education sciences

Review

Using Cooperative Learning to Enhance Students' Learning and Engagement during Inquiry-Based Science

Robyn M. Gillies

School of Education, The University of Queensland, Brisbane, QLD 4072, Australia; r.gillies@uq.edu.au

Abstract: Much attention over the last two decades has been given to inquiry-based learning in science as a way of capturing students' interest and participation in learning. However, while the research on inquiry-based learning consistently demonstrates that students do attain higher learning outcomes than peers who are taught by traditional transmission approaches, little research has been attached to researching the key elements of this approach that contribute to its success. This review focuses on the role of inquiry-based learning where students work in cooperative groups to investigate topics that challenge their curiosity, encouraging them to ask questions to clarify their understandings, evaluate evidence that may help to explain phenomena, and predict potential solutions to the problems at hand. The key role teachers play in inducting students into ways of thinking and reasoning and providing opportunities for them to work with others in the context of inquiry-based learning will also be discussed.

Keywords: inquiry-based science; cooperative learning; dialogic teaching and learning

1. Introduction

Over the past two decades there has been a concerted effort to teach science using an inquiry-based approach as a way of galvanizing students' curiosity and motivation to actively participate in learning science. Learning through inquiry encourages students to actively participate in learning science so they ask questions about the topics that challenge their thinking, test out potential solutions to problems, and consider alternative possibilities as they learn to reconcile their developing understandings with previous knowledge and experience [1]. "Inquiry refers to a variety of processes and ways of thinking that support the development of new knowledge in science" ([2], p. 19). Inquiry teaching requires teachers to not only teach the content but also help students to understand the approaches and processes scientists use as they conduct their investigations.

Understanding how science works is critically important to understanding the processes involved in scientific inquiry. Science is a set of processes that are interconnected, and students, like scientists, learn to ask questions about the world in which they live as they investigate different phenomena [3]. In essence, students learn science by actively engaging in the practices of science. These practices involve learning to ask and answer questions and compare answers with what is currently known, collect and analyse data, formulate and test their suppositions, and work collaboratively with others to resolve issues with the intention of sharing the results of their investigations [4]. Being able to collaborate with others often involves students working together on problem-based learning activities involving real-world contexts that are topical and of interest to students; for example, issues on climate change where the goal is to solve a challenging problem. In this sense, students have opportunities to collaborate with others on topics that are of socio-scientific interest and likely to generate student discussion, motivation, and learning [1].

However, many teachers appear to experience difficulties embedding inquiry-based science approaches into their science curricula, possibly because enacting inquiry requires teachers to situate learning in authentic problems that often require them to guide and

Citation: Gillies, R.M. Using Cooperative Learning to Enhance Students' Learning and Engagement during Inquiry-Based Science. *Educ. Sci.* **2023**, *13*, 1242. https://doi.org/10.3390/educsci13121242

Academic Editors: Laurinda Leite, Luis Dourado and Neil Gordon

Received: 17 October 2023
Revised: 12 December 2023
Accepted: 14 December 2023
Published: 15 December 2023

scaffold students' investigations in the context of classrooms where they are expected to not only teach the content but also simultaneously manage a variety of roles. In fact, Duschl and Duncan [5] reported that it takes approximately 20 days of professional learning across a period of two to three years for elementary teachers to feel skilled and competent in teaching using an inquiry-based approach. This, Crawford [3] maintains, is why this type of teaching is often not evident.

This paper provides a review of the role of inquiry-based learning in science where students work in cooperative groups to investigate topics that challenge their curiosity, encouraging them to ask questions to clarify their understandings, and evaluate possible solutions to the problems they are confronting. Implementing inquiry-based science instruction involves extensive changes in classroom management practices with learning situated in authentic problems that often require teachers to guide and scaffold students' investigations. In this respect, teachers have a key role in inducting students into different ways of thinking and reasoning and providing opportunities for them to discuss their ideas with others. This type of teaching is referred to as dialogic teaching, where students learn to engage in talk to promote thinking by exchanging ideas, negotiating meaning, and reconciling their understandings with previous knowledge and experience. Finally, this paper discusses these developments in the context of current research.

