BE COOL! a digital learning environment to challenge and socially include gifted learners

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Abstract

This paper describes the development of the BE COOL! learning environment that gives all children, gifted and non-gifted, the opportunity to learn at a level matching their specific needs and abilities within the social context of regular education. BE COOL! uses the ability-adjusted jigsaw method, in which children of varying ability levels work together on a design for which they acquire knowledge by working on tailored assignments in groups with children with the same ability level. This differentiation method unites elements of learning by design, learning together, and learning by inquiry. In this article, we first present the conceptual foundations underlying BE COOL! Next, we describe the learning environment and its components as incorporated in a seven-week science lesson series in which fourth to sixth graders must design a liveable house on the moon for a family of four. Then, we describe our design process, in which research and development alternated and we end with a brief presentation of the learning environment's added value for educational practice.

Keywords Giftedness · Differentiation · Inquiry learning · Collaborative learning · Learning by design · Primary education

Introduction

This paper describes the theoretical foundations, design, and implementation methods of a digital learning environment that challenges gifted children while socially including them in the regular classroom. Gifted children, as defined by the National Association for Gifted Children (2010), are “those who demonstrate outstanding levels of aptitude (defined as an exceptional ability to reason and learn) or competence (documented

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performance or achievement in top 10% or rarer) in one or more domains” (p. 1). Providing gifted children with the opportunity to gain knowledge and skills at their own level is critical for developing their talent (Olszewski-Kubilius et al. 2016). Talent development can be stimulated by tailoring their education. In Dutch primary education, this tailoring is most often realized by differentiation within the regular classroom in which learners who are gifted in the cognitive domain share the classroom with average-ability learners and at-risk, or low-ability, learners of the same age. Another commonly-used educational adaptation consists of pull-out classes that gifted children in regular education visit once a week, in most cases. As a third option, some schools have a department consisting of classes that gifted children attend fulltime (Doolaard and Oudbier 2010).

Although all three scenarios can be viewed as valuable ways of adapting education to the gifted child, they also have specific drawbacks. Differentiation within the class is often implemented as a combination of compacting, acceleration, and enrichment (Renzulli et al. 1982). In current educational practice, this often means that the gifted learner works individually and independently, a situation not always preferred by themselves (French et al. 2011; Samardzija and Peterson 2015). An educational answer is provided by pull-out classes, in which gifted children work together with gifted peers. Meta-analytical studies (Kulik and Kulik 1982; Vaughn et al. 1991) have shown that this benefits the performance of gifted children as well as their attitude towards school subjects. A drawback is that the gifted children only attend these classes two or three hours a week; for the rest of the week, they have to cope with the regular curriculum with little or no differentiation and cognitive challenge. In schools specializing in education for the gifted, this drawback is replaced by another: namely, gifted children do not learn to work together with their less gifted peers and are socially excluded from them. From a societal point of view, this is an undesirable situation, as working together with less gifted peers is an important skill in later life, too. In addition, a considerable portion of gifted learners indicate that they prefer to keep in touch with their less gifted friends during the school day (Adams-Byers et al. 2004).

In sum, finding a balance between demands regarding the cognitive development of gifted children and their needs on the social-emotional level appears to be difficult and a solution can be seen as a valuable contribution to education. In the BE COOL! project, we searched for this balance by pursuing a learning arrangement in which gifted children are given the opportunity to engage in learning activities matching their specific needs and abilities, in which ideas can be exchanged and discussed at a high cognitive level with their gifted peers, and in which they are able to work with other (less gifted) classmates. During this four-year design project, several studies building upon each other were conducted which, in the end, resulted in the BE COOL! learning environment. By presenting these studies collectively, it becomes clear how they are related and how the learning environment evolved. The paper starts with the description of the conceptual foundations and the rationale to use them in our context. Next, we describe how these foundations are brought together in our differentiation method that aims to provide opportunities for both the gifted and the non-gifted to develop their talents. This is subsequently illustrated by a seven-week science lesson series in which children from grades 4 to 6 work together on the design of a moon house and in which they learn by inquiry about light and heat, oxygen, water, and nutrition. Finally, we describe the different studies that were part of the design process and which led to the final version of the learning environment.

Conceptual foundations

BE COOL! stands for ‘Bevorderen van Excellentie door Coöperatief Onderzoekend en Ontwerpend Leren’, which translates from the Dutch as ‘Promoting possibilities for excelling by learning together within the context of inquiry learning and learning by design’. The name includes three conceptual foundations, learning by design, learning together, and learning by inquiry, which will be discussed one by one.

