# Introduction

In educational research, theoretical standpoints are important to understand the reasoning behind a particular intervention. For instance, in inquiry-based science education (IBSE) literature, an understanding that knowledge is constructed on the basis of experience often lies at the heart of any intervention (Minner et al. 2010; Pedaste et al. 2015; Rönnebeck et al. 2016). Other interventions rely on other theoretical standpoints, such as direct instruction (Hattie, 2007) or cognitive evaluation theory (Plass, Moreno, and Brünken, 2010), leading to very different teaching strategies and recommendations (see for example, the classic dispute concerning inquiry learning between Kirshner, Sweller and Clark (2006) and Hmelo-Silver, Duncan and Chinn (2007). Even within a field in education, such as IBSE, different theoretical standpoints might co-exist and sometimes compete; inquiry has been defined and understood in a multitude of ways as evidenced by systematic reviews (e.g. Minner, Levy and Century, 2010; Pedaste et al., 2015; Rönnebeck and Sascha, 2016). The purpose of this article is to illustrate a novel method for extracting, analysing, visualising, and synthesising different standpoints in a body of literature. This is a form of review of the literature, which would often be conducted by a critical review (see e.g. Alake-Tuenter et al., 2012), where authors may draw on literature to derive new theory or model, or a review relying on thematic analysis (Grant and Booth, 2009).

Critical reviews rely on the authors’ careful and extensive reading of a sub-field of research and are generative with regards to theory and future research questions (Grant and Booth, 2009). However, in line with AUTHORS (2019), we argue that such readings may overlook important relationships in the textual presentations, which in turn could have led to different interpretations and theory. A method which explicitly aims at revealing such relationships might help generate theory that can encompass more nuances.

The purpose of thematic analysis (Braun and Clarke, 2006) is to develop patterns of meaning and themes across a set of data. The process entails data familiarisation, coding of data, development of themes, revisions, and weaving an analytical narrative from themes and data extracts (Braun and Clarke, n.d.). This approach to reviewing has found some use in educational research (e.g. Cremin et al. 2015; Horntvedt et al. 2018), sometimes in parallel with systematic reviews (e.g. Darbyshire and Baker, 2012).

As a qualitative method, thematic analysis is very flexible, which means that it has a wide range of applications. It also means that it is hard, if not impossible, to reproduce, and great care has to be taken in order to ensure transparency. While reproducibility is not the intention for such an analysis, transparency certainly is. Recently, reviews utilising networks of article keywords have emerged (e.g. Heradio, de la Torre, Galan, Cabrerizo, Herrera-Viedma and Dormido, 2016; Valverde-Berrocoso et al. 2020). These reviews could be seen as a kind of quantitative counterpart to thematic analysis, in that they produce what can be called *thematic networks* (Heradio et al., 2016). The method is inherently transparent and reproducible in the sense that it is clear how authors arrive at thematic networks, and researchers using the same data set and the same method should arrive at the same results. However, the purpose of these *mapping* reviews (Grant and Booth, 2009, 94)) are rather to map and categorise a field than to extract meaningful themes.

In this paper, we illustrate a novel method of literature review, which combines thematic analysis with recent mapping review techniques by thematic network analysis (TNA). In doing so, we expand on keyword network analysis by using textual excerpts as our data. The method is inspired by previous work from the authors on other types of textual data (AUTHORS, 2019; AUTHORS in press). Our purpose is not only to map and describe themes, but to synthesise, analyse, and map different positions in a subfield of education.

## Early childhood inquiry-based science education as an exemplar

We have chosen recent literature in the field of early childhood inquiry-based science education (ECIBSE) as our illustrative example. More precisely, we are interested in the theoretical bases of empirical studies in ECIBSE.

There are several reasons for using ECIBSE as an exemplar for our methodology. First, IBSE has a century long history where well-known positions have been proposed and discussed. Thus, we aim to compare, and contrast themes and positions synthesized from our analysis of recent work with well-known educational philosophies and arguments. Often the work of John Dewey (1859–1952) is considered foundational to inquiry with a focus on fostering curiosity and relating that to scientific practice (Johnson and Christensen, 2014).