2. Inquiry-Based Teaching in Science

Given the importance attached to teaching science using an inquiry-based approach, this section reviews current meta-analyses that report on the effects of inquiry-based teaching on students' academic outcomes in primary and secondary schools. It also reviews the research on teachers actively guiding or structuring the learning tasks in contrast to more open-inquiry situations where guidance is less evident or traditional transmission approaches to teaching science.

Implementing and managing inquiry-based science instruction involves extensive changes in classroom management practices [6]. The National Research Council [1], in a report on teaching and learning science in K–8 classrooms, emphasise that if students are to become proficient in science, they need to be able to: "know, use, and interpret scientific explanations; generate and evaluate scientific evidence and explanations; understand the nature and development of scientific evidence, and participate productively in scientific practices and discourse" ([1], p. 36).

These proficiencies, the NRC [1] argues, are interrelated and connected and represent ways of thinking about scientific ideas where conceptual understandings of natural systems are linked to the ability to develop explanations of different phenomena and conduct empirical investigations to evaluate knowledge claims. However, if students are to engage productively in science, they need to understand how to participate in scientific discussions where they are able to listen to others, share their thinking, and be willing to ask questions to clarify their understandings or challenge others' perspectives. Such ways of thinking, though, only develop when teachers actively induct students into these ways of thinking and reasoning and provide opportunities for them to interact with others in the context of inquiry-based learning.

Furtak, Seidel, Iverson, and Briggs [7], in a meta-analysis of 37 empirical studies of inquiry-based science published between 1996 and 2006, reported that inquiry-based teaching contributed to improved student achievements with an overall mean effect size of 0.50. Furthermore, this result was greater than previous meta-analyses reviewed by the authors (see p. 303). Furtak, Seidel, Iverson, and Briggs [7] also found that studies that contrasted epistemic (E) activities (e.g., nature of science, conclusions based on evidence, or generating and revising new theoretical perspectives) and the combination of procedural, epistemic, and social (PES) activities had the highest mean effect sizes, with mean effect sizes of 0.75 (epistemic) and 0.72 (PES). Moreover, studies that involved activities that were led by teachers had mean effect sizes that were about 0.40 larger than those which were led by students, indicating that students achieved higher learning outcomes when teachers actively guided the learning tasks.

Firman, Ertikanto, and Abdurrahman [8] conducted a meta-analysis across 15 articles that reported on the use of inquiry-based learning in science education in primary and secondary schools. The results showed that 10 of the studies recorded median to large effect sizes with the overall effect size being 0.45 (median effect). Of the five studies with low effect sizes, none of them recorded negative effect sizes. The authors argued that the results demonstrate that inquiry-based learning had a positive impact on students' learning in science in comparison to students who learn via traditional teacher-centred approaches. Interestingly, the effect sizes were higher when students were involved in structured-inquiry or guided-inquiry where the teacher actively guided the activities in contrast to more open-inquiry situations where guidance was less evident.

Similar results were reported by Heindl [9], who investigated the efficacy of inquiry-based learning to improve students' academic performance in comparison to students who learn by traditional teaching approaches. Thirteen studies met the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria for inclusion in this meta-analysis. Eight studies were conducted in secondary schools with an effect size of 0.81, and five were conducted in primary schools with an effect size of 0.67. The results showed that inquiry-based learning is an effective teaching approach that can be used in primary and secondary schools leading to higher academic outcomes for students learning science. Moreover, Heindl [9] argued that inquiry-based learning is more effective when teachers and students are well prepared for inquiry-learning through practice-coaching or training.

In summary, meta-analyses by Furtak, Seidel, Iverson, and Briggs [7], Firman, Ertikanto, and Abdurrahman [8], and Heindl [9] demonstrate that inquiry-based learning in science has a positive impact on students' academic learning in science in comparison to peers who learn via traditional transmission approaches. Furthermore, inquiry-learning is more likely to have a greater impact when teachers actively guide the inquiry process.

