Op een racefiets moet Peter thuis ontbijten. Op de fiets ontbijten heeft een ongunstig effect op de tijd.	20. 'Hij moet perse met de racefiets thuis ontbijten, met de racefiets kan hij geen boterham meenemen dan komt hij te laat.' 21. 'Racefiets met thuis ontbijt, normale fiets kan op de fiets eten.' 22. 'Racefiets + thuisontbijt + alleen fietsten snelste op tijd.' 23. 'Racefiets met boterham is minder snel dan normale fiets met boterham.'
Interactie 2e gedeelte (Intermediate comprehension) Op een normale fiets heeft ontbijt thuis of op de fiets geen invloed op de tijd.	X
Bijna een correct statement	24. 'Met een boterham op de gewone fiets ben je sneller dan op een racefiets.' 25. 'Er zijn verschillen in de ontbijten en er zijn verschillen in de fietsen.' 26. 'Racefiets is sneller als je thuis ontbijt maar op de normale fiets kun je beter op de fiets eten.' 27. 'De racefiets en het ontbijt thuis.' 28. 'Vrienden, fiets en thuis ontbijt zijn de grootste invloeden.'