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Effect of confirmation and structured inquiry on attitudes toward school science

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Abstract

Guided and open inquiry strategies are found to improve students' attitudes toward science. Yet, confirmation and structured inquiry are more often enacted by teachers. The effectiveness of these approaches involving high teacher guidance remains unexplored. Students in six classes ($N = 119$, $M_{age} = 11.25$ years) were assigned to control (lecture) or treatment (confirmation or structured inquiry) groups. The intervention consisted of two units of 3 h each. Following the intervention, students in the structured inquiry condition reported more intentions to enroll in school science than their counterparts in the confirmation inquiry or lecture group. There were no differences in enjoyableness, self-efficacy, usefulness, and relevance of school science between pedagogical conditions. The findings support the use of structured inquiry over confirmation inquiry and lecture-based strategies for developing students' science career aspirations, which has implications for science teacher professional development and the design of instructional resources.

KEYWORDS

attitudes toward science, confirmation inquiry, elementary education, structured inquiry, teacher guidance

1 | INTRODUCTION

Scientific inquiry has a prominent status in science education. Research on the effect of inquiry-based science teaching on attitudes toward science abounds (Aguilera & Perales-Palacios, 2020; Demirel & Dağyar, 2016). Studies show promising results for inquiry strategies offering the least teacher guidance. Yet such approaches present drawbacks and constraints when enacted by teachers, such as time and classroom management issues, limited resources, and lack of pedagogical content knowledge (Baroudi & Helder, 2019; Chichekian et al., 2016; Romero-Ariza et al., 2019). As a result, teachers rely on inquiry strategies that do offer much guidance to students (Lucero et al., 2013). The educational value of such teacher-directed inquiry approaches has been neglected in the literature, and its impact on students' attitudes is yet to be addressed (Aguilera & Perales-Palacios, 2020). Therefore, this study attempts to pursue such an endeavor.

2 | BACKGROUND

2.1 | Defining inquiry

Different interpretations of the term "inquiry" coexist (Abd-El-Khalick et al., 2004). On the one hand, inquiry as *means* refers to a teaching approach that engages students in "generating and evaluating scientific explanation of the natural world as they participate in scientific practices and discussion (...) grappling with data and using evidence and logic to make sense of some event" (Crawford, 2014, p. 517). Educational reforms and policy documents perennially promoted such a conceptualization. For example, the Next Generation Science Standards posits inquiry as a major scientific practice for students to engage in from the early stages of the educational system (NGSS Lead States, 2013). In the Spanish context, the current educational syllabus calls for inquiry-based science education in all elementary school grades.

On the other hand, inquiry is also considered an *end* of science education. Here, it refers to a set of cognitive and manipulatives skills, and also to understandings about scientific inquiry. Such skills include, but are not limited to identifying variables, formulating hypotheses, using evidence, evaluating explanations, and drawing conclusions (Bunterm et al., 2014; Fang et al., 2016). The latter aspects depart from *doing* inquiry in favor of *understanding* the nature of scientific inquiry (Lederman et al., 2021). This includes aspects necessary to make informed decisions about scientifically based personal and societal decisions, such as procedures affecting results, differences between data and evidence, or the myth of the scientific method (Lederman et al., 2014).

This investigation focuses on inquiry as a teaching approach, which is enacted by teachers following different learning cycles consisting of: (i) formulation of research questions; (ii) design of research procedures; and (iii) data generation and interpretation (Pedaste et al., 2015). Based on the amount of teacher guidance, the inquiry learning process can take many forms (Vorholzer & von Aufschnaiter, 2019). During *confirmation inquiry*, the teacher supplies the research question, procedures, and results in advance. Hence, students confirm a phenomenon by following detailed instructions. If results are not provided in advance, students engage in *structured inquiry*. When students design the research procedure and do not know the results in advance, they conduct a *guided inquiry*. Finally, *open inquiry* lacks teacher guidance. In such a case, students formulate research questions, design the procedures, and generate the results (Bevins & Price, 2016).