3. Promoting Scientific Thinking and Reasoning

It is critically important that teachers induct students into different ways of thinking and reasoning by explicitly teaching and modelling how to express ideas, ask for assistance, challenge alternative perspectives, and reason logically. It is well known that learning occurs when students have opportunities to discuss ideas with others, and emphasis in recent years has been on encouraging teachers to engage students in class discussions where they are able to interact with their teachers and peers on problem-based topics that challenge their curiosity and understandings [10]. This type of teaching is known as dialogic teaching, and it is designed to encourage students to be more active in their learning by expressing their thoughts and understandings and asking questions to clarify topics they do not understand. Interactions between teachers and students not only enable students to demonstrate what they know but they also enable teachers to gain an understanding of any misconceptions that students may hold. This allows teachers to adjust their teaching so any misunderstandings can be discussed and clarified.

Alexander [10] maintained that dialogic teaching is predicated on teachers and students addressing learning tasks together; listening to each other, sharing ideas, and considering alternative perspectives; encouraging students to share their ideas without feeling self-conscious or embarrassed; and building on each other's ideas in order to develop rational and logical solutions. During this process, the teacher needs to guide classroom discussions with the purpose of achieving specific educational goals.

When this occurs, Alexander [10] maintained, a number of changes occur in how talk is enacted in the classroom, with more talk occurring among students and between students and teachers. Student and teacher exchanges tend to be longer, with teachers building on student responses to prompt and facilitate students' thinking. Students, in turn, begin to build on each other's ideas as they seek to extend others' ideas or clarify misunderstandings. Their responses become more diverse as they learn to provide more explanations, justifications, and suppositions on topics they are discussing. In short, students are initiating more talk as they speculate, think aloud, and help each other as they realise that they can be active in their own learning. There is also more participation by children who are less academically able, as the chance to talk provides them with the opportunity to express their opinions and demonstrate competence. This, in turn, Alexander notes, leads to "the interactive culture in these classrooms is becoming more inclusive" ([10], p. 108).

In a comprehensive account of the Dialogic Teaching Project, Alexander [11] discusses the development and randomised control trial that was funded by the UK Education Endowment Fund (EEF) between 2014 and 2017. The purpose of the intervention was to invigorate classroom talk to promote student engagement, learning, and attainment in the context of social and educational disadvantage. The intervention's professional development for teachers included a full day's induction program where they were introduced to dialogic teaching and the professional development program that would be implemented across the following 20 school weeks. This included mentoring from experienced teachers in the schools, guided planning and target setting with the mentees, reflections by teachers on lesson video recordings of classroom talk, reading materials, and mentoring from the Dialogic Project Team. Data were collected from 76 schools across three United Kingdom cities that met the criteria of having at least 25% of their students eligible for free school midday meals (a marker for social disadvantage).

Alexander [11] reported that the children in the Dialogic Teaching Schools gained two additional months' progress in English and Science and one additional month's progress in mathematics in comparison to children in the non-intervention schools. Furthermore, the children who were eligible for a free school lunch (marker of disadvantage) made a further two months' progress on standardised assessments in English, Science, and Mathematics compared to their peers in the non-intervention schools. Interestingly, independent analysis of the video-recorded lesson episodes showed that classroom talk in the intervention classrooms began to become more dialogic early in the intervention, with marked differences between the intervention and the non-intervention classrooms. Differences in talk were evident in both teacher and student talk by week 19, with talk becoming more dialogic as teachers and students spent more time listening to each other and incorporating each other's ideas into their discussions. Additionally, the principals, mentors, and teachers reported that the Dialogic Teaching approach had a positive effect on students' self-confidence and participation in learning.

While meaningful gains were recorded in the children's progress in the intervention schools in comparison to their peers in the non-intervention schools, feedback from the teachers in the intervention schools felt it would take longer than 20 weeks to fully embed the Dialogic Teaching approach in their curricula and suggested that the study should be scaled up to a longer period of time to see the full effects. The outcomes achieved by the Dialogic Teaching Project led Alexander [12] to acclaim that "evidence shows that well-founded classroom dialogue improves student engagement and learning" ([12], p. 1).