Learning by design

The overarching pedagogical approach used in the BE COOL! learning environment is learning by design. The main idea of this approach is to engage learners in designing a solution for an authentic problem so that they achieve an understanding of complex systems (Hmelo et al. 2000). Kolodner et al. (2003) shaped this approach by proposing a cycle of two core activities: Design/Redesign and Investigate and Explore. This cycle depends on a problem or design challenge that is formulated at a level such that learners have the need to learn (Kolodner et al. 1996). Learners engage in activities that are applied to the cycle to guide the process (see, e.g., van Breukelen et al. 2017): They review their prior knowledge in the context of the problem and identify what they need to know, what they already know, and what still needs to be learned. Next, they acquire this knowledge by investigation and use this knowledge in their design. This results in an initial prototype which can be iteratively tested and adjusted until the final design is reached and presented. Research has shown that learning by design results in deep and transferrable knowledge and skills (Etkina et al. 2010).

Based on the activities incorporated in a typical learning-by-design approach (e.g., Kolodner et al. 2003), seven steps were included in the BE COOL! learning environment to guide learners through their design process: (a) problem statement: learners are introduced to the problem (e.g., design a moon house in which a family of four can live), (b) orientation: learners are stimulated to activate relevant prior knowledge (e.g., think about what is needed to survive on the moon), (c) gathering information: learners receive assignments through which they acquire knowledge and information needed to make substantiated design decisions (e.g., assignments on light and heat, oxygen, water, and nutrition), (d) designing: learners share and discuss their knowledge and make a first design (i.e., a drawing of their moon house), (e) testing and improving: learners reflect on their design by checking whether it satisfies predefined conditions and improve the design if necessary (e.g., is the moon house equipped with facilities for producing and storing oxygen?), (f) developing a prototype: learners convert their first design into a prototype (i.e., a moon house crafted to scale), and (g) reporting: learners write a report in which they describe and justify their design decisions.

Learning together

The second foundation on which BE COOL! is built is learning together, in which learners work together to reach a common goal or to complete a group assignment (Lou et al. 1996). Learning together effectively is characterized by sharing ideas, actively listening to each other, asking questions, building upon each other’s reasoning (i.e., transactivity), commenting constructively on others’ ideas, and making decisions democratically (Gillies 2016). When these conditions are met, learning together is associated with good learning

outcomes (Kyndt et al. 2013) and social benefits (Johnson and Johnson 2002; Lou et al. 2001).

Learning together, by definition, takes place in groups. With the goal of giving gifted children the opportunity to work together with their non-gifted classmates as well as with their gifted peers, learning together is implemented in the BE COOL! learning environment as a combination of learning in heterogeneous and homogeneous ability groups. In *heterogeneous ability groups*, children experience the value of working together with children of different ability levels. They learn to interact with such other children and they are stimulated to take into account and act upon differences between themselves and their group members (Castelijns and Stevens 1996; Förrer et al. 2000). *Homogeneous ability groups*, on the other hand, give teachers the possibility of challenging children at their own ability levels. Assignments can be matched and support can be adapted to the ability level within the group. This can result in interactions in which children can have discussions with each other at their own level. There is a joint degree of comprehension and each child is able to contribute at the same level. In addition, it enhances engagement of all children in the discussion (Murphy et al., 2017).

Inquiry learning

The third foundation of BE COOL! is inquiry learning. In inquiry learning, learners actively engage with the subject matter by collecting and processing information, drawing conclusions based on this, and constructing new knowledge (National Research Council 2012). Research has shown that inquiry learning can lead to deep learning (Alfieri et al. 2011; Minner et al. 2010) and that it results in better learning outcomes than learning by more direct forms of instruction (e.g., Aditomo and Klieme 2019; Eysink and de Jong 2012; Furtak et al. 2012; Smetana and Bell 2012). Besides its general cognitive benefits, we adopted this instructional approach in our method because it is suitable for differentiation. First, inquiry learning provides enough room to present challenging tasks to gifted children. It is a type of instruction that aligns with the advanced knowledge schemas of the gifted (Kalyuga et al. 2003) and with their preferred modes of learning (Kanevsky 2011; Scager et al. 2013). Due to its open-ended tasks that call for scientific reasoning, inquiry learning is considered to be an appropriate instructional approach for gifted children (De Corte 2013). Second, in order to be effective, inquiry learning should be supported (Furtak et al. 2012), even when gifted children are involved (Eysink et al. 2015), and inquiry learning provides ample possibilities for differentiation in this support. There are different types of guidance available that can be used to adapt to the learners' level (de Jong and Lazonder 2014). For instance, nondirective types of guidance, such as prompts, provide help without informing learners about exactly what to do, whereas directive types of guidance, such as scaffolds and explanations, are more explicit and steer the learners in a certain direction (de Jong and Njoo 1992; Lazonder and Harmsen 2016). Furthermore, the level of support can differ, as suggested by research showing that children with lower cognitive abilities benefit from extra structure and guidance in their learning process in comparison to their gifted peers (Wang et al. 2010).