2.2 | Attitudes toward science

There is a general agreement on defining attitudes as a "(...) psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor" (Eagly & Chaiken, 1995, p. 414). Thus, attitudes encompass cognitive, affective, and behavioral aspects. However, the attitudes toward science is a nebulous and often poorly articulated construct that is conflated with scientific attitudes (Tytler, 2014). The former refers to evaluative aspects (e.g., beliefs, thoughts, feelings, emotions) toward science-related aspects, such as science as an enterprise, scientists, and school science, learning experiences, or science-related careers (Toma & Lederman, 2020; Tytler & Osborne, 2012). The latter included aspects inherent to scientific thinking and research, such as curiosity, open-mindedness, or rationality (Çalik & Coll, 2012; Summers & Abd-El-Khalick, 2018).

Developing positive attitudes toward science stands as a central aim of science education (Tytler, 2014; Wendt & Rockinson-Szapkiw, 2018). Such an aim gained momentum in recent years given the worldwide decrease in students pursuing science-related careers (DeWitt & Archer, 2015; Kennedy et al., 2016). Other grounds for research on attitudes toward science include their relevance for science achievement and support of government-funded research (Besley, 2018; Newell et al., 2015). Likewise, there are many determinants of attitudes, such as gender—affecting girls—(Kang et al., 2019), grade level—negative attitudes as grade level increase—(Said et al., 2016), or teaching approaches, to be discussed below.

2.3 | Attitudes and inquiry

Research suggests that inquiry teaching approaches do improve students' attitudes toward science (Potvin & Hasni, 2014). Positive effects of inquiry-based pedagogies on attitudes are found at all educational levels, with an overall medium to large effect size (Aguilera & Perales-Palacios, 2020; Savelsbergh et al., 2016). This is especially the case for inquiry approaches using low levels of teacher guidance and interventions longer than 4 weeks (Aguilera & Perales-Palacios, 2020). Indeed, Sadeh and Zion (2012) found better attitudinal scores in the open rather than the guided inquiry groups. Koksal and Berberoglu (2014) reported improvements in students' attitudes toward science when engaged in guided inquiry lessons. Roll et al. (2018) concluded on the benefits of guided inquiry in the development of positive attitudes toward science. Similar findings were also identified worldwide using data collected by the *Programme for International Student Assessment* (PISA). In this sense, inquiry teaching predicted students' science career aspirations and resulted in better attitudes toward science (Jiang & McComas, 2015; Kang & Keinonen, 2017).

3 | PROBLEM STATEMENT

Much research has been conducted on the impact of inquiry teaching on students' attitudes toward science.

However, studies targeted guided or open inquiry, which exhibit many constraints when enacted (Baroudi & Helder, 2019; Chichekian et al., 2016; Krämer et al., 2015). In consequence, teachers turn to short-term, confirmation, or structured inquiry where much guidance is offered to students (Lucero et al., 2013; Romero-Ariza et al., 2019). These approaches to inquiry, though more feasible, remain unexplored for their effectiveness in improving attitudes toward science (Aguilera & Perales-Palacios, 2020; Savelsbergh et al., 2016). This is especially the case for students enrolled at the end of elementary school when career aspirations and attitudes are largely established (Toma & Meneses Villagrá, 2019a; Maltese & Tai, 2011). Hence, it is an important issue worth investigating.

The goal of this study is to extend the research regarding the effect of different types of inquiry on the development of elementary students' attitudes toward science. It examines the effectiveness of confirmation and structured inquiry, in comparison to the traditional, lecture-type approach. Specifically, this investigation addressed the following research question:

(i) What effects do short-term, confirmation, and structured inquiry have on students' attitudes toward science when compared with traditional, lecture-types approaches?

4 | METHODS

4.1 | Study design

A posttest-only control group design was adopted, with two treatment (confirmation and structured inquiry) and one control (traditional lectures) group pedagogical conditions (Shadish et al., 2002). The lack of pretest scores hampers the ability to draw generalizable causal effects. However, given the short treatment (described below), the administration of a pretest would have elicited major threats to the internal validity of the study (Shadish et al., 2002). These include attention bias (i.e., participants altering their behavior when they know they are being tested) and testing effect (i.e., taking a test may influence scores when taken for the second time in a short period). Besides, studies show a decreasing pattern in attitudes toward science during elementary education. Thus, changes between treatment and control group scores are indeed due to the intervention.