The results obtained from the Dialogic Teaching Project [11] led to Alexander [13] developing a framework on eight dialogic teaching repertoires designed to help teachers to engage with the different forms of classroom talk between and among teachers and students including the key areas of: questioning, extending talk to open up students' thinking, discussing, deliberating and arguing, and finally, argumentation, where students learn to advance reasons and evidence and challenge and refute claims to solve a problem or address an identified question. (NB: Repertoires 1 and 2, involving Interactive Culture [how talk should be managed] and Interactive Settings [ways students are grouped], will be discussed in the section on Cooperative Learning).

Dialogic teaching, Alexander [13] argues, is a talk pedagogy that utilises the influence of talk to excite and extend students' thinking and learning to enable them to discuss, reason, and argue as they participate in discussions with their teachers and other students.

This includes engaging in talk to promote thinking where students learn to talk and exchange ideas with others, which promotes a better understanding of different issues under discussion. It also includes recognising that talk is very much a social process, and in classrooms, talk engages students' attention and motivations as they interact to communicate in everyday transactions where they exchange and negotiate meaning.

When teachers engage in dialogic teaching with their students, Alexander [13] notes, there is more talk about how the participants will interact with each other as well as the procedures they will follow. Teachers, in turn, often ask more open questions that encourage students to participate in the discussion, enabling students to feel more welcome and able to contribute in ways that are more mutually beneficial to the discussants. Boyd and Markarian [14] also noted that dialogic teaching is apparent when teachers engage in conversations with students where they actively listen to what students have to say, encourage them to share their thinking, or they ask questions to clarify issues. In dialogic classrooms, students are encouraged to consider alternative propositions, make their thinking explicit, and support each other so both students and teachers build on each other's ideas as they develop "coherent lines of thinking and enquiry" ([15], p. 8). The following section on Dialogic Teaching in Classrooms discusses the way dialogic teaching is enacted in classrooms by teachers and students and the evidence that supports this approach to teaching and learning.

4. Dialogic Teaching in Classrooms

Teaching and learning in the dialogic classroom, Reznitskaya [16] argues, is characterized by authority over the content and form of discourse shared among participating group members, where students accept responsibilities for turn taking, asking questions, reflecting on each other's answers, and suggesting new topics. Teachers challenge students' answers, ask for justifications, and provide meaningful feedback to help students negotiate and construct new meanings. These types of dialogic discussions promote meta-level reflections that challenge students to seek clarification and connect ideas across contexts. In so doing, they learn to elaborate on their thinking as they collaborate with others to construct new understandings and mutually agreed-upon knowledge.

Garcia-Carrion, Aguileta, Padros, and Ramis-Salas [17], in a review of the social impact of dialogic teaching and learning, noted that there is a large volume of evidence from small- and large-scale studies that dialogic teaching contributes to academic achievement and social cohesion, resulting in classrooms that are more inclusive as students are invited to take an active and meaningful role in discussions. In effect, it transforms classroom relationships as students realise their contributions are valued as they cooperate to reach a common agreement, enabling them to complete tasks.

Others who have investigated the role of different types of talk in classrooms are Scott and Mortimer [18], who developed a framework for analysing the different ways discussions are undertaken in science classrooms in secondary schools and the functions they serve. One type of interaction that they highlighted is the interactive and dialogic approach. This involves the teacher listening to students' ideas, probing their thinking on a particular topic, and working together to explore different ideas and suggestions. This type of interaction tends to be characterized by high levels of interaction as teachers and students participate in animated discussions with each other.

A second form of interaction is the interactive and authoritative approach, where the teacher focuses mainly on one specific point of view and leads students through a series of questions with the aim of helping them to gain a clearer understanding of the topic. In this type of interaction, the teacher is active in guiding the discussion with the students to help them develop an understanding of the specific goals of the lesson [19]. Scott, Mortimer, and Aguiar [20] argued that changes between these styles of interaction are an unavoidable part of teaching science as the interactive and authoritative approach is often used to introduce new information and ideas while the dialogic and interactive approach provides opportunities to investigate the information presented in more detail.