In the BE COOL! learning environment, inquiry learning is embedded in the third step of the design cycle, in which children work in homogeneous groups (see Fig. 1 for an overview of steps, phases, and group compositions). In this step, learners must gather information by inquiry learning. Based on different frameworks for inquiry learning (see, for example, Pedaste et al. 2015), five phases were distinguished to guide learners through

Fig. 1 Overview of steps, phases, and group compositions

the inquiry cycle: (a) orientation: learners are stimulated to think about what they already know about the topic, (b) investigation: learners actively engage with the topic by performing an investigation (e.g., by conducting an experiment, constructing a concept map based on a text or video, or collecting data from the outside world in a diary), (c) drawing conclusions: learners examine the data collected in the investigation phase and think about what the data mean and what conclusions can be drawn, (d) evaluating: learners reflect on their learning process, from a content perspective (e.g., was my hypothesis correct?), a cooperation perspective (e.g., did we work well together?), and/or a learning perspective (e.g., did we reach our learning objectives?), and (e) broadening: learners are stimulated to transfer their newly acquired knowledge to other situations.

The ability-adjusted jigsaw method

The three conceptual foundations just described are united in the ability-adjusted jigsaw method (see also Eysink et al. 2017). This method is based on the original jigsaw procedure of Aronson et al. (1978) which, compared to more traditional types of instruction, has proven to be effective in terms of academic achievement (Karacop and Doymus 2013; Tarhan et al. 2013). In the ability-adjusted jigsaw method, children of varying ability levels work together in design groups. They are presented with a complex, open-ended problem for which they must design a solution. The solution requires knowledge about different topics. Each child in a design group is made responsible for one of these topics (resulting in positive interdependence and individual accountability; Johnson

et al. 2007). The topic assignment depends on the child's ability level. In order to gain knowledge about their specific topics, the individual members of the design groups split up to work in so-called expert groups. These expert groups consist of children of similar ability levels who are responsible for becoming experts about the same topic. They learn about their topic by completing inquiry learning assignments matching the ability level of their expert group. After having acquired this knowledge, all children return to their original design group in which the knowledge gained is shared with the other members and integrated in order to design a solution for the original problem. See Fig. 2 for a visual overview.

Using this method, gifted children experience the stimulation of working with gifted peers while working on inquiry assignments and at the same time, they interact in a goal-driven way with less gifted children. As such, the method combines learning by design, learning together, and inquiry learning, while taking the cognitive as well as the socio-emotional needs of gifted and non-gifted children into account.

Fig. 2 Overview of the ability-adjusted jigsaw method as implemented in the BE COOL! lesson series on the topic of living on the moon. Note. The four colors represent the four topics assigned to children of different ability levels. The plus signs and minus signs represent the ability levels of the children (i.e., + = gifted, - = average-ability, and - = low-ability). The numbers identify the heterogeneous design groups to which the children belong

BE COOL! learning environment

The ability-adjusted jigsaw method was implemented in the BE COOL! learning environment. This environment is illustrated using the example of a seven-week science lesson series designed for grades 4 to 6 that focuses on the topic of living on the moon.

A personal learning environment

When logging into the BE COOL! learning environment, registered children are redirected to their personal learning environment that corresponds to the topic and groups to which they are assigned (see Fig. 3 for an example). The menu on the left displays the different steps of the learning by design approach, and the names on the bottom left indicate whom the child works together with during that step. Upon clicking on the buttons, the assignments are shown that define the corresponding step of the learning by design approach. In the following sections, these steps and assignments are described in more detail, for each phase of the adapted-jigsaw method.

Heterogeneous prior knowledge phase

Children start by working in heterogeneous groups in which they are introduced to the problem and the inquiry method, and in which their prior knowledge is activated.

In the *Problem statement*, they receive a letter from the ‘Research & Design Department of BE COOL!’ that calls upon them to design a house on the moon so that a family

Fig. 3 Overview of the set of assignments in the homogeneous expert phase for the gifted children [screenshot, translated from Dutch, names are fictitious]

of four can live there. Moreover, they are introduced to the procedure that they are going to follow in order to design the moon house (i.e., the groups are told that they are going to design a house on the moon by following the learning-by-design approach, that each group member is individually responsible for gathering information on one specific topic, and that they will gather this information in another group by following the learning-by-inquiry cycle).

In the *Orientation* step, the children are introduced to the inquiry cycle while learning about gravity and air friction in a simulation. Following the literature, this is done by direct instruction (Klahr and Nigam 2004; Lorch et al. 2014; Zohar and Peled 2008). The five different steps of the inquiry cycle are explicitly named and treated by the teacher on the smart board. In a second assignment, children's prior knowledge is activated (Ausubel 1968). In heterogeneous groups, the children think about what is needed to survive on the moon, they connect their ideas and knowledge to four topics it is relevant to know about when designing a moon house (i.e., 'Light & Heat', 'Oxygen', 'Water', and 'Nutrition'), and they reflect on what knowledge is still lacking but relevant to be gathered to design the moon house.