Second, we expect that there are different theoretical positions to be identified. IBSE is conceptualised and implemented in different ways across different contexts and domains, as Rönnebeck et al. (2016) illustrate for the upper secondary level. Even within a single domain and context, IBSE may be conceptualised differently in terms of theoretical stance as is illustrated for middle and secondary school by Martin-Hansen (2012). Thus, we would expect our new method to find patterns that can be distinguished as different positions.

Third, IBSE is an important area of research in science education. Educational policies around the world emphasise inquiry-based science (IBSE) approaches to teaching as vital ingredients in building a scientifically literate community for all age groups and educational levels (Harlen and Allende, 2006), including early childhood levels. We argue particularly for the importance of focusing on early childhood IBSE (ECIBSE) studies, because encounters with science learning likely shape children’s future attitudes towards science and science learning (Eshach and Fried, 2005). Science in early childhood context has increasingly been of interest for researchers, policymakers and practitioners (Trundle, 2015). In this vein, we argue that it is worthwhile to focus on the theoretical bases of empirical studies, because the theoretical bases underpin the design and recommendations of such studies.

## Research questions

The purpose of this article is to provide an illustrative example of a review which investigates and synthesises theoretical positions in recent literature on the nature of inquiry. To this end, we construct and analyse maps of theoretical expositions in recent empirical studies in early childhood inquiry-based science education (ECIBSE) literature by combining word-adjacency networks with thematic analysis.

The review addresses the following research questions:

1. Which themes and meanings arise in analysing such maps, and how can these themes and their meanings be interpreted in light of the literature they were derived from?
2. Which theoretical positions about the nature of inquiry can be synthesised from maps and meanings, and how do these relate to original historical philosophy of inquiry?

To frame our later interpretations, analyses, and synthesis, the next section provides an overview of the origins of IBSE with a focus on Dewey’s perspective. We then present and provide methodological arguments for our methodology, thematic network analysis, which combines thematic analysis with network analysis to identify theoretical conceptualisations in empirical studies. The thematic network analysis leads to a network map of interconnected themes, where themes represent different aspects of theoretical conceptualisations. We analyse the map in detail and proceed to use our methodology to synthesise different theoretical positions, which can be found in recent ECIBSE literature. In our subsequent discussion, we begin by relating the synthesised theoretical positions to ECIBSE and implications. We shall then discuss the methodology in terms of how it integrates qualitative and quantitative ways of analysing and synthesising and what kind of knowledge it may produce.

# A sketch of the origins of inquiry-based education

The philosophy underlying IBSE has deep roots in pragmatism, which was developed for education by John Dewey (Biesta and William, 2003). Dewey was concerned with mediating dichotomous ideas, e.g., the separation of human experiences and nature. He regarded the physical, mental and social worlds as a coherent organism.

Dewey (2005) outlines fundamental conceptual phases, such as defining a problem, formulating a hypothesis, and conducting tests, and contemporary inquiry cycles involve elaborations of these phases (Johnson and Christensen, 2014; Biesta and William, 2003). Dewey’s idea of inquiry is related to both contemporary IBSE conceptualisations and scientific practice. For example, for Harlen and Allende (2006), IBSE encompasses experiences that enable children to develop understanding about scientific aspects of the world through the development and use of scientific inquiry skills in educational settings.

Dewey stressed that we must obtain new knowledge through experiences within situations where children create and recreate knowledge as part of the educative process. For Dewey, this is the underlying idea of inquiry (Dewey, 2015). Experience consists of three mutually dependent categories; situation, interaction, and continuity (Dewey, 2015). ‘Situation’ refers to the fact we interact with other individuals and with objects in a concrete world and our lives here consist of a series of situations. ‘Interaction’ refers equally to interactions between individuals and objects and interactions between individuals. Contemporary literature consistently provides evidence that hands-on experience with science phenomena is a necessary (but not sufficient) component for conceptual learning, especially when coupled with guidance from a teacher (Minner, Levy and Centtury, 2010). Within a series of situations, continuity needs to emerge before it can contribute to the fulfilment of an educative experience (Dewey 2015; 2005). Continuity itself can be interpreted through three aspects: emotional, practical, and intellectual (Dewey 2005, 61). For Dewey, ‘*continuity of experience means that every experience both takes up something from those which have gone before and modifies in some way the quality of those which come after’* (Dewey, 2015, 35).

