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Abstract

Several reforms in national and international curricula have been implemented to introduce inquiry-based activities to promote different science process skills. Science skills require high cognitive effort for students and, thus, they need supports to develop them in an inquiry process. Among these supports, video-worked examples demonstrate how to perform these skills and provide students with a scheme for an inquiry activity. Recently, video-examples has been explored in primary and secondary education with promising results. However, to gain a broader perspective on their effectiveness, this article aims to evaluate the consistent improvement of each science skill from a comparison with a control group carrying out two consecutive classroom interventions. This research included 44 students in fifth and sixth grades and a quasi-experimental research design with a quantitative method has been applied. In the experimental group, video examples had a positive influence on the participants' inquiry behavior. For most of the science skills, students showed a consistent improvement in both the first and second inquiries supported by these videos. However, the control group showed less predictable outcomes, as some skills improved only during the first or the second intervention, but not throughout the whole study.

Introduction

Scientific literacy can be defined as the capacity to use scientific knowledge to identify questions, explain scientific phenomena and draw evidence-based conclusions to understand the natural world and the changes made to it through human activity (Organisation for Economic Cooperation and Development [OECD], 2016). Based on this definition, students need procedural and conceptual understanding, enhanced and validated through scientific investigations (Chin & Osborne, 2008; Harlen, 1999). Thus, there has been a reform effort in science primary education towards an inquiry-based model at both national and international levels (Harlen & Qualter, 2009; Rönnebeck et al., 2016). In this way, the European Commission Rocard Report highlights the importance of introducing inquiry-based activities in educational curricula throughout European countries (European Commission, 2007). Trends in International Mathematics and Science Study (TIMMS) also highlights this fact by assessing students' process skills and content knowledge to solve scientific investigations contextualized in real and daily situations (National Center for Education Statistics [NCES], 2003). In line with the European standards, in 2015, there were changes in the methodological guidelines in Catalan primary education curriculum. The new vision of the curriculum for science education highlights the inquiry methodology and emphasizes a progressive development of a set of different science process skills (or 'science skills') throughout the educational levels (Decret 119/2015).

Developing science process skills by performing authentic scientific tasks is a fundamental component to learning concepts and developing procedural understanding of science (Harlen, 2013; Harlen & Qualter, 2009). In the present work, the notion 'science skill' is based on activities that reflect scientists' behaviour and refers to the ability to apply rules, principles or conventions about the design and performance of a scientific investigation. Although science skills can be named and organized in different ways, there is considerable agreement about their objectives and definition. In this study, science skills are related to identifying research questions, formulating predictions and hypotheses, designing investigations, organising and interpreting evidence and drawing appropriate conclusions (Durmaz & Mutlu, 2016; Harlen & Qualter, 2009; Rönnebeck et al., 2016).

Understanding and performing science process skills is not an easy task and requires a high cognitive effort for the students (Piekny & Maehler, 2013). In order to accurately identify and define the cognitive demands of each science skill, several studies have considered these skills in two categories. On the one hand, basic science process skills are considered to be those that provide the intellectual basis of scientific inquiry and are acquired in the early stages of primary education, such as observing, measuring and using numbers, and classifying. On the other hand, integrated science process skills may involve the use of many basic science process skills and thus, require more advanced knowledge and higher cognitive effort, such as hypothesizing, designing an investigation under a control of variables, interpreting data or drawing conclusions (Ergül et al., 2011; Özgelen, 2012). Some studies highlight the need to introduce continuous practice in scientific inquiry activities to improve integrated science process skills in different contexts (Yumusak, 2016; Lati, 2012).

Scientific inquiry is one of the most effective teaching approaches to enhance students' process skills, which allows them to incorporate these skills with other aspects such as scientific reasoning, scientific knowledge and critical thinking (Lati, 2012; Harlen & Qualter, 2009; Rönnebeck et al., 2016). Learning through inquiry involves students to participate actively in developing their understanding by asking questions, designing and conducting investigation, collecting data and interpreting results (Harlen & Qualter, 2009; Kandil & Işıksal-Bostan, 2019; Schallert et al., 2020). In this regard, various studies have highlighted how science process skills are not clearly understood and implemented by primary education students in an inquiry activity, probably because they are not scaffolded or explicitly explained (Coil et al., 2010; Durmaz & Mutlu, 2016). Different authors indicate that inquiry methodology is effective only when explicit instructional supports are introduced to novice learners (Kruit et al., 2018; Lazonder & Harmsen, 2016). Among these supports, several authors highlight those that introduce task-structuring in their inquiry activities and offer an explicit vision of the science skills involved in an investigation (Lazonder & Egberink, 2014; Lazonder & Kamp, 2012).

Various authors have explored the use of video to guide science learning (Kay, 2012; Otrel-Cass et al., 2012). In particular, video-worked examples have been highlighted as a support that provides students with a general scheme for a problem-solving activity. When implemented in an inquiry environment, video-worked examples (hereafter, 'video-worked examples', 'video examples' or 'videos') provide a step-by-step expert instruction about how to complete an inquiry task. By using multiple visual resources, video examples demonstrate how to perform the science skills and explain the reasoning underlying the choice and implementation of each one. These videos also intend to illustrate the complex nature of scientific investigations by highlighting their open and iterative structure (Kant et al., 2017; Mulder et al., 2014). The examples, explanations and demonstrations shown in the video examples can benefit novice learners especially, as they can better focus on the needed steps to solve a scientific inquiry (Kant et al., 2017). From this point, as the students become more proficient with the approach, they become more active and autonomous along the way in the investigation process and can tackle increasingly complex inquiry activities (Kruit et al., 2018).