There is no doubt that successful inquiry-based learning experiences are predicated on teachers creating learning environments where students are not only amazed and challenged by the experiences they have, but also are able to interact with their teacher and peers to ask questions, seek clarification, offer explanations, justify their positions, and build on the ideas of others: in short, dialogue with others [21]. This type of interaction, Lehesvouri, Ramnarain, and Viiri [22] argue, improves students' willingness to engage in dialogic exchanges during inquiry-based learning activities. Moreover, it is through teacher interactions that students learn how to engage in appropriate ways of interacting in different classroom settings [23].

Rojas-Drummond, Littleton, and Velez [24] report on a study that investigated dialogic literacy, essentially the interplay between talking, reading, and writing, among 120 Grade 6 students in two primary schools as they collaborated in small groups on a literacy task involving reading and writing. The study utilized an intervention program called Learning Together which uses collaborative learning to enhance the development of children's oracy and literacy skills. One school implemented the intervention program (experimental condition), while the other continued with its regular literacy program (control condition).

Collaborative learning is critically important for helping students to understand the guidelines that they need to follow if they are to explore topics together. The ground rules that were proposed to help students to understand how they were to collaborate as they worked together were adopted from Mercer, Wegerif, and Dawes [25] and included:

(a) All relevant information needs to be shared.
(b) Group members need to reach agreement on all topics under discussion.
(c) Members need to accept responsibility for group decisions.
(d) Members need to provide reasons for positions adopted.
(e) Members need to accept challenges from others both within and outside the group.
(f) Alternative propositions need to be considered before the group makes a decision.
(g) All group members are encouraged to participate in the discussion.

Concurrently to establishing the guidelines for collaborate discussions, Rojas-Drummond, Littleton, and Velez [24] reported that the teachers played a key role in encouraging students to share their thoughts, outline their reasons for adopting a particular position, and explicitly state what they know about a topic and share this information with the class. They also modelled ways of using language that children could adopt for themselves, in peer group discussions and other settings, and they provided opportunities for students to make extended contributions to the discussion, enabling them to express their current understandings or communicate their difficulties [26].

The Learning Together program involved 18 sessions of 90 min each across a seven-month period in which the students in the experimental condition worked together on a variety of oral and written communication tasks [24]. Data on the written summaries produced by the students in both conditions were analysed using the Test of Textual Integration (TTI). The results indicated that the students in the experimental condition scored significantly higher on the quality of the text they produced and on each of the partial scores: title (comprehensive, informative, and concise), main ideas (six main ideas), organization of ideas (coherence of ideas), and level of expression (sophisticated expression).

Follow-up micro-analysis of the discussions and co-regulatory processes of four student triads (two experimental and two control triads) in the Rojas-Drummond, Littleton, and Velez [24] study while solving the group version of the Test of Textual Production (TTP) is reported in Rojas-Drummond, Omedo, Cruz, and Espinosa [27]. The purpose was to identify how the interactive, communicative, and co-regulatory processes emerged in each group, as well as how these processes might give way to the utilization of these processes in the written composition in the Learning Together groups (experimental groups). The results showed that the experimental student triads (in comparison to their control peers) gradually learned to adopt a more collaborative, dialogic, and strategic way of working together. The results highlighted the key role dialogic discussions and co-regulatory processes play in facilitating the development of written text in primary students.

Given that the knowledge-building practices of scientists are essentially social and collaborative, cooperative small group learning provides opportunities for students to investigate different observable trends, discuss potential solutions and research questions, identify the data to be collected and analysed, and communicate their understandings to others in ways that are seen as logical and well-thought through. However, many teachers experience difficulties in establishing cooperative learning experiences where students have opportunities to share, critique, and evaluate possible explanations for the phenomena under investigation. The following section will discuss some of the perceived difficulties teachers face.

5. Cooperative Learning: Creating an Interactive Culture and Setting

Inquiry-based science requires students to cooperate to investigate problems, ask questions, challenge each other's conceptions or misconceptions, and negotiate acceptable solutions to the problem at hand. When students cooperate, they learn to listen to what others have to say and reflect on their points of view, share their thinking on issues, challenge and rebut misconceptions, and engage in the practices of building new understandings and knowledge that promote learning. However, creating cooperative groups where students are able to discuss tasks in a meaningful way can be quite challenging unless students have a clear understanding of how they are expected to cooperate and what they are expected to achieve [28].