Dewey was concerned with mediating the progressive and traditional school, both of which he found mis-educative, because neither apply a carefully developed philosophy of experience (Dewey, 2015). Here, we focus on three of Dewey’s reflections. First, he argued that utilising science subject-matter found in the immediate life-experience of the learner is the best model for how educative experiences can contribute to growth (Dewey 2015, 82). Thus, educators can use opportunities in children’s interaction with the world to develop science education that contribute to the personal growth of children.

Second, Dewey argued that traditional schooling exerts social control and consequently children lose personal, emotional and meaningful relationships to subject-matter (Dewey, 2015). Recent research supports this view, since children’s interest towards science seems to decline with traditional teaching (Trundle, 2015). In contrast, progressive schools believed that any involvement from adults destroys and disturbs the child’s natural development through his/her own experiences. For Dewey, this stance contributes to discontinuity because children often will not relate their knowledge to a wider perspective. In current literature, Hamlin and Wisneski (2012) discuss similarities and differences between free play and learning science. Furthermore, achieving a balance between children’s natural playful mode and the teacher’s tasks for learning science has been identified to be a main challenge to solve (Vartainen and Kumpulainen, 2020; Campbell, Speldewinde, Howitt, and MacDonald, 2018). Thus, it seems that mediating between children’s natural playful mode and teachers’ tasks for learning science is still a concern. In our understanding, Dewey might reply that experience, understood in terms of situation, interaction, and continuity, is needed to mediate between play and leaning (Dewey, 2015).

Third, Dewey reflects upon organisation on subject-matter (ibid). One major difference between scientific inquiry and IBSE is that teachers often know what children may learn, whereas the attained knowledge in scientific inquiry by nature is unknown. Furthermore, there is a difference between the amount of existing knowledge obtained by scientists over the course of centuries and the knowledge and experiences had by children. Dewey advocated the facilitation of creative environments in which children undergo development through educative experiential situations. Attention to children’s interests should guide educators in their choice of instructional strategies and materials to use. Questions or problems arising from the child’s everyday experiences are meaningful because they are driven by genuine curiosity (Dewey, 2015).

Contemporary research suggests that children are born curious and behave like natural scientists but that their interest in science decreases during education (Trundle, 2015). Furthermore, poor science instruction in an ECE context contributes to negative attitudes towards science (Trundle, 2015). From this child-centered perspective, it is essential to inquiry-based approaches that educative experiences and learning always include values, emotions, the act of doing and cognition.

# Materials and methods for literature review with thematic network analysis

One possible strategy when using thematic analysis is to conduct a search for relevant and representative literature, analysis and code literature in order to produce thematic networks (Attride-Stirling, 2001). In fact, Braun and Clarke (2006) illustrate how such networks (or maps) develop and serve as tools for understanding during analyses. We expand on this thematic analysis by integrating network analysis. As shown by AUTHORS, 2019 and AUTHORS, in press, integrating network analysis with qualitative forms of analyses highlights relational aspects of the data and may aid in finding patterns otherwise hidden. Below, we will initially describe how we performed this study’s literature search, followed by how we conducted our thematic network analysis.

## Literature search

We performed a literature search to identify studies with relevant ECIBSE focus inspired by Petticrew and Roberts’s (2008, 27) stages for systematic reviews. We started by carefully reading previous reviews of IBSE and ECIBSE. We focused on Alake-Tuenter (2012); Furtak et al. (2012); Minner, Levy and Century (2010); Pedaste et al. (2015) and Rönnebeck, Sascha and Ropohl (2016). These reviews provided information about gaps in the field and relevant keywords, which we used to identify relevant papers. We selected 2 strings: i) Population and ii) Intervention. We omitted the search strings iii) Outcome and iv) Comparison, because our research questions do not pertain to outcomes or the relation between intervention and outcome.