Video-worked examples as a support during an investigation task have been explored in secondary education where this support helped to enhance the quality of the students' scientific explanations and to systematize their experimentation task (Kant et al., 2017; Mulder et al., 2014). In primary education, preliminary results obtained in a case study showed that video examples provided the pupils a better inquiry schema and a progression in the proficiency of some science skills, such as the formulation of investigable questions, the organization of data and the interpretation of evidence (Solé-Llussà et al., 2019). Despite the improvement in the students' investigative behavior, in this work it is also highlighted that there is still room for improving their inquiry competence. Some integrated science skills, such us hypothesizing or controlling variables, could be improved by doing a broader study after carrying out consecutive classroom interventions supported by different video examples.

The Present Study

The present research adds to the current discussion by delving into the effects of video-worked examples for conducting more advanced scientific inquiries in elementary education. Introducing inquiry-based activities in primary education is a challenging issue. Elementary students usually lack experience, strategies and knowledge of the different science skills involved in a scientific investigation (D'Costa & Schlueter, 2013) and, thus, some authors emphasize the need of analyzing proper scaffolds and supports that could help to structure the inquiry task and separate it into more manageable subtasks for students (Lazonder & Kamp, 2012). Such support can come from the implementation of video worked examples and, thus, the present work builds on previous investigations on implementing video examples for enhancing the performance of the different scientific skills (Solé-Llussà et al., 2019).

This study is addressed to discuss deeply the importance of providing helpful support to perform effective scientific inquiries in elementary education and to show how video-examples can help students to implement the different science skills during an investigation task. By performing research comparing both control and experimental groups and by increasing the number of video-worked examples introduced in the classroom, deeper knowledge could be obtained about the consistent effects and the benefits of this support in primary education. The present paper attempts to evaluate the continuous effectiveness of video-worked examples in the performance of students' scientific skills when two consecutive scientific inquiries are implemented.

Method

Research Design

A quasi-experimental research design was implemented to obtain information about changes among the participants and create a reliable picture of achievement before and after the performance of an intervention (Sampieri, 2018). Two natural groups of students (experimental and control) were analyzed to test the contribution of video-worked examples as a support during an inquiry task to promote the participants' science process skills. In the experimental condition, video-worked examples were available in all the educational intervention. Students in the control condition did not receive support from video-worked examples. Both the experimental and control group students were guided by the same teacher, who had 25 years of experience as a primary science teacher and two years of experience in teaching by applying an inquiry methodology. To determine whether the instructional intervention made a difference in the experimental group students' science skills at the end of the intervention, quantitative data was obtained from both groups, using open-ended pre- and post-questionnaires, before and after the intervention. Moreover, audio and video recordings of the intervention were carried out for collecting examples of specific classroom events which will be helpful to further support the quantitative results and to gain a broader perspective of the performed intervention (Creswell, 2014).

Context and Participants

The present research study was conducted with 44 elementary school students in the fifth and sixth grades. In the experimental group, 24 pupils participated (14 females, age M = 11.24 years, SD = 0.75) while in the control group there were 20 pupils (13 females, age M = 11.32 years, SD = 0.71). Both groups were from one rural public school in Catalonia (eastern Spain). The experimental and control group students were from different classrooms to prevent any interaction between pupils from each group. Students in both groups had no previous knowledge about the scientific topics that were going to be tackled and had not been introduced to inquiry and the related scientific skills. The students worked in groups of 2 or 3 in a medium and flexible classroom with a teacher who has more than 10 years of science-subject teaching experience (which included implementing inquiry-based science) in an elementary school. The school was willing to participate on the bases of different pragmatic factors such as a written informed parental and children's consent for the study, interest of the teacher and available time.

Educational Intervention

The process diagram in Figure 1 summarizes the sequence followed in the implemented educational intervention performed by both the experimental and control groups. This intervention presented two subsequent training phases. In each phase, students were asked to carry out a training inquiry task about a particular scientific topic (see Figure 1). One month separated the investigation tasks. The first inquiry task was related to electrical direct current circuits, where students analyzed the relationship that exists between the voltage of a battery and the electric current. The second inquiry task was about the decomposition process in a fruit, where pupils investigated the physical and chemical changes that occur during the rotting of an apple. These two topics were chosen based on their inclusion in the elementary education curricula (Decret 119/2015). The type of both inquiries is a structured one where students investigate a given research question by following a prescribed procedure and explicit step-by-step guidelines in order to collect and represent the data. Students analyze their results and formulate the corresponding scientific explanations (Eick et al., 2005). Each inquiry task was performed during three working sessions of 75 minutes, with each session dedicated to a key phase of the inquiry process: introduction to the research topic, planning of the research and interpretation of the results (Figure 1) (Rönnebeck et al., 2016). During all the sessions, participants worked collaboratively and were organized in small groups of two or three students.