Productive classroom talk, Alexander [12] argues, requires developing a shared understanding of the way talk should be managed, often requiring that some explicit ground rules are established. These rules may eventually become part of the classroom routine, so students understand that these are the accepted norms for communicating, as occurs when an interactive culture is promoted. Alexander also maintained that talk is affected by the way students are grouped. Interaction is facilitated when students work in small groups (often three to four students) where they can see and hear each other as they work on a designated task.

In a review of five studies where teachers explicitly structured cooperative small group learning, Gillies [29] reported that students demonstrated higher levels of cooperation, group interaction, and learning than peers who learnt in unstructured small groups. Furthermore, "the benefits of cooperative learning are enhanced when groups do not exceed four members, are gender-balanced and of mixed-ability, instruction is designed to meet the groups' needs, and teachers have been trained in how to implement this pedagogical strategy" ([29], p. 47). These results were consistent across both primary and high school settings.

While cooperative learning is well established as a pedagogical approach that can be implemented in science classrooms to promote students' engagement and learning [30], establishing the conditions for it to be employed effectively can be a challenge both for the teachers and the students involved. Teachers are often reluctant to embrace cooperative learning possibly because of the challenge it poses to their control of the instructional process, where teaching tends to be more teacher-centred rather than learner-centred. Furthermore, the changes that teachers need to make to accommodate this organisational change to how they teach and the personal commitment they need to make to sustain their efforts are often regarded as further impositions on their role as teachers. It may also be due to a lack understanding of how to embed cooperative learning pedagogy into their classroom curricula to foster open communication and engagement between teachers and students to create learning environments where students feel supported and emotionally safe and secure.

6. Conditions Needed for Successful Cooperative Learning

Placing students in groups and expecting them to work together does not ensure that they will cooperate, as some students will often defer to more able students who may assume the important roles and tasks for themselves, leaving the less able students to undertake more diminished roles. One way to ensure that all students have opportunities to participate in groups is to structure the group, so students understand that they are linked interdependently around the task. When this structure is in place, students know how they are expected to work together, what they are expected to achieve, and how they are expected to behave [28, 29).

Research has identified five key components that need to be embedded in groups for members to cooperate [30]. These components are:

1. Positive interdependence exists when group members perceive that they are linked together in such a way that in order to achieve their goals, they must assist others to do so as well. Positive interdependence can be structured in a group so that each member has to complete part of the group's task, for example, a group project where each member works on one part of the larger task. Members then share their contributions with other group members so the larger task can be completed. Johnson and Johnson [31] found that when positive interdependence is established in a group, two important psychological processes occur. The first involves members allowing one member's actions to substitute for the actions of another. This occurs when one member undertakes an action that other members of the group accept as an action they see as important to the group. The second psychological process involves being open to the influence of others and willing to accept their ideas as valuable. When these two processes are evident, the group members become psychologically interdependent, with members realising they need to work together, be open to assisting others, and contribute their ideas to ensure the group completes its task or achieves its goal/s.
2. Promotive interaction enables group members to discuss topics with others and think about issues in ways that they may never have considered previously. In so doing, the information and ideas exchanged are transformed so they become part of their new ways of knowing and doing. In fact, when this occurs in science classrooms, Ford and Forman [32] found that the interactions that the students had with each other encouraged them to work together to collaboratively construct and critique different ideas and points of view. This participation in talk where students learn to give and take in their discussions, Ford and Forman believe, is essential if productive scientific talk is to occur. Moreover, it is these dialogic interactions that, in turn, support changes to students' reasoning and ways of thinking in science.
3. Interpersonal and small-group social skills are critically important if students are to work successfully together. However, these skills do not develop automatically, and teachers need to ensure that students understand how to interact respectfully and appropriately with others. Gillies [33] reported that when students were trained in how to use these skills, they demonstrated more cooperative behaviour, provided more help to each other, and used more inclusive language or language that invited others to participate than peers who had not been taught these skills. This may have been because when students learned to interact appropriately with other group members, they felt more supported by their group and were more willing to reciprocate in kind. There is no doubt that social support tends to increase group cohesion and sense of purpose, which, in turn, affect pressure to be a productive group member.
4. Individual accountability is evident when students accept responsibility for completing their part of the group task. When individual accountability or personal responsibility is evident, group members realise that they are also contributing to the group's goals. This responsibility, in turn, helps create a sense of group cohesion and motivation to cooperate as members realise the importance of their contributions to the group's goals. Johnson and Johnson [30] found that that individual accountability or personal responsibility increases the effectiveness of a group and the work each member completes. By supporting each other as they work together, students learn that they can not only achieve the group's goal, but their own performances also improve.

5. Group processing and reflecting are processes that are critically important for students' learning, as they allow students to discuss how well the group is working to achieve its goals and maintaining effective working relationships [30]. Johnson and Johnson [34] argue that this includes making decisions about what behaviours to continue or change; discussing how to streamline the learning process so all group members understand what they need to do; reviewing the group's progress as they complete specific tasks; and evaluating how they are working together as a team.

7. Inquiry-Based Science and Cooperative Learning

Successful implementation of an inquiry-based science approach in classrooms is very dependent on students working cooperatively together to investigate problems, search for possible solutions, make observations, ask questions, consider different perspectives on the issue, think innovatively, and use their intuition. Given the emphasis attached to the importance of students being actively involved in their own learning, as inquiry-based investigations enable them to do, questions naturally arise about the effectiveness of this approach to learning in the context of cooperative learning. Howe et al. [35] reported on a study of twenty-four classrooms across twelve schools where students worked in small cooperative groups on inquiry-based science tasks (intervention condition), while the three classrooms in the control schools participated in their regular classroom science program. The results showed that the students in the intervention condition achieved significantly higher scores on their inquiry-based science tasks than students in the control condition. Furthermore, the students in the intervention condition obtained significantly higher scores in their dialogic interactions (proposition, disagreement, explanations, and questions) than students in the control condition. Howe et al. [35] attributed the success of the students' progress in science to their cooperative group experiences.

Thurston et al. [36] reported on a two-year longitudinal study of the effects of cooperative learning on science attainment, attitudes towards science, and the social connectedness of 204 students involved in the Howe et al. study [35]. The study investigated whether the gains recorded in the Howe et al. study in science understanding, attitudes, and social relationships transferred and persisted even though the students were now in high school in comparison to students in the control condition. The study found that attainment gains that were recorded during the original study persisted over time and were maintained in the intervention condition 18 months after the original cooperative learning project. Furthermore, the social relationships that were developed by students before the transition were significantly related to higher post-transition attainment. In short, the use of cooperative learning during inquiry-based science may allow the transfer of knowledge and skills acquired to new learning environments.

Gillies, Nichols, and Burgh [37] reported on a study that involved thirty-five groups of sixth grade students in eighteen classrooms from nine elementary schools who worked on two inquiry-based units of science in three conditions: the cognitive questioning condition, the philosophy for children condition, and the regular classroom (comparison) condition. Teachers from all three conditions participated in four professional development days that provided them with background information on the inquiry-science units and the cooperative learning strategies they were to implement. Each inquiry-science unit ran for 6–10 weeks and required students to work together in small cooperative groups to investigate topics, test out ideas, evaluate their conceptions, and build new working theories or understandings in a continuous cycle of inquiry, the outcomes of which were shared with the wider class.

While the children in the cognitive questioning condition and the philosophy for children condition were taught specific ways of asking questions to prompt discussion and think carefully about issues that emerged, the results showed that the children in all conditions demonstrated more helpful discourses or discourses known to mediate learning. This outcome was encouraging because it is the way the students were taught to help each other by providing explanations, elaborating on points, and providing reasons for their thinking that promoted follow-up learning. In effect, it was the opportunities that the students had to participate in the inquiry-based science units where they were taught how to cooperate that promoted the dialogic interactions that occurred.