Homogeneous expert phase

In the next phase, children split up to work in homogeneous groups to learn more about the topic they are assigned to according to their ability level. 'Light & Heat' is for the gifted children, 'Oxygen' or 'Water' for the average-ability children, and 'Nutrition' for the low-ability children. The four topics differ in complexity and the amount of structure and support given (Tomlinson 1996).

The *Gathering information* step consists of a set of 8–10 inquiry learning assignments for each topic (see Fig. 3 for an example: the overview of all assignments for the topic 'Light & Heat'). The type of inquiry varies, from investigating and drawing (e.g., drawing the process of photosynthesis as part of the topic 'Oxygen') to building an experimental design (e.g., investigating the optimal conditions for growing tomato plants as part of the topic 'Nutrition'). Similar types of inquiry assignments are provided for each topic.

In order to enhance learning and activate self-evaluations, specific, challenging learning goals are formulated (Seijts and Latham 2001). When an assignment is opened for the first time, the learning goals associated with that assignment are presented, and the children must indicate to what extent they think that they already have met these learning goals (i.e., self-judgment; Schunk 1990). When handing in the assignment, they must reflect on what they learned by indicating to what extent they now think that they have reached these learning goals.

All inquiry assignments consist of a short introduction ("What are you going to do?" and "Explanation") and a list of materials ("What do you need?") followed by the five steps of the inquiry cycle (see Fig. 4 for an example). These steps themselves provide guidance to the children (Lazonder and Harmsen 2016); depending on the targeted ability level, more or less structure is given within these steps. In addition, children have access to relevant resources and additional support, which can be requested by clicking the tabs Resources and Help at the top of the task window.

After finishing all inquiry assignments, the children complete a core assignment in which they summarize the most important information they gathered by answering six core questions about the topic (see Fig. 5 for an example, for the topic 'Oxygen').

Problem statement

Orientation

Gathering information about water

Designing moon house

Testing and improving

Developing prototype

Reporting

Harry

Pippi

Robin

Bridget

Be cool!

Learning goals Task Resources Help Back purifying and recycling water

What are you going to do?

In this assignment you are creating your own small water purification system.

Explanation

Have you ever heard of the water ducts in Amsterdam? This is a dune area between Zandvoort and Noordwijk. Here, water is extracted from the dunes. In other places in the Netherlands, water is also extracted from the ground to become drinking water.

What do you need?

- Worksheet: Purifying and recycling water
- Plastic bottle
- Little pebbles (well rinsed)
- Cotton pads
- Clean sand (for example, from the school sandpit)
- Dirty water, with mud and/or other filth, to test your system
- Bucket
- Resources

1. Orientation

Look at the worksheet together. Read the worksheet carefully. Do you know what you have to do?

On the worksheet is a picture of a small water purification system. Discuss together what you think will happen with the dirty water when it is poured into the system. Write your hypothesis below.

"We think that the dirty water, when poured through the small water purification system, will be dirtier/just as dirty as before/cleaner than before it went through the purifying system, because..."

2. Investigation

Now you will build your own small water purifying system. Follow the instructions on the worksheet. Answer the questions on the worksheet together.

3. Drawing conclusions

Answer the following questions:

a. What is filtered out of the water when it has been poured through your water purifying system?

b. What might still be in the water that makes it not ready to drink?

c. For what purpose could you now use this water?

4. Evaluating

a. Was your hypothesis correct?

b. How could your small purifying system be compared to the extraction of water in the dune area?

Hand In

Fig. 4 Inquiry assignment for the topic 'Water' for the average-ability children [screenshot, translated from Dutch]

Problem statement

Orientation

Gathering information about oxygen

Designing moon house

Testing and improving

Developing prototype

Reporting

Don

Mickey

Ron

Violet

Be cool!

Learning goals Task Help Back Core assignment

What is your assignment?

You are going to answer six questions that are central to your topic. This is your opportunity to show what you have learned about your topic in the past three weeks. By answering the questions, you will create an overview of your knowledge. You can use this overview during the next lesson. In the next lesson you will share your knowledge about your topic with your design group.

What do you need?

- Answers and elaborations from the previous tasks
- Resources from the previous tasks

Questions

Try to answer the questions below to the best of your ability. Of course, you do not have to do this by heart. Check your completed tasks, re-read the resources when necessary, or discuss with your oxygen-group members.

a. Why do we need oxygen?

b. How does breathing work?

c. How do we obtain oxygen on earth, and how does oxygen disappear from earth?

d. You have learned that humans 'consume' oxygen by breathing. So, new oxygen has to be fabricated. Plants can help to provide oxygen. Explain how a plant provides oxygen.

e. You have learned that plants provide oxygen on earth. How can you provide oxygen on the moon?

f. What do you need in and around the moon house to create and store oxygen on the moon?