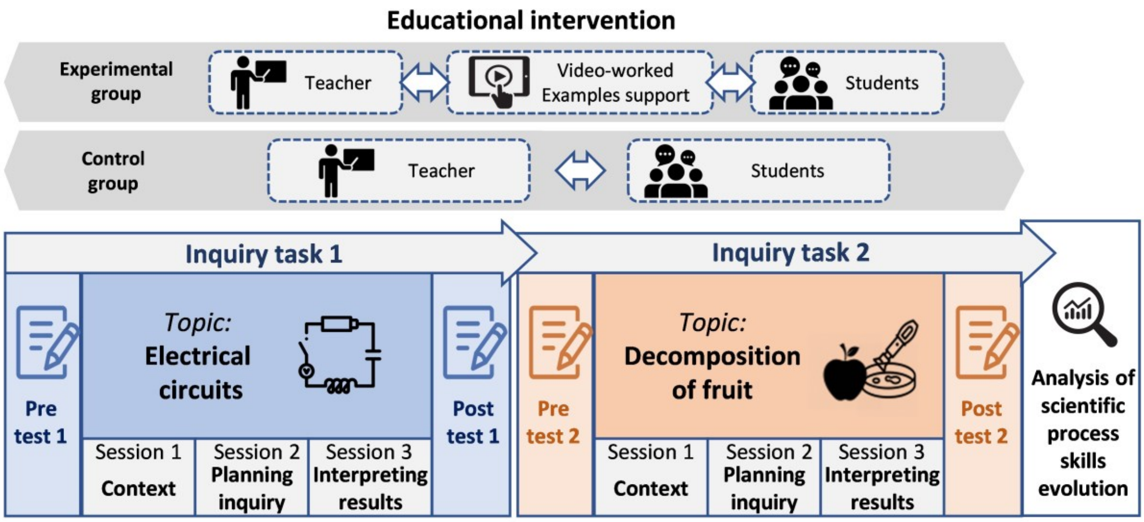

Figure 1. Sequence of the Performed Educational Intervention

Experimental Group: Participants in this group received the support of video-worked examples during the performance of both inquiry tasks. The videos implemented in this group are available in previously published documents (see Table 1) and were designed and produced by a group of schoolteachers and university lecturers with more than ten years of experience of science teaching (Solé-Llussà et al., 2019). Specifically, the two inquiry tasks carried out in the performed educational intervention were supported by a different set of video-worked examples. Each set of videos was focused on the particular scientific topic (electrical circuits and decomposition of the fruit) and both explain and exemplify, step-by-step, how to perform an inquiry process and the involved scientific skills. Both sets segment the inquiry task into more manageable smaller parts for helping students to better understand how an investigation can be organized (Lazonder & Kamp, 2012). Thus, each set was composed of three videos: 1) an introduction video, which presented the context of the research and proposed an investigable question, 2) a planning video, which exemplified how to design an investigation following a control of variables and 3) an interpretation video, which described how to represent and analyze the collected data to build scientific explanations (see details about the set of video-examples in Table 1). Although the inquiry is not a linear process, this segmentation of the inquiry process in three more manageable stages could be especially helpful for novice learners that are unfamiliar with this methodology. On the one hand, it could help them to better organize and structure their investigation process and, on the other hand, it aids them to better clarify and understand the different involved science process skills (Lazonder & Kamp, 2012; Mulder et al., 2014). The acquisition of scientific skills from a structured investigation can contribute to the investigative students' autonomy and can help them to develop more advanced and complex scientific activities in the future (National Research Council [NRC], 2012). Moreover, the video examples were designed and produced considering different pedagogical and technical characteristics in order to facilitate their introduction in an elementary education classroom. For example, these videos include text and voice for helping to follow the provided explanations; graphical elements such as icons, schemes or diagrams were used to clarify the presentation and organization of the provided information; everyday images familiar to the students were used to illustrate the exemplified inquiry processes; vocabulary was adapted to the pupils' academic level.

Table 1. Details of the Implemented Video-worked Examples

	Structure and content of the implemented video-examples		
	INTRODUCTION	**PLANNING OF THE RESEARCH**	**INTERPRETATION OF THE RESULTS**
	Introduces the topic to be investigated Contextualizes the topic in students' everyday lives Introduces concepts to support the context Proposes an investigable question	Presents how to plan the inquiry Exemplifies the formulation of initial ideas (predictions and hypotheses) Introduces the concept of variable Presents the material and instruments needed to develop the inquiry Shows how to collect and organize the data	Shows how to build graphs Helps to find patterns between the data Explains how to build explanations Compares results with initial ideas Summarizes the research
			
Electrical circuits video set	http://hdl.handle.net/10459.1/66476	http://hdl.handle.net/10459.1/66497	http://hdl.handle.net/10459.1/66501
Fruit decomposition video set	http://hdl.handle.net/10459.1/66190	http://hdl.handle.net/10459.1/66191	http://hdl.handle.net/10459.1/66192

In the experimental group, and in both inquiry tasks, the corresponding three video-worked examples were introduced consecutively in each session. The sessions were structured in a similar way: 1) first, students visualize the corresponding video examples (10 minutes), 2) students and teacher discuss the content of the video (10 minutes), 3) pupils carry out collaboratively and autonomously the inquiry task and the involved scientific skills by following the descriptions and examples that can be watched in the videos (45 minutes) and 4) finally, students and teacher summarize the most relevant aspects of the session (10 minutes). The experimental group students had continuous access to video examples though a Tablet. According to the authors' experience, it is remarkable that this mobile technology facilitates the adaptation to different learning rhythms, as participants have the freedom to watch the video as many times as they need, view a certain segment several times, stop the video when necessary, etc. Previous researchers highlight similar observations (Kant et al. 2017; Mulder et al., 2014). In this group, the teacher also offered complementary support to the one offered by the videos. The teacher extended the explanations watched in the videos, provided redundant help on the described scientific procedures, promoted the dialogue and collaboration between students and solved possible technical problems.