4.2 | Sample

The sample was drawn from six classrooms in three elementary schools located in the city of Burgos, in Spain. A total of 119 students participated in the study, all of whom were enrolled in the sixth grade of elementary education. Half of the participants were girls (53.8%). The mean age of students was 11.25 years ($SD = 0.43$).

The six classes were randomly assigned to either the treatment or control group, resulting in two classes for each pedagogical condition. There were a total of 39, 37, and 43 students per control (lectures), confirmation, and structured inquiry. To minimize potential differences between groups and teacher effects, the participating schools had similar characteristics in terms of ownership (semi-private) and teaching practices (lecture-based pedagogies). In addition, each school was assigned two different conditions, such as control/confirmation, control/structured, or confirmation/structured to further minimize differences.

4.3 | Intervention units

A short-term intervention was designed in line with Spanish curricula and the educational milieu. Two 3-h units addressed the curricular content of *inclined planes* and *air resistance*. In the control groups, units were delivered using traditional, lecture-based approaches. In the treatment groups, inquiry strategies were enacted. The first unit addressed the following research question: *What factors affect the amount of force that must be used to move an object on an inclined plane?* The research procedure involved testing the relationships between force and inclined planes' inclination, lengths, and roughness. The second unit focused on the following research question: *What factors influence the descending speed of a parachute?* The research procedure was to investigate the relationship between the descent time of parachutes of varying rope lengths, sizes, shapes, and materials.

Confirmation inquiry groups were provided with the research question, research procedures, and potential results in advance. In contrast, in the structured inquiry groups, the research question and procedures were introduced progressively. Students were first allowed to formulate research questions and hypotheses and to propose a research design. Then, progressively, they were introduced to the same research question and procedures as the confirmation inquiry groups. Finally, the potential results were withheld from the students.

4.4 | Procedure

Units were delivered in the ordinary classroom following regular conditions (i.e., usual teachers, the same schedule and classroom organizations, and no intervention by the researcher). Teachers in the treatment groups were provided with specific instructions and the necessary materials to implement the inquiry units as intended. Implementation fidelity of the pedagogical conditions was confirmed by direct, nonparticipating observation conducted by the author of this study.

4.5 | Instrument

Data were gathered using the School Science Attitude Survey (SSAS) (Kennedy et al., 2016). The instrument comprises short, valid, and reliable measures of the major attitudinal dimensions related to the school science domain: (a) intention to enroll; (b) enjoyableness; (c) perceived difficulty; (d) self-efficacy in school science; (e) usefulness; and (f) relevance. Sample items include *I think I am very good at science; Science helps to make life better*, or *I think science is boring/fun* (p. 445).

Specifically, the Spanish version of the instrument was used (Toma & Meneses Villagrá, 2019b). It was cross-culturally validated with elementary school students. The psychometric analysis supported its validity (content, predictive, concurrent, discriminant, and discriminative) and reliability (internal consistency and temporal stability). Since the *perceived difficulty* dimension refers to homework, it was not included in this study. A five-point response option with endpoints labeled was used (see Toma & Meneses Villagrá, 2019b, p. 4).

4.6 | Data analysis

All six dimensions of the SSAS are conceptually related, consistent with the contemporary definitions of the attitude domain. However, as they represent a distinct trait of attitudes toward school science, they can not be grouped into a single overall score. Likewise, since research consistently found differences between girls' and boys' attitudes, gender should be considered when analyzing the impact of educational interventions (Liou, 2021). Therefore, data were analyzed using a 2 (gender) × 3 (pedagogical condition) multivariate analysis of variance (MANOVA). Students' gender (girls vs. boys) and pedagogical condition (lectures vs. confirmation inquiry vs. structured inquiry) were used as independent variables. Scores of attitudes toward science dimensions were the dependent variables. Partial eta squared (η_p^2) was used to determine the effect size, following conventional guidelines: 0.01 (small), 0.06 (medium), and 0.14 (large).