IBSE approaches to teaching are varied both in formats, in terms used and in names given to approaches. We argue that there are several terms for the same overall core ideas. For example, the United States’ official bodies have moved away from using the term ‘inquiry’ and now refer to scientific practices instead (National Research Council, 2012). Thus, to avoid losing key information, our search included inquiry-based education as well as related terms.

***Table 1.*** Summary of literature search criteria

|  |  |  |  |
| --- | --- | --- | --- |
| Publication dates | 01/01/2008-31/01/2019 | Literature language | English |
| Database | EbscoHost (Education): Academic Search Complete, Education Research Complete, ERIC, Psychology and Behavioural Sciences Collection and SocINDEX with Full Text. | | |
| Search string name | Keywords in string | | Syntax |
| POPULATION | Primary school, Kindergarten, Primary education, Child\*, Preschool, Early childhood, Preschool class | | “OR” separated items in block |
| INTERVENTION | Inquiry-based teaching, Inquiry-based science education, Inquiry cycle\*, Inquiry-based learning\*, Inquiry phases, (IBL), (IBSE), Inquiry learning process\*, Inquiry-based instruction, Inquiry model, Scientific inquiry, Scientific practices, (IBI), Inquiry-based learning framework. | | “OR” separated items in block |
| Search syntax | POPULATION keywords “AND” INTERVENTION keywords | | |

Table 1 summarises our search criteria, indicating date range, language keywords and database. We chose a recent period of publication in order to find theoretical positions as they appear in recent work. The POPULATION and INTERVENTION keywords were combined to yield the intersection between ECE and IBSE. We limited ourselves to literature in English because preliminary searches indicated very few non-English publications. In doing so, we accept the possible exclusion of regions without strong traditions for publishing internationally.

Diagram

Description automatically generated

***Figure 1.*** A visualisation of the process leading to the final corpus.

Figure 1 summarises how we arrived at the final corpus of articles used in this study. We excluded more than a fifth of the initial papers based on reading headlines (Petticrew and Roberts, 2008). We excluded papers which concerned primarily age groups of 8 years and above, children with disabilities and cooperation with parents. For the remaining 386 papers, we read abstracts and further excluded papers without an empirical basis, papers addressed solely to practitioners, and non-scientific research (e.g. papers which had not undergone any peer review). Applying these criteria resulted in a corpus of 35 peer-reviewed research articles, all of which featured theoretical sections and empirical descriptions of an intervention, where a teacher taught/facilitated learning for 4-8-year-olds.

## Selection of excerpts

We made a strategic choice to focus on sections and passages which were clearly part of a theoretical positioning. For this illustrative example, the first author read through each article multiple times and extracted theoretical excerpts and passages.

Some articles, such as Bruce and Casey (2012), featured a section which could readily be identified as a theoretical exposition on inquiry. Bruce and Casey (2012) do mention inquiry teaching in the introduction, but do not begin their theoretical exposition here. Rather, they advocate inquiry “as a lens through which classroom pedagogy can be both analyzed and effected” (191). In other cases, theoretical claims appeared other places as well, for instance in an introduction. We included passages which pertained clearly to inquiry learning and focused on the goals and possibilities of inquiry rather than limitations. For instance, Enyedy et al. (2012) writes (our highlighting):

Young children can, under the right circumstances, learn more complicated ideas than we currently ask of them in early elementary science education. *With support, early elementary students can engage in productive inquiry, collect and analyze data, produce models, and learn complex concepts.* However, one argument against ‘ambitious’ science instruction is that aspects of classical experimental design such as controlling variables and separating hypotheses from evidence have proven difficult for young children (Klahr, 2000; Schauble, 1996; Siegler and Liebert, 1975, 347).

In the quote above, we only included the highlighted sentence. The first sentence is not inquiry-specific – other theoretical frameworks could make the same claim. The third sentence states an argument against inquiry learning, which may be relevant but does not directly state anything about the nature of inquiry.