Hand In

Fig. 5 Core assignment for the topic 'Oxygen' [screenshot, translated from Dutch]

Heterogeneous design phase

After having gathered information in the homogeneous expert groups, children return to their heterogeneous design groups to share their knowledge and integrate it into their design.

In the step, *Designing the moon house*, children work on an assignment in which the knowledge that has been gathered in the homogeneous expert groups must be shared and converted into design proposals. This process is guided by a worksheet, which strengthens the principles of the jigsaw method by stressing children's different, yet equally important roles as experts in creating the final design of the moon house. It emphasizes the role of each expert and the content of the four topics by: (a) stimulating children in a structured way to share their knowledge using the core assignment from the previous phase as input, (b) actively involving their group members in this process by prompting them to listen carefully and writing down the most important information, (c) stimulating them to evaluate the information on each topic and translate it into concrete design ideas, and (d) having them all sign the worksheet to ensure that each child's topic and ideas are represented in the group's design ideas.

Next, groups engage in *Testing and improving* their design ideas using four flowcharts, one for each topic, that help them to identify further improvements (see Fig. 6 for an example). Then, the design decisions and improvements are implemented when *Developing a prototype*. The children create a house on the moon to scale. Finally, they have to *Report* on their design decisions by writing a design report in which they describe their decisions, justify them, and reflect on the project.

BE COOL! teacher section

The BE COOL! learning environment also includes a personal teacher section that enables teachers to register their class and group them, and to monitor the children's progress and provide them with feedback. The features of the teacher section are described in the following sections.

Fig. 6 Flowchart for the topic 'Water' [translated from Dutch]

Registration and grouping

Teachers can register their class in the BE COOL! learning environment by entering children's names and ability levels. Teachers can use formal systems to indicate their children's ability. The teachers in our studies used a categorization procedure based on children's scores in the Dutch student monitoring system CITO, which indicates children's achievement level for different subjects, and, if available, information from the Dutch 'Digital Action Protocol for Giftedness' (i.e., Digitaal Handelingsprotocol Hoogbegaafdheid; van Gerwen and Drent 2011) which identifies gifted children, including gifted underachievers.

After registration, the BE COOL! system assigns the children to their heterogeneous design groups and homogeneous expert groups (see Fig. 7 for an example). Teachers can make changes to the groups suggested by the BE COOL! system.

Monitoring and providing feedback

Teachers are provided with an overview of the children's progress. For each topic, the names of the children responsible for that topic and the status of the assignments they must complete are given. Children's progress is displayed by five different symbols (see Fig. 8): (a) an opened envelope showing that children opened the assignment and are working on it, (b) a closed envelope showing that children handed in the assignment, (c) a red cross showing that the teacher has given feedback on an assignment that was handed in, (d) a green exclamation mark showing that the assignment is approved by the teacher, but that there is feedback, and (e) a green curled ribbon showing that the assignment is fully approved by the teacher.

Fig. 7 Teacher's overview of the categorization and group assignments of a fictitious class with fictitious children [screenshot, translated from Dutch]

Assignments that groups hand in can be approved and/or provided with feedback. By clicking on the closed envelope symbol, teachers are forwarded to the feedback page consisting of different elements: (a) name of the assignment and names of the children who worked on the assignment, (b) the assignment with children's answers, (c) a response model supporting teachers in checking children's work, (d) an overview of feedback on this assignment previously given to the group by the teacher, and (e) an input field in which teachers can write their feedback and provide the assignment with a rating (i.e., red cross, green exclamation point, or green curled ribbon). See Fig. 9 for an example of a feedback page.

In the children's learning environment, the feedback is presented in an additional tab, 'Feedback'. When children who worked on the assignment log into their digital learning environment, they see the teacher's rating(s) in the overview of assignments. Upon clicking on the assignment, it opens with the feedback tab, so that the feedback is immediately visible.

Teacher manual

A teacher manual provides information on the digital learning environment (i.e., technical information and practical information) and an overview of children's assignments, supplemented with printable worksheets that are part of some assignments.

Design process

The BE COOL! learning environment was developed in a four-year design project in which research and development alternated. The overall research question was what a learning environment should look like, in which gifted learners are socially included in the regular classroom and still being challenged cognitively by using the ability-adjusted jigsaw method in which learning by design, learning together, and inquiry learning are combined. Based on this overarching research question, three underlying questions were defined. The first question was "What are the needs and expectations of the teachers concerning such

The screenshot shows the 'teachers' overview page for the 'Astronauts' class in 'EXAMPLE 2017'. The 'water' tab is selected, showing a progress table for five students across various water-related topics. The table uses icons: a green ribbon for 'good', a green exclamation mark for 'warning', a red cross for 'bad', and a closed envelope for 'no feedback yet'.