Ting et al. [38] reported on a meta-analysis of the effects of active learning (i.e., collaborative learning, discovery learning, experiential learning, group inquiry-based learning, problem-based learning, and activity-based learning) on Asian students' performance in science, technology, engineering, and mathematics (STEM) subjects. A main criterion for inclusion was Asian students' experience with an active learning experience in comparison to traditional, didactic lecture-based pedagogy. All the active learning approaches were defined as "any instructional method that engages learners in their own learning process through their active involvement in class" ([38], p. 381). Forty-four studies met the criteria for inclusion in the meta-analysis. The results showed that a moderately large effect of 0.66 was detected, indicating a positive effect of active learning on Asian students' academic performance. Moreover, the effect sizes for active learning pedagogies in the different STEM disciplines were similar, and there were no significant differences between different countries or regions in Asia.

Ting et. al. [38] concluded that by changing traditional learning to active, learner-centred, inquiry-based, and collaborative approaches, Asian students became fully engaged and found learning more relevant to their needs. "The deep learning process that results from this active learning instructional approach as opposed to the passive and rote learning approach, ultimately leads to higher order learning, meaningful learning outcomes and enhanced academic performance" ([38], p. 389).

Nugroho, Suranto, and Masykuri [39] reported on a meta-analysis of the effectiveness of inquiry learning in science on the development of argumentation skills: skills needed to make claims, explain reasons, justify decisions, and provide evidence for decisions taken. Seventeen inquiry learning studies that had focused on developing argumentation skills met the criteria for inclusion in the meta-analysis. All studies investigated the effectiveness of inquiry learning on the development of argument in biology, physics, chemistry, and integrated natural science in secondary schools and colleges. The results showed that argumentation skills had a positive impact on the quality of students' written and oral arguments, with effect sizes ranging from 0.41 (moderate effect size) to 2.00 (very large effect size). The authors concluded that "scientific activities in inquiry provide opportunities for students to discuss and debate arguments, do their assignments to make valid conclusions, and are supported by original evidence" ([39], p. 100011-4).

8. Conclusions

The research by Howe et al. [35], Thurston et al. [36], Gillies, Nichols, and Burgh [37], Ting et al. [38], and Nugroho, Suranto, and Masykuri [39] highlight the academic and dialogic benefits that students achieve when they have opportunities to participate in inquiry-based tasks in science in comparison to peers who learn through traditional transmission approaches.

Inquiry-based learning emphases the importance of students investigating problems, making observations, asking questions, testing out ideas, challenging the ideas of others, and thinking creatively as they work cooperatively on solutions to the problem at hand. There is no doubt that the inquiry process is complex, as it requires students to be adept at engaging with others, sharing their ideas, acknowledging the contributions others make, evaluating new information, and communicating their various understandings in ways that are logical and well-reasoned. In such situations, teachers need to play an active role in not only structuring inquiry-based experiences that will help students to develop an understanding of the content, but also the dialogic practices that will help them to engage in well-reasoned discussions that facilitate critical thinking and learning.

When teachers dialogue with students, they not only model and scaffold different ways of talking, but also provide feedback to help students develop clearer understandings of their learning. These types of dialogic discussions promote meta-level reflections that help students to connect ideas across contexts, promoting higher order thinking that leads to learning that is more meaningful and enhanced academic outcomes. In short, student learning and engagement is promoted when they have opportunities to work cooperatively together on inquiry-based science tasks that have been well-structured.

Limitations and Recommendations for Future Research

There are three limitations to the research reported in this paper. Firstly, the focus is on inquiry-based teaching in science where students work in cooperative groups to investigate challenging problems. This requirement automatically limits the number of studies that have addressed these issues. Secondly, while meta-analyses are used to describe the impact of inquiry-based learning on students' achievements, no information is provided on how teachers can implement inquiry-based teaching in science in their classrooms; this is a clear indication of the limitations of meta-analyses. Finally, the paper focuses specifically on academic achievement and does not address student motivation to learn during inquiry-based science activities. Future research will need to address these limitations if inquiry-based teaching in science is to be fully embedded in science curricula.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created of analysed in this study.

Conflicts of Interest: The author declares no conflict of interest.

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