Control Group: students perform both inquiry tasks without the support of the video-worked examples. The teaching principle implemented in this group was that knowledge resides with the teacher who transfers it to the students. Throughout the three sessions of each inquiry task, the teacher first introduces and explains the inquiry steps to be performed and the characteristics of the different scientific skills to be implemented. Then, pupils carry out collaboratively the corresponding inquiry task. In this group, the role of the teacher became more predominant. The teacher was responsible for the different guides and explanations provided during the performance of the different inquiry tasks in the classroom. For example, the teacher explained scientific concepts, showed how to use some of the scientific instruments, introduced the next steps to follow, stimulated the students' collaboration, etc. The teacher only used slides and voice explanations to introduce the aforementioned information and did not implement any video as a support in the control group.

In both the control and experimental groups, students had the appropriate resources to carry out the corresponding inquiry tasks. For example, in the investigation of electrical circuits, students had a computer with direct access to a virtual laboratory related to this topic. In the fruit decomposition inquiry, pupils managed real scientific instruments, such as a digital balance, refractometer, thermometer, etc. and collected data during the fruit decomposition process (approximately one week). Students maintained a laboratory notebook, where they recorded their tasks during the inquiry process and where they collected and organized, with the corresponding graphic treatment, the empirical data that came from their investigation. The laboratory notebook was not considered for the students' assessment of the science subject. Finally, it is important to highlight that, despite the importance of the role of the teacher in both groups, it is outside of the scope of this research and it will be analyzed in future studies.

Data Collection

To examine whether the instructional intervention made a difference on the experimental group students' science process skills after the intervention, we collected quantitative data in both conditions (experimental and control group) from pre-and post- inquiry test tasks. For each training phase of the intervention, a pre- and post-inquiry test was performed by the students (see Figure 1). These tests were carried out just before the corresponding training inquiry task and fifteen days after the end of the task. In particular, two different tests tasks were implemented in the present research, one for each training inquiry task. The objective of the test tasks was to assess the students' ability to apply the different scientific process skills and to analyze the change over time. These tests shared the same structure as other similar assessment instruments published in the literature (Kant et al., 2017; Kruit et al., 2018; Solé-Llussà et al., 2019).

The test tasks of this work included six open-ended questions about how the students would perform the different scientific skills during a research process. They were asked to 1) identify researchable questions, 2) propose a prediction and hypothesis related to the formulated researchable questions, 3) identify the appropriate study variables for tackling a research question, 4) describe the experimental design that leads to the collection of empirical data useful to test the proposed hypothesis and answer the research question, 5) collect, organize and represent empirical data and 6) interpret the evidence and propose scientific explanations related to the investigable question and the proposed hypothesis. The main difference between both inquiry test tasks was the scientific topic on which they focused. Thus, a test about the buoyancy of solids was implemented before and after the electrical circuits inquiry and a test about plant growth was implemented before and after the fruit decomposition inquiry. The use of different topics other than the ones from the training inquiry tasks allows studying the participants' proficiency in the different scientific skills when applied to different scientific contexts. As an example, the following link provides access to the implemented test corresponding to the second inquiry task https://inquiry991331.typeform.com/to/injrX3.

The test inquiry task was validated by a group of seven experts composed of schoolteachers and university lecturers, with more than ten years of experience of science teaching, who assessed the test items by attending to the criteria published in Carrera et al. (2011): (1) the unicity and linguistic precision of the question for its understanding and (2) the relevance, adequacy, and relationship of each question with the object of evaluation. Definitions of "unicity" and "relevance" were provided to the group of experts before performing the validation task. After a few iterations, the final test was validated with an agreement rate of 80% (buoyancy test) and 100% (plant growth test).

Data Analysis

The answers to the test were analyzed by applying the rubric available in previous research (Solé-Llussà et al., 2019) and that can be accessed in the following link: https://primariacafe.wixsite.com/my-site. This rubric allows the assessment of the main scientific skills involved in an inquiry process. Each scientific skill was evaluated with an ascending numerical grade, with a minimum of 0 and a maximum of 4 points, according to the level of proficiency. In order to show how the scoring model has been implemented, in the aforementioned rubric, each skill level has been exemplified with an answer obtained from the students' inquiry test tasks. Two evaluators, both university lecturers and researchers in science education, received training for the scoring of the test inquiry task. Evaluators were schooled using student answers from the pre- and post-tests. Twenty-five percent of the pre- and post-tests were scored by both evaluators. Interrater reliability was calculated by determining interclass correlation (e.g., ICC, two-way random, absolute agreement). The ICC ranged from .91 to 1.00 and the tests were randomly distributed to be scored by individual evaluator. Each evaluator scored one question for all students before moving on to the next one in order to achieve more sensitivity to different performance levels for a particular scientific skill. Once the initial and final questionnaire scores were assessed for each participant in both interventions, the Wilcoxon test was performed to determine whether there was a statistically significant difference between the levels of initial and final performance for each scientific skill. From the results obtained in *Z*, we calculate the effect size (r), taking the *n*, as an objective and standardized measure of the magnitude of observed effect (Field, 2005). Data were analyzed statistically with the IBM SPSS Statistics 24.0 software (IBM Corp, 2016). The results were evaluated at a significance level of $p < 0.05$.

Results

Descriptive statistics involving median (*Med*) and interquartile range were used to determine the students' scientific skills proficiency. The Wilcoxon test was applied to determine whether the training inquiry task guided by video-worked examples made a difference between pre- and post-test results in experimental and control groups. The results obtained from the first inquiry task based on buoyancy are shown in Table 2.