	Water on earth	Water cycle	Water diary (1)	Water use in the house	Purifying and recycling water	Water in and out of your body	Water diary (2)	Core assignment	Water phases
Harry									
Ron									
Pippi									
Albus									
Cruella									

Fig. 8 Teacher's overview of children's progress in the 'Water' group in a fictitious class [screenshot, translated from Dutch]

Status of the assignment

<p>project phase task sub-group group status</p> <p>Astronauts Gathering information about water Water cycle Bridget, Pippi Bridget, Harry, Pippi, Robin</p> <p></p>	<p>Who, what, where?</p> <p>Previous feedback</p> <p>EXAMPLE 2017: </p> <p>22 Sep 2014, 20:21:25</p>				
<p>Feedback</p>	<p>Student answers</p>				
<p>Feedback can only be provided when students have handed in the assignment.</p> <p>CANCEL</p> <p>Answer key:</p> <p>Step 1 - Orientation Their own answer</p> <p>Step 2 - Researching Not applicable - No assignments</p> <p>Step 3 - Concluding Their own answer</p> <p>Step 4 - Evaluating The drawing of the water cycle should contain at least the following features:</p> <ul style="list-style-type: none"> - Clouds - Sea - River - Rainfall - Evaporation - Arrows that create the idea of a cycle/loop <p>See the drawing below for an example:</p> <p>Step 5 - Broadening</p> <p>a. Hot air could contain more water vapour than cooler air. The amount of water vapor increases by six percent whenever the temperature increases by one degree Celsius. In addition, evaporation increases by about 2 percent whenever the temperature increases by 1 degree Celsius. The amount of rainfall on earth is on average similar to the evaporation. This means that the rainfall also increased by 2 percent, on average.</p> <p>Because the amount of water vapor has increased greatly as a result of global warming, the vapor also remains longer in the atmosphere. Obviously, the time between rain showers is therefore also longer. But when it starts raining, these rain showers often also take longer.</p> <p>b. There will be no water cycle, because there will be no evaporation and no rainfall on the moon.</p>	<p>What is the assignment? In this assignment you will start with individually creating a sketch of the water cycle. Then, you will compare your sketch with a group member. Together you will create a final drawing of the water cycle using the tool in the learning environment.</p> <p>Explanation In the Netherlands, we like to complain about the rain. Have you ever wondered where all the rain goes after the rain showers have stopped? And how did the rain end up in the sky anyway?</p> <p>What do you need?</p> <ul style="list-style-type: none"> - Paper - Pencils - Resources <p>1. Orientation You will start with creating an individual sketch of the water cycle. Try to imagine what the water cycle is. Your drawing has to be clear and schematic. This means you do not have to create a piece of art. Your sketch should be clear enough to explain to somebody else how the water cycle works.</p> <p>2. Researching Look at the resources.</p> <p>3. Concluding Check your drawing by reading and looking at the information in the different resources. Did you represent the water cycle correctly in your drawing?</p> <p>4. Evaluating Compare your drawings. Do they look alike? What could be improved? Together you will create a new drawing of the water cycle in the tool below. This drawing will combine the best of both your drawings. Mistakes in the previous versions should be left out or fixed. Your good ideas from the previous versions should be incorporated in your new, shared version. One thing is most important: you have to agree on the drawing.</p> <p>5. Broadening Answer the next two questions.</p> <p>a. What will happen with the water cycle when the earth becomes warmer (global warming)?</p> <p>It will rain more often</p> <p>b. Do you think that there is a water cycle on the moon? Explain your answer.</p> <p>no, because there is no water and no atmosphere</p> <p>This is what you thought you knew about the learning goals of this assignment:</p> <table border="1"> <tr> <td data-bbox="505 1234 770 1296">You learn how water on earth circulates in a water cycle.</td> <td data-bbox="770 1234 1017 1296"> ☐ ☐ ☒ ☐ ☐ </td> </tr> <tr> <td data-bbox="505 1296 770 1358">You will think about what will happen when the water cycle is interrupted.</td> <td data-bbox="770 1296 1017 1358"> ☐ ☐ ☒ ☐ ☐ </td> </tr> </table>	You learn how water on earth circulates in a water cycle.	☐ ☐ ☒ ☐ ☐	You will think about what will happen when the water cycle is interrupted.	☐ ☐ ☒ ☐ ☐
You learn how water on earth circulates in a water cycle.	☐ ☐ ☒ ☐ ☐				
You will think about what will happen when the water cycle is interrupted.	☐ ☐ ☒ ☐ ☐				

Fig.9 Example of feedback page for the assignment 'Water cycle' from the topic 'Water' [screenshot, translated from Dutch]

a learning environment?”, which gave input for the learning environment in general. The second question was “How much and which type of support do children of different ability levels need when working on inquiry assignments?”, which gave input for the design of the homogeneous expert phase. And finally, the third question was “Should the knowledge sharing and integration process between children of different ability levels be supported and how?”, which gave input for the design of the heterogeneous design phase. This section summarizes all studies that were performed and which together form the scientific basis of the BE COOL! learning environment.