Preliminary checks were conducted to examine assumptions for MANOVA (Knapp, 2018). Specifically, $n > 30$ per each pedagogical condition group satisfied n quota criteria. After deleting eight cases for univariate outliers, an inspection of the histograms revealed a bell-shaped curve for each dependent variable and pedagogical condition, which satisfied the criterion of normality. Bivariate correlation between dependent variables ranged from $r = -0.05$ to 0.57, suggesting no multicollinearity in the data. Box's test was not significant, $M = 101.59$, $p = .135$, indicating no violation of the homogeneity of variance-covariance criteria. Finally, Levene's test was not significant (p values > .05), thus satisfying homogeneity of variance.

4.7 | Statistical power

Inquiry-based teaching strategies have medium to large effects on students' attitudes (Aguilera & Perales-Palacios, 2020). Hence, a power analysis using the G*Power software indicated that a sample size between 141 and 63 participants would be needed to detect a medium ($\eta_p^2 = 0.06$) to large ($\eta_p^2 = 0.14$) effect size with 80% power using MANOVA with five dependent variables and alpha level set at 0.05 (Faul et al., 2007). Therefore, this study has enough power to detect differences between pedagogical conditions.

5 | RESULTS

The secondary interaction effect between pedagogical condition and gender was not statistically significant, $F(10, 204) = 0.36$, $p = .96$; Pillai's Trace = 0.03. This suggests that the intervention did not have a differential impact depending on the gender variable. The gender effect was also not statistically significant, $F(5, 101) = 0.32$, $p = .90$; Pillai's Trace = 0.02. Thus, girls and boys did not differ in their attitudes toward school science.

There was a statistically significant difference between the pedagogical conditions on the combined dependent variables, $F(10, 204) = 2.06$, $p = .03$; Pillai's Trace = 0.18; $\eta_p^2 = 0.09$. However, groups only differed in their intentions to enroll in further school science, $F(2, 105) = 6.70$, $p < .01$. Girls and boys in the structured inquiry groups reported significantly higher intentions to enroll in school science than students in the confirmation and control groups (Figure 1).

6 | DISCUSSION

The effectiveness of guided and open inquiry has been studied extensively. However, there is a lack of investigations undertaking such efforts concerning confirmation

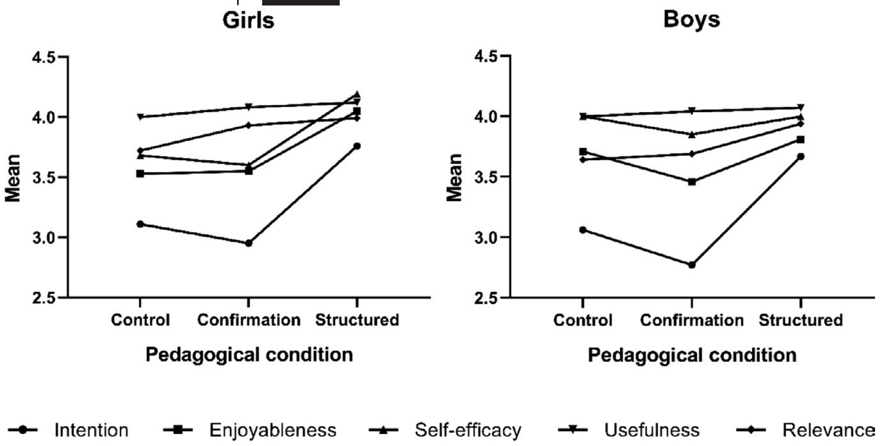

FIGURE 1 Estimated marginal means for each attitudinal dimension

and structured inquiry. Consequently, the present study addressed the differential effect of such inquiry strategies on students' attitudes toward school science compared with traditional lecture-based approaches. Taken together, students in the structured inquiry groups outperformed their counterparts in confirmation inquiry and lecture-based groups in all five attitudinal dimensions examined: intentions, enjoyableness, self-efficacy, usefulness, and relevance. However, these differences achieved statistical significance only for intentions to enroll in future school science subjects.

Overall, findings related to intentions to enroll are consistent with those reported in earlier studies, suggesting more benefits of inquiry approaches with less guidance (Kang & Keinonen, 2017; Koksal & Berberoglu, 2014). In this sense, previous studies speculated that less guidance may broaden students' sense of agency, which ultimately shapes their attitudes (Roll et al., 2018). Therefore, it seems that structured inquiry enabled learners to exercise control and gain a sense of ownership of the learning experience. However, this was not the case for the remaining attitudinal dimensions where less guidance was not associated with more positive attitudes (Liou, 2021).

6.1 | Contribution to the literature

These findings have not been reported previously and thus represent a novel contribution to the literature. This study contributes to closing the gap in knowledge about the effectiveness of different types of inquiry approaches. Given that guided and open-inquiry induce constraints that limit teachers' enactment of such pedagogical strategies, it was necessary to compare the effect of short-term confirmation and structured inquiry interventions. It also adds to the inquiry and attitudinal literature related to late elementary school students. A review of the studies analyzed in major meta-analyses on this topic reveals that investigations targeting elementary education are very scarce (Aguilera & Perales-Palacios, 2020; Furtak et al., 2012; Lazonder & Harmsen, 2016). Elementary students represent a key target group for the promotion of career aspirations (Toma & Meneses Villagrá, 2019a). Hence, the findings of this study are of particular value for the development of educational interventions before students enter secondary education, a moment when it may be too late (Maltese & Tai, 2011).

6.2 | Implications

The main implications emerging from this study relates to teachers' practices, professional development, and the design of educational resources to enhance the use of inquiry as a teaching strategy. First, the findings of this study support the use of structured inquiry as opposed to confirmation inquiry and lecture-based strategies for developing students' attitudes toward school science. Therefore, if the aim is to promote science career aspirations, the structured inquiry may seem to be a sufficient effort to achieve such a goal, especially considering that it does not present the constraints associated with guided or open inquiry. In this sense, inexperienced teachers benefit from adopting inquiry strategies with high guidance before moving on to open inquiry strategies (Koksal & Berberoglu, 2014).

Second, research has consistently shown that inquiry is challenging. Therefore, there is a need for professional development on how to develop or adapt existing material to be delivered following structured inquiry procedures (Capps et al., 2012). This should be done with both preservice and in-service teachers. The inclusions of inquiry pedagogies during teacher training programs improve their attitudes toward science teaching, pedagogical content knowledge, and beliefs about inquiry (Correia & Harrison, 2020; Smit et al., 2017; Yakar & Baykara, 2014). A focus on changing beliefs and attitudes about inquiry is also necessary, as these outcomes affect teaching practices (van Aalderen-Smeets et al., 2017; Correia & Harrison, 2020).

Finally, these findings draw attention to the role that easily accessible educational resources play in the implementation of inquiry strategies. The lack of preparation time and instructional resources are major challenges reported by teachers for not enacting inquiry (Baroudi & Helder, 2019; Romero-Ariza et al., 2019). In this sense, the nonparticipant observation of the sessions confirmed that the teachers succeed in implementing structured inquiry. However, this can mainly be attributed to the fact that they were provided with comprehensive guidelines and all the necessary materials. Therefore, there is a need to develop resources and educational materials to assist teachers seeking to adopt structured inquiry in their school science classes. This is particularly important for the Spanish context where teachers rely mainly on textbooks and manuals as educational resources (Gil-Flores, 2014). It might therefore be particularly useful to include in such textbooks inquiry-based units to enhance teachers' behavioral intentions to use this teaching strategy.

6.3 | Avenues for future research

The findings of this study suggest that confirmation inquiry failed to improve students' attitudes. Moreover, intention to enroll, self-efficacy, and enjoyableness of school science were lower in confirmation inquiry groups when compared with lecture-based groups. However, important issues are worth addressing in future studies before reaching conclusions on the lack of value of confirmation inquiry approaches. In this sense, the question of whether it may be more useful and appropriate for low-achieving or unmotivated students remains unanswered at present, and thus future studies are warranted. Berg et al. (2003) found that students with low attitudes benefited more from teacher guidance. Likewise, the present study was conducted with 6th graders; it may be the case that lower graders may benefit more from teacher guidance, which is an aspect worth undertaking in future studies.

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