Table 2. Results for Paired Sample Wilcoxon Test of Pre- and Post-tests on the First Inquiry Task in Experimental (n=24) and Control (n=20) Groups' Science Process Skills Assessment Test

Science Process Skills	Group	Measure	*Med*	Interquartile range		*W*	*Z*	*p*	Effect size (r)
				min	max				
Identify research questions	Experimental	Pretest	.00	.00	2.00	42.000	-.852	.394	0.1739
		Posttest	2.00	.00	2.00				
	Control	Pretest	1.00	.00	3.00	55.000	-.680	.497	0.1521
		Posttest	.50	.00	2.00				
Formulate previous ideas	Experimental	Pretest	2.00	2.00	2.00	70.500	-.135	.893	0.0276
		Posttest	2.00	1.25	3.00				
	Control	Pretest	1.00	.00	3.00	39.500	-1.244	.214	0.2782
		Posttest	2.00	1.25	3.00				
Identify variables	Experimental	Pretest	2.00	1.00	3.00	13.500	-2.523	.012*	0.5150
		Posttest	2.00	.00	2.00				
	Control	Pretest	1.50	.00	3.00	21.000	-1.228	.219	0.2746
		Posttest	2.00	.00	3.00				
Plan an investigation	Experimental	Pretest	.00	1.00	3.00	21.000	-2.280	.023*	0.4654
		Posttest	2.00	.00	2.00				
	Control	Pretest	1.00	.00	2.00	37.000	-1.059	.289	0.2368
		Posttest	1.00	.00	3.00				
Collect, organize and represent data	Experimental	Pretest	1.00	.00	1.75	159.000	-3.294	.001*	0.6724
		Posttest	1.00	.25	2.00				
	Control	Pretest	.00	.00	1.75	120.000	-3.531	.000*	0.7896
		Posttest	1.50	1.00	3.00				
Analyze data and draw conclusions	Experimental	Pretest	2.00	.00	2.00	123.000	-2.246	.025*	0.4585
		Posttest	2.00	.25	3.00				
	Control	Pretest	.00	.00	2.00	73.000	-1.979	.048*	0.4425
		Posttest	2.00	.00	2.00				

The shortcut to the hypothesis testing of the Wilcoxon signed rank-test is knowing the critical z-value for a 95% confidence interval (or a 5% level of significance), which is z = 1.96 for a two-tailed test and directionality. Table 2 reveals that there is a contrasted, statistically-significant difference in favor of the post-test inquiry task in the experimental group science process skills assessments ($p < 0.05$). In particular, students who participated in the experimental intervention supported by video examples identify variables, plan an investigation, collect, organize, represent and analyze data more suitably in the post-test inquiry task. Meanwhile, for the control group, statistical significant changes have been found only in the collecting, organizing and representing data, and drawing conclusions skills. Results from Table 2 show a pattern that leads to pairing the scientific skills into three couples as a result of the inquiry instruction effect: (a) identifying questions and formulating previous ideas (predictions and/or hypotheses), where no significant instruction effect is measured in both the control and the experimental groups, (b) identifying variables and planning investigation, where some progress could be attributed to the video-worked examples implemented, because no improvement is found in the control group and (c) collecting, organizing, representing and analyzing data and drawing conclusions, where the video-worked examples advantage remains questioned because both groups show statistical improvement.

Table 3. Results for Paired-sample Wilcoxon Test of Pre- and Post-tests on the Second Inquiry Task in Experimental (n=24) and Control (n=20) Groups' Science Process Skills Assessment Test

Science Process Skills	**Group**	**Measure**	***Med***	**Interquartile range**		***W***	***Z***	***p***	**Effect size (r)**
				min	**max**				
Identify research questions	Experimental	Pretest	1.00	.00	1.75	90.000	-1.721	.085	0.3513
		Posttest	1.00	.00	2.75				
	Control	Pretest	1.00	.00	1.00	68.000	-2.389	.017*	0.5342
		Posttest	1.00	1.00	2.00				
Formulate previous ideas	Experimental	Pretest	2.00	.00	2.00	73.500	-1.349	.177	0.2754
		Posttest	2.00	1.00	3.00				
	Control	Pretest	1.00	1.00	2.00	125.000	-2.424	.015*	0.5420
		Posttest	2.00	1.00	3.00				
Identify variables	Experimental	Pretest	1.00	.00	2.00	97.000	-2.177	.029*	0.4444
		Posttest	1.50	1.00	3.00				
	Control	Pretest	1.00	.00	2.00	46.000	-.566	.571	0.1266
		Posttest	.50	.00	2.00				
Plan an investigation	Experimental	Pretest	1.00	.00	1.75	116.500	-2.638	.008*	0.5385
		Posttest	1.50	.25	3.00				
	Control	Pretest	.00	.00	1.00	54.000	-1.222	.222	0.2732
		Posttest	.50	.00	2.00				
Collect, organize and represent data	Experimental	Pretest	1.00	.00	2.00	71.000	-2.565	.010*	0.5236
		Posttest	1.00	.00	3.00				
	Control	Pretest	3.00	.25	2.00	25.000	-1.933	.053	0.4322
		Posttest	3.00	1.00	4.00				
Analyze data and draw conclusions	Experimental	Pretest	1.00	.00	2.75	84.000	-2.750	.006*	0.5613
		Posttest	2.00	2.00	3.00				
	Control	Pretest	1.00	.00	2.00	60.000	-1.705	.088	0.3812
		Posttest	2.00	.25	3.00				

To obtain a deeper view of the impact of video-worked examples, the results obtained from the second inquiry task are analyzed in Table 3. The statistical parameters show a significant improvement for the experimental group on the same four science process skills obtained in the first inquiry task. However, the improvement observed in the scientific abilities in the first task in the control group is not maintained in the second inquiry task of the classroom intervention. Conversely, for the second inquiry in the control group, there are statistically significant differences in favor of the post-test in identifying a research question and formulating previous idea skills. These results are supported by the data from the effect size (r) column which shows the strength of the relationship between pre- and post-tests in the control and experimental group.