Needs assessment

In order to answer the first question, a needs assessment was performed prior to the first design. For this purpose, 14 teachers were interviewed about their needs and expectations of the BE COOL! learning environment. Eight main issues were raised by the teachers: (a) the domain of the lesson series and the corresponding assignments should fit into the standard curriculum, (b) topics and assignments should be challenging and feasible for children of different ability levels, (c) the learning environment should contain clear information and (links to) resources must be provided, so that children can work independently, (d) heterogeneous cooperation should be supported, (e) children should be given freedom to choose their own assignments and order of completion, (f) children should be stimulated to evaluate and reflect on their learning process, (g) the learning environment should enable teachers to monitor children’s progress and to provide completed assignments with feedback, and (h) a teacher manual should be available to give teachers information about group composition, assigning topics, lesson plans, and response models.

The results of the needs assessment gave input for the learning environment in general (including the teacher dashboard and teacher manual) and for the design of the homogeneous expert phase and the heterogeneous design phase in particular.

Designing the homogeneous expert phase

The idea of the homogeneous expert phase was to challenge children with tasks that match their abilities. For this to happen, we needed insight into the amount and type of support children of different ability levels needed when working on inquiry assignments (question 2). We started with a usability study among 37 fourth, fifth, and sixth graders of varying ability levels working on different types of inquiry assignments. Children were asked to think aloud while performing their activities in the learning environment and the researcher recorded their actions and choices by means of a checklist. The study showed that, independently of age, gifted children needed less support than lower-ability children, and if support was needed, they were satisfied with more abstract prompts than the lower-ability children, who preferred and needed more concrete instructions for successful completion of the inquiry assignments.

Based on the usability study, support was designed to guide children of different ability levels in their inquiry process. Support by means of prompts that children could access when they needed them was implemented in an inquiry assignment and tested in an exploratory study with 478 fifth and sixth graders of three different ability levels (for details, see van Dijk et al. 2016). A comparison was made between groups that had these prompts available and those who did not. Children’s use of prompts and

the quality of their inquiry processes were derived from logfiles; their domain knowledge was assessed by pre-, post-, and retention tests. Results showed that children who had support available displayed a more active and effective inquiry process than those who did not. Moreover, gifted children used the support frequently, whereas average- and low-ability children hardly used it. However, if they did, their learning process improved. These results gave insight into how to support gifted children and made clear that the average- and low-ability children needed to be instructed more explicitly.

Based on these results, four complete sets of inquiry assignments (i.e., 'Nutrition' for low-ability children, 'Water' and 'Oxygen' for average-ability children, and 'Light & Heat' for gifted children) were developed, matching structure and support to ability level. These four sets of assignments were piloted with 155 fourth, fifth, and sixth graders of varying ability levels. Based on observations and interviews with teachers and children, it became clear that the gifted children were able to work with the assignments. The average-ability children needed a more concrete explanation of the learning goals in order to place their newly-acquired knowledge in the overall context and they needed more structure when performing experiments. The low-ability children also needed more structure, not restricted to the experiments, though, but they needed a more concrete step-by-step description of the assignment as a whole and what they were supposed to do.

In addition to testing the individual assignments and their suitability for the three ability levels, in this pilot study we also focused on the sets of inquiry assignments as a whole and children's ability to select assignments and make a plan. In the first version, children were given a large set of inquiry assignments from which they could choose. The idea of this non-structured set of assignments was to give children the opportunity to make their own plan by selecting assignments of their interest in the order they preferred, and to provide them with ample assignments to work on during extra time or at home. Teacher evaluations, however, showed that children were overwhelmed by the large non-structured set of assignments and did not have enough planning skills to work through the assignments as intended. These results led to a reduction of the number of assignments. In addition, the assignments were assigned to specific weeks in a predefined order and this schedule was implemented in the learning environment.

Both the predefined schedule for the set of assignments as a whole and the additional structure within the assignments for the average-ability and low-ability children were monitored in the next study. That study focused on the design of the heterogeneous design phase (see next section), but before entering this phase children had to go through the homogeneous expert phase. Evaluations showed that children were better able to work with the predefined schedule of assignments and were able to finish them within the set time, and they showed that all children were now able to work with the assignments.

Designing the heterogeneous design phase

In this phase, children of different ability levels must work together on their design. Each child, independent of ability level, is now an expert on one of the four topics and must share the newly-acquired knowledge with the other group members so that all knowledge can be integrated into their design. Although the jigsaw method in itself (with the elements of positive interdependence and individual accountability) is presumed to elicit this

knowledge-sharing and integration process spontaneously, the needs assessment as well as the literature indicated that elementary school children might still experience problems with this (Mercer 1996; Mercer et al. 1999) and that these problems might even be amplified when children differing in knowledge level and pace of learning must work together (Lou et al. 1996; Wang et al. 2010). For example, gifted children often believe that they have the expertise and ability to complete the task on their own (Webb et al. 2002). They tend to dominate the cooperative process by solving problems individually and not leaving room for their lower-ability group members or ignoring their suggestions (Mugny and Doise 1978). At the same time, low-ability children often consider their gifted classmates as more knowledgeable, resulting in less motivation to contribute (see also Shepperd 1993) and acceptance of statements made by the gifted without critical reflection (Chaiken and Maheswaran 1994).

In order to get insight into whether the knowledge sharing and integration process between children of different ability levels should be supported or not (question 3), we developed a support tool which could guide the children in this process. The tool was based on insights from literature which shows that scripting this process is an effective type of support (Dillenbourg and Tchounikine 2007; Weinberger et al. 2010). It systematically guided the heterogeneous groups through four steps of knowledge sharing and knowledge integration. The steps were intended to increase children's awareness of positive social interdependence and their individual accountability, and they were designed to stimulate promotive interaction and evaluation of the group process. As a consequence, the tool which was implemented as a worksheet, was expected to lead to more equal participation in the knowledge-sharing process, more focus on domain knowledge sharing, and more knowledge acquisition. A full description of the worksheet can be found in van Dijk et al. (2019).

In the earlier mentioned pilot study, an initial version of the worksheet was piloted. The study showed that children were able to work with the four steps on the worksheet that guided them through the cooperative knowledge-sharing process. In addition, in line with the literature (e.g., Vuopala et al. 2019), an initial comparison with groups that did not use the worksheet showed that there was a more equal distribution of contributions to the cooperative process in the worksheet groups. However, the second step of the worksheet, which focused on writing down knowledge that was shared by the other group members, was not self-evident. Children did not always understand what the step involved and they needed additional explanation about the purpose of this step. Therefore, more extensive explanation of the second step was provided in a new version of the worksheet.

This version was used in an experimental study investigating its effectiveness (for details, see van Dijk et al. 2019). In the study, 136 fourth to sixth graders worked cooperatively in heterogeneous groups of four while being videotaped. A comparison was made between groups that worked with and without the worksheet. Children's cooperative processes were coded on participation and content. Results showed that the group dialogues benefited from working with the worksheet: Children of all ability levels who worked with the worksheet participated more equally in domain-related dialogue, groups who received the worksheet spent more of their dialogue on discussing content regarding the four topics that were central to the assignment, and children who used the worksheet also spent a larger proportion of their dialogue on providing theoretical explanations about the domain than the unsupported groups. On the grounds of that, the worksheet was implemented in the final version of the BE COOL! learning environment.

Conclusion

In educational practice, there is often a struggle to find a balance between demands regarding the cognitive development of gifted children and their needs on the social-emotional level. In the BE COOL! project, we searched for this balance which resulted in a differentiation method using the ability-adjusted jigsaw method which was implemented in the BE COOL! learning environment.

In this method, gifted children are given the opportunity to investigate topics together with their gifted peers and to exchange and discuss ideas at a high cognitive level, resulting in knowledge and skills development matching their cognitive needs and abilities. For this purpose, the method uses inquiry assignments which are, following the results of our research, combined with differentiated support which fosters active and effective ways of learning, not only for the gifted, but also for the non-gifted children.

In addition, the method encourages and supports cooperation between children of different ability levels. Following the results of our research, this is done by a worksheet guiding them through the different steps of the knowledge sharing and knowledge integration process. Working in these heterogeneous ability groups takes into account the social-emotional needs of the gifted with regard to social interaction with their peers.

Moreover, gifted and non-gifted classmates work together on a design problem in a setting in which the input of each group member, gifted or not, is indispensable. Each child becomes an expert in a specific field which results in a situation in which gifted and non-gifted children not only learn *with* each other, but also learn *from* each other. Children are individually accountable as well as socially interdependent from each other. They do not receive enrichment materials that are not related to what their classmates following the regular curriculum get and which they have to work on individually and independently. Instead, they work on a project together with their classmates in which everybody has his or her own role and responsibility. As such, the method truly includes the gifted children in the classroom.

Finally, using this differentiation method is not at the detriment of the cognitive outcomes, as shown in a large-scale experimental study in which the ability-adjusted jigsaw method as implemented in the BE COOL! learning environment was compared to a setting, in which children received more traditional tailored tasks that had to be performed individually (van Dijk et al., submitted). This shows that including children of all ability levels in an encompassing learning environment is possible, without giving away the cognitive outcomes. This makes it a valuable tool teachers can use to challenge and socially include gifted learners in the regular classroom.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the BMS Ethics Committee of the University of Twente.

Informed consent Informed consent was obtained from all individual participants included in the studies.

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