All excerpts and references can be found as supplemental material.

## Thematic network analysis

We analysed the selected excerpts via a modification of thematic discourse network analysis (TDNA). TDNA is an iterative methods approach to analysing and visualising relationships in textual data (AUTHOR et al., 2019; AUTHOR et al. in press). Our modified approach mirrors Braun and Clarke’s (2006) thematic analysis in that we seek to ‘minimally organise and describe [our] data set in [rich] detail’ (79), and want to couple that organisation and description with our reading of the literature to create a convincing narrative about theoretical descriptions of ECIBSE.

In contrast to Braun and Clarke (2006), we rely on using computer software for creating linguistic networks and maps. Thus, the phases of our approach differ somewhat from Braun and Clarke (2006). While the description below appears ordered in a linear fashion, our movement from phase to phase was not. For example, we at times went through multiple small loops of generating networks and generating algorithmic rules for changing texts before generating new thematic maps.

Throughout our analyses, we have used the software products Gephi 0.9.2 (Bastian, Heymann and Jacomy, 2009), R (R Core Team, 2019) and RStudio (R StudioTeam, 2020). In R, we have used these packages: Igraph (Csardi and Nepusz, 2006) and tm (Feinerer and Hornik, 2019). Our detailed work can be found at GitHub [repository name released upon acceptance of present manuscript; scripts attached as supplemental files].

### Familiarising with data and generating linguistic networks

In this study, this step was closely connected to the selection of excerpts. The first author used her reading of the articles to identify preliminary themes in the data as well as possible grammatical reductions (see below). As a precursor to generating the linguistic network, we then implemented the grammatical reductions decided upon. Then, we created weighted and directed linguistic networks where ‘a directed link is established from *Word A* to *Word B* if *Word B* follows *Word A* in the pre-processed [text]’ (AUTHORS, 2019). We created a combined linguistic network, which represented an amalgamation of excerpts from articles. Thus, the combined linguistic network contained all connections in all pre-processed theoretical excerpts from all articles.

### Generate algorithmic rules for changing texts

In this critical phase, we decided on grammatical reductions (AUTHOR, 2019), such as removing words and deciding on simplified forms and synonymous words. The rationale for these reductions came from our evolving qualitative analysis. In both early and later stages of the analytical process, we would return to the excerpts before making decisions to see how words were used in the contexts of the different articles.

### Generate thematic maps

The purpose of this phase was to reduce the complexity of the network representation of the data while still preserving critical relationships. Inspired by AUTHOR (2019), we used ‘fast-and-greedy community detection’ (Clauset, Newman and Moore, 2004) to find clusters of tightly knit words. These clusters were seen as representations of candidate themes (our final set of networked clusters of words can be found in the supplemental materials). We then calculated links between clusters/candidate themes by counting the number of word links between themes. We visualised the map, showing only the most prevalent connections (Foti, Hughes and Rockmore, 2011) and, by re-applying community detection but now on the thematic map, were able to find clusters of themes (represented in colour in Figure 2).

Diagram, radar chart

Description automatically generated

***Figure 2.*** Thematic map for excerpts. Each circle represents a cluster of words/candidate theme, and each arrow represents word connections between clusters. The size of circles indicates the number of words contained in that cluster. Circle colours represent clusters of themes found by applying community detection on the map.

### Critical review of themes and thematic maps

This phase involved close comparison between the original excerpt texts and both the thematic maps and the internal structure of themes (each theme is a sub-network of the original network). We scrutinised connections between words and themes; questioned why particular words appeared central or prevalent in the network; and why particular words had been clustered together. This led to new algorithmic rules that were implemented, and the results were scrutinised again.

### Naming and describing themes and between theme patterns

To name a theme, we looked for the most prevalent connections between words and used our evolving understanding as well as less prevalent connections to guide the naming. For example, the theme *Learn science through inquiry* on Figure 2, contained the prevalent connections *science -> learn* and *learn->inquiry,* but also less prevalent ones such as *guide->inquiry* and *understand -> science,* as well as numerous minor connections supported that interpretation. This interpretation corresponded with our reading of the original articles.