Therefore, and following the same association described previously, results from Table 3 show (a) identifying questions and formulating ideas, where a significant instruction effect is measured only in the control group, (b) identifying variables and planning investigation, where some progress could be attributed to the video-worked examples implemented, because no difference is found in the control group and (c) collecting, organizing, representing and analyzing data and drawing conclusions, where only the video-worked examples instruction shows statistical improvement.

In summary, for the first two science skills (identifying questions and formulating ideas) no difference between pre- and post-test is measured in the experimental group for one or two consecutive inquiry task applications. For most of the science skills (four out of six), the experimental group results show a consistent improvement in both the first and the second interventions. The results in the control group show less predictable outcomes, because significant differences in the science skills development are found only either during the first inquiry task or during the second task, but in any case, not all along the study.

Discussion

The present study aims to examine the effect of an instructional intervention based on video-worked examples on the improvement of elementary students' science process skills. First, the study provides information about the difference between the performance of each science process skill in experimental and control groups when a scientific inquiry is implemented. Second, to obtain a deeper and wider view of the effect of video-worked examples on improving science skills, a second inquiry task was implemented in both the experimental and control groups. Attending to the results obtained through the study, it will be discussed the improvements and difficulties that students have shown during the performance of each science process skill.

The results from the experimental group show a consistent progress after the first and second intervention for most of the science process skills (four out of six skills). However, the results in the control group show more scattered outcomes because significant differences in science skills (two out of six) are found only for the first or the second task, but in no case throughout the study. Results from Tables 2 and 3 are summarized in Table 4.

Attending to the results obtained from both the first and the second inquiries, scientific skills can be paired in three different couples (see Table 4): (a) skills 1 and 2: significant differences are found only for the second task in the control group; (b) skills 3 and 4: there is continuous improvement in the experimental group but no significant differences in the control group and (c) skills 5 and 6: there is continuous improvement in the experimental group but only in the first task for the control group. These groups of results are discussed in the following sections.

Table 4. Wilcoxon test *p*-value in the first and second inquiry task in experimental and control groups *($p < 0.05$)*

Science process skills	**Experimental group**		**Control group**	
	First task	**Second task**	**First task**	**Second task**
1. Identify research questions	.394	.085	.497	.017*
2. Formulate previous ideas	.893	.177	.214	.015*
3. Identify variables	.012*	.029*	.219	.571
4. Plan an investigation	.023*	.008*	.289	.222
5. Collect, organize and represent data	.001*	.010*	<001**	.053
6. Analyze data and draw conclusions	.025*	.006*	.048*	.088

Identifying Research Questions and Formulation Previous Ideas

The first inquiry task of the intervention showed no significant instruction effect in these skills between pre-and post-test results in both control and experimental groups. However, after the second inquiry task, a significant improvement was found exclusively in the control group. The obtained results from the experimental group in the formulation of both research questions and hypotheses or predictions are in agreement to previous studies about the use of video-worked examples in school inquiry tasks (Solé-Llussà et al., 2019). A slight improvement is observed in the development of these skills after the first inquiry task with the use of video examples (Table 2). Primary students tend to confuse the research question with hypothesis (for instance, '*The large cubes will float better because they are heavier'*) or identify the problem in a generic way or with conceptual problems. The performance of a second inquiry task using the digital support did not provide better results (Table 3). This evidence could be explained by taking into account the static nature of video-worked examples. This support, designed previously to classroom intervention, exemplifies the formulation of both a research question and hypothesis in a specific scientific context (Table 1). The implemented videos do not provide details about the particular features of these skills and they do not explain in a specific way how to formulate and implement these abilities. Furthermore, the less systematic nature of these skills and the requirement of scientific knowledge about the inquiry topic could also explain the results from the experimental group (Ferrés-Gurt, 2017).

On the other hand, results from the control group are slightly better and, in fact, after the second inquiry task, a significant improvement in the proficiency of both skills was observed (Table 4). In this group, learners start to pose better-focused research questions on the inquiry topic; there is also observed an increase in the formulation of cause-effect hypotheses or predictions that are coherent with the problem and that can lead to an experimental design. For instance, in the second post-test, we find research questions such as '*Does the sun influence plant growth?',* which fits with the investigation problem and includes possible study variables. As observed in other studies (Ferrés-Gurt, 2017), it is also identified that the formulation of a well contextualized research question usually leads to a better-structured cause-effect hypothesis (‘*The roses will grow higher because they are located in a sunny place*’). The adaptive support provided by the teacher, who *in situ* detects the main difficulties of the students and provides them the procedural and/or conceptual information when needed, could explain the results obtained in the control group (Çakiroglu et al., 2020; Martin et al., 2019; Mora, 2019). Teachers continuously diagnose the understanding of learners and can provide different supports based on the student’s responses, adapting to the specific background knowledge of each student (Martin et al., 2019). In this group of students, one could observe the greater role of the teacher, who focused her support towards the scientific knowledge and the features that were needed to formulate adequate research questions for the proposed inquiry tasks.

Thus, in the present study, the performance of consecutive inquiries supported mainly by the exemplifications shown in the video examples was not enough to obtain a significantly better proficiency in the formulation of investigable questions and hypothesis. As expressed by some authors, these are high cognitive skills that need differing information from various sources and supports (D’Costa & Schlueter, 2013; Rönnebeck et al., 2016). It seems interesting to explore the introduction, in the video examples, of clearer instructions about the implementation of these abilities and to analyze further the combination of this support with the teacher’s (Lehtinen & Viiri, 2017). This combination of supports could promote the development of the abilities that are dependent on previous knowledge of the inquiry topic (Durmaz & Mutlu, 2016; Kruit et al. 2018).

Identifying Variables and Planning an Investigation

For these two science skills, continued improvement was observed only in the experimental group, where a significant statistical improvement for these abilities was identified between the pre-and post-test results for both inquiry tasks. However, in the control group, this kind of improvement was not observed (see Table 4). Before the intervention, students did almost no contemplation of any study variables and proposed very general experimental designs that usually did not fit with the researchable question or the proposed predictions or hypothesis. In the experimental group and after the first inquiry task using video examples, a clear improvement in both skills was observed. Learners started to identify study variables coherent with the inquiry problem and proposed better structured experimentation plans, including the selection of suitable material and measuring instruments for tackling the research question. After the second intervention, a continuous improvement was observed in the same group (Table 3), as learners tended to differentiate between dependent and independent variables and designed better controlled investigations (‘*We will plant the seed independently, arranged so the sunlight arrives to only one seed. Every two days we will measure the plants and compare the color and quantity of flowers to see if the light is important’*). The support provided by video-worked examples can explain the results obtained in the experimental group. The implemented videos show with high accuracy how to perform, step by step, these science process skills and provide visual explanations and demonstrations about how to execute reliable investigations by choosing and applying the different types of variables. These demonstrations were illustrated with graphical elements (such as animations, icons, schemes, or diagrams) and were presented with voice explanations that clarified the presentation of the information provided by the videos.

This set of different and systematic visual aids, which students can access when needed and as many times as needed, may have contributed to provide a clear scheme of the inquiry process to the pupils and, thus, to the improvements observed in the experimental group. In fact, identifying and controlling variables to obtain reliable data are considered integrated science process skills, which required a more advanced scientific reasoning and cognitive effort and therefore demand a special support for their development (Ergül et al., 2011; Kruit et al., 2018). According to some authors, the providing of explicit instructions, illustrated with visuals supports and demonstrations, may help students to learn these particular scientific skills and to successfully transfer them to different inquiry topics (Kant et al. 2017; Kruit et al., 2018). As has been observed in the present study, these types of instructions can come from video examples whose particular features may have been key to students for mastering the aforementioned science skills.

The obtained results indicate that consecutive interventions guided by video examples helped students to further enhance the planning skills. Some authors highlight the importance of analyzing the proficiency in the planning skills after performing successive investigations supported by explicit instructions (Dean & Kuhn, 2007). The gathered data provides new evidence in this sense and shows how primary education students can retain these skills over a longer period and how it is possible to keep enhancing them after different classroom interventions with suitable supports.

As for the control group results, no significant improvement was observed after the first and the second inquiry tasks performed with just the teacher's guidance. Learners kept a similar proficiency level during both inquiry tasks, usually proposing ambiguous research plans with study variables that do not fit with the research question and the proposed prediction – for instance, from the second post-test, checking whether a seed will not germinate if it has no sunlight: '*First, we add fertilizer and the seed inside a pot. We put the pot in a place where the sun arrives and, as the day progresses, we collect data'*. As opposed to the formulation of research questions and hypothesis skills, the teacher's adaptive support was not efficient enough for enhancing the planning abilities. These results lead us to think that the teacher's guidance may not have been sufficiently explicit, systematic and exemplified, which are important aspects to consider when working with these skills (Lazonder & Harmsen, 2016). In this sense, the instructional intervention with video examples showed some positive effects, highlighting the possibilities of freely accessing the demonstrations and examples shown in the videos when learners need them during their inquiry task. These are very encouraging results for the planning abilities, with which learners usually show frustration and reluctance (Gormally et al., 2009).

Collecting, Organizing, Representing and Analyzing Data and Drawing Conclusions

A statistically significant enhancement of these skills was found for both the experimental and the control group after the first intervention. However, only in the experimental group was a sustained improvement identified after the second inquiry task. Before the intervention, students in both groups showed poor data treatment, without graphic representation, and their interpretations of the obtained evidence were based mainly on descriptions of their results or poor explanations without relation to the collected data. After the first intervention, students in both groups improved in these abilities. In the first post-test of the experimental group, learners started to show an adequate organization of the gathered evidence (i.e., use of tables) as well as the use of some graphic representations, a skill that primary education students usually lack (Durmaz & Mutlu, 2016). Similarly, to the planning skills, the use of the video-example support seems to have contributed to the development of this skill. The implemented videos provide very clear examples and demonstrations about how to organize and treat the gathered data, which students seem to have integrated and transferred successfully to other scientific inquiry contexts. In this way, video examples seem to be a particularly useful support for skills that need very clear instructions and steps: for instance, in this case, videos showed how to prepare a table for organizing data and which steps are needed to build a useful graph. The possibility of accessing these kinds of hints at the precise moment when students require them may have helped in the improvement of this ability, too. A significant enhancement was observed also for the analysis of data, as learners improved in their coordination between the experimental data and their scientific explanations. Some students' answers summarized hints or explanations delivered by the videos for drawing conclusions, which indicates that this digital support can provide useful problem-solving schema when performing this scientific skill.

Previous studies have demonstrated how video examples seemed effective in the development of the data representation and reasoning skills (Kant et al., 2017). However, a remarkable finding of the present study is that solving two consecutive inquiry tasks guided by video examples provided continued improvement of these skills. After the second inquiry task, adequate representation of data in graphs became more general among the students as well as well-founded data analysis based on evidence, including causal patterns and a check on the initial predictions: '*As I predicted, the plant that is alone in a pot grows faster because all the water and mineral salts are for her; but when there are more plants in a pot, they have to share it'*. These are encouraging results that enforce the idea that, according to some authors, consecutive interventions performed over longer periods of time are required for achieving more advanced scientific models (Kruit et al., 2018).

The sole guidance of the teacher in the control group also provided positive results, since a significant improvement in these skills was identified after the first inquiry task. Although a statistically significant enhancement was not maintained after the second intervention, learners usually kept the level of mastery achieved in the previous task. In this sense, it seems that the teacher provided adequate assistance for organizing data and building graphs. When interpreting data, it is interesting to highlight that her intervention focused especially on providing both scientific vocabulary and contents that could be useful for understanding the obtained evidence. Thus, students learnt the importance of incorporating theoretical explanations when interpreting data. However, the lack of clear instructions and general hints about how to proceed when analyzing the collected data in an investigation led to some difficulties when transferring this skill to a different scientific context. This may explain the lack of sustained significant improvement in the second post-test.

Interpreting data is considered an integrated science process skill that requires not only conceptual understanding but also very specific guidance (Kruit et al., 2018; Mora, 2019). Video-worked examples seem especially efficient by providing problem-solving schema, which helps students to reduce mental effort and to have more working-memory capacity when applying this scientific skill to different inquiry topics (Kaiser & Mayer, 2019). Moreover, the continuous scaffolding within an ongoing activity that provides video examples is a particular feature that, according to some authors, benefits the formulation of scientific arguments (Chen et al., 2016; Li et al., 2019). However, it is important not to underestimate the role of the teacher. Interpretation and argumentation need prior knowledge of the inquiry topic and a considerable metacognitive load, aspects that the teacher's adaptive support can manage properly (Martin et al., 2019; Piekny & Maehler, 2013).

Conclusion

The present study provides new insights into how elementary students can improve on the proficiency of different science process skills when performing inquiry tasks supported by video-worked examples. In this study, the efficiency of this digital support was analyzed by comparing both experimental and control groups. Moreover, the effects of video examples in the development of scientific skills were explored when two consecutive inquiry tasks are performed.

Results from the experimental group show that video examples have a positive influence on the pupils' inquiry behavior, while stimulating higher levels of autonomy. It was observed that this support especially promotes the development of integrated science skills such as identifying and controlling variables, planning an investigation and interpreting data to draw scientific conclusions. The explicit instructions, examples and demonstrations provided by video examples seem to have contributed to these positive results. The possibility of accessing these step-by-step explanations whenever students need them seems to help students to build a clearer inquiry schema and, thus, to reach better levels of proficiency in these skills. After doing a second intervention in a different specific domain, students continued progressing in the same scientific skills, which implies a better integration of the student's scientific practices. In line with previous research, performing consecutive inquiries supported by video examples helped learners not only to implement different scientific skills properly, but also to understand how they can be applied, which is a tough aspect to achieve in a classroom setting (Kaiser & Mayer, 2019).

However, less consistent outcomes were obtained in the control group. Some skills improved significantly only during the first or the second intervention, but in no instance throughout the whole study. For instance, and in contrast to the experimental group, a significant improvement was observed for the *identifying research questions* and *formulating hypothesis* skills only after the second intervention. These results could be explained by taking into account the adaptive support provided by the teacher, who detects the main difficulties after the first intervention, adapts to the specific students' background knowledge and provides them with the needed procedural and/or conceptual information (Mora, 2019). This adaptive support has been especially efficient for the kinds of scientific skills related to content knowledge acquisition, which is challenging for elementary students (Çakiroglu et al., 2020).

Probably, the teacher's guidance was not sufficiently explicit, systematic, exemplified or distributed, which could explain the variable results obtained in the control group. On the other hand, the continuous scaffolding during the inquiry tasks provided by video examples and combined with teacher's support seemed to contribute to the systematization of the scientific skills and to reduce the degree of complexity. This resulted in a better sustained performance of the inquiry abilities throughout the performed consecutive investigation tasks.

Thus, results from this work suggest the importance of combining the adaptive support from the teacher and the static guidance from video examples. The responsive support of the teachers, who can *in situ* manage the procedural and content needs of students, combined with the systematic and explicit instructions provided by video examples, can contribute to the improvement of the inquiry-based science-learning in primary education. Despite the limitations of this study – such as small sample size, the lack of analysis of specific guides provided by the teacher (this will be considered in future studies) – the results show the potential of using repeatedly video-worked examples to promote scientific skills in elementary education. Moreover, the nature of video examples opens new learning opportunities in the current pandemic situation (Daniel, 2020). In this way, it is planned to investigate the effectivity of asynchronous distance learning strategies that include video examples.

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