### Producing report

In reporting our findings, we found that one theme was too prevalent. The theme *Learning science through inquiry* lead attention away from possible underlying hidden patterns relevant for understanding positions. Therefore, in later analyses, we removed this theme from the thematic map and worked with the most prevalent remaining connections between themes. In this paper, we report on our integrated understanding of the final thematic maps, the network structure of themes and our careful reading and re-reading of the excerpts.

# Results of illustrative thematic network analysis of ECIBSE

Here, we report on our thematic network analysis (TNA) of theoretical excerpts. We present our final thematic network map and then elaborate on themes shown in the map and their connections, including our final thematic map of theoretical excerpts.

Chart, radar chart

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***Figure 3.*** This study’s final network map of theoretical excerpts. Overarching themes are colour coded. The size of circles represents the number of words within each (overarching) theme, and the size of arrows represents the number of connections between each (overarching) theme.

Using community detection, we were able to group themes into three clusters of overarching themes shown in colour in Figure 3 that contains of 19 themes:

* The orange-coloured themes comprise the following themes: Instructional models and evidence, Agency of children during inquiry, Open-ended investigation, Previous and new knowledge, Inquiry not linear, Scientific practices, Hands-on authentic experiences, Educational/Policy context and Influences of mental function. As we will argue below, this overarching theme seems to capture a group of theoretical descriptions of inquiry that aims at modelling science education practice through a phase-driven instructional model. We have named this overarching theme *Modelling scientific practice*.
* The second overarching theme is composed of the three green themes: *Process skill, Problem solving* and *Share products with others*. Together, these themes highlight a position which places emphasis on the ability to solve problems by using process skills and being able to share with others. Interestingly, these elements are very often part understandings of competencies as they appear in science education literature where competencies are related to everyday life by focusing on problem solving of personal interest combined with relevance for today’s society (see e.g. Ropohl et al., 2018, 10). However, competencies in this understanding involve both knowing and doing, individually and with others. Thus, the elements of competencies which we can see only partially cover the concept of competencies in science education, so we have named the corresponding overarching theme *Developing competencies*.
* The purple themes constitute the third overarching theme: Young child explores, Development, Reflect and discuss, Pedagogical tools, Allow student expressiveness, Experiential education and Surrounding world. These themes emphasise a notion of inquiry, in which the experiences, development and curiosity of the child takes centre stage as a starting point for inquiry, and in which the child’s playful exploration of the world is central. We named this overarching theme Child exploration/experience.

We argue that the three overarching themes represent theoretical positions with regards to ECIBSE in the literature. In order to relate the map to the literature in detail, we shall now analyse each conceptualisation in turn, linking network representations to the literature with overarching themes in *italicised and underlined*, while themes and words are *italicised* only.

## The Modelling scientific practice position

Almost all of the themes in the overarching theme point to the central *Instructional models and evidence*. One way to interpret this structure is to view themes that point to the central theme as elaborations of important aspects of that theme. With this interpretation in mind*, Agency of children during inquiry, Open-ended investigations, Previous and new knowledge, Scientific practices* and *Hands-on experiences* are important aspects to consider when applying inquiry instruction models. If we interpret the size of the circles (the number of words in the underlying theme networks) as an indicator of importance, these are roughly equally important. Thus, the three smaller orange themes are not prevalent in the theoretical positioning in the literature. Overall, the patterns in *Modelling scientific practice* draw attention to aspects of inquiry processes used by real scientists. García-Carmona, Criado and Cruz-Guzmán (2017, 990) provide an example of how references to scientific practice that is consistent with this conceptualisation:

They [the children] use skills employed by scientists such as raising questions, collecting data, reasoning and reviewing evidence in the light of what is already known, drawing conclusions and discussing results. (990).

Many studies make use of phase-driven instructional models adapted to ECIBSE-contexts. For example, Desouza (2017) modifies the 5E model by Bybee et al. (2006) to be suitable for ECIBSE.Phase-driven instructional models are implemented to help model scientific practice, and they act as a paedagogical structure to underpin planning of science activities.

*Agency of children during inquiry* represents how the child can be seen as an agent in an inquiry lesson. For example, Margett and Witherington (2011) predicts and compares what pre-schoolers do with what adults do in inquiry situations in biology - and thereby demarcates children’s agency.

*Open-ended investigation* covers the view of inquiry through which adults allow students to investigate a prescribed problem which has more than one correct solution, using their own methods as described in Leonard, Boakes and Moore (2009). Open-ended investigations are often seen as a landmark in instructional models like 5E (Bybee et al., 2006).

*Previous and new knowledge* is part of an instructional approach to inquiry. The theme contains the word *construct* and the link *construct →knowledge.* However, words and connections in the theme also suggest that there are constraints on the new knowledge which fit with modelling scientific practice.

*Scientific practices* contain links such as *collect →data*, *ask → questions*, *make → observation*, and *interpret → observation*. We take this theme to represent the idea that children should engage in science-like practices as part of inquiry instruction.

*Hands-on and authentic experiences* may be seen as an elaboration of the nature of the activities which children should learn from. Other ways of wording this sentiment include ‘real life’ and ‘phenomena from everyday life.’ The theme also highlights that time is a necessary component for such activities.

## The Developing competencies position

This position concerns the development of skills, literacy and affect, which children should learn through inquiry. In science education, most definitions of competence involve knowledge and skills, and the ability to use this in complex situations (Ropohl et al., 2018). In addition to this, our understanding of competence also includes affective terms (such as curiosity, emotion and values and the will to act), collaboration, and participation in relevant decision-making processes (AUTHORS, 2012; Ropohl et al., 2018). Note that this understanding of competencies may have a much broader scope than science.

The theme *Process skill* includes the words *process*, *skill*, *literacy*, *thinking skill*, *communication* and *knowledge*. *Process* may refer to ways by which to learn and experiment; in iterative cycles, in which skills are gradually learned. Process skills may also refer to the skills that need to be developed in order to engage in science-like practices (e.g. Bell and St.Clair, 2015).

*Problem solving* as a theme appears as a many-faceted process that may involve constructing solutions to given tasks (Wu and Lin, 2016), ‘detecting and solving life-related problems in [the children’s] own ways’ (Wu and Lin, 2016, 846), and ‘as a means for supporting children to construct nuanced meanings of the world that surrounds them’ (Philippou et al., 2015). Solving problems is often seen as part of inquiry and scientific literacy and can be connected to aesthetic, intellectual, and emotional states (Bruce and Casey, 2012), and may involve dialogical and collaborative elements (Bruce and Casey, 2012; Siry, Ziegler and Max, 2012).

*Sharing products with others* is a small but central theme. In early childhood, it can be a challenge for teachers to facilitate sharing, ‘since early childhood students are [just] beginning to build early literacy skills’ (Eckhoff, 2017, 220). We believe that this theme represents an important bridge, since it is important to focus on the child’s ability to even participate in the processes of inquiry as part of *Developing competencies*. If children in a class do not have a concept of how to share work or engage productively in a communicative process, then peer discussions may not teach them to draw conclusions based on evidence.

## The Child exploration/experience position

Two arrows point from the central *Young child explores* Circle. One points to *Experiential education,* another to *Surrounding world*. This could signify that *Young child explores* somehow modifies or informs these two other themes.

The theme *Young child explores* is named after thick connections *young* → *child* and *child →* *explore*. The word *child* is central and connected to encouragement, inciting, stimulating, empowering, assisting and enabling. These all seem like strategies for letting children explore by using curiosity, experience and language, and for giving weight to childrens’ decisions. Curiosity can drive action so that the child comes to own the inquiry process (Bruce and Casey, 2012; Samarapungavan, Patrick and Mantzicopoulos, 2009; Senocak et al. 2013; Van hook and Huziak-Clark, 2008), rather than being provided with information on scientific concepts (Ilhan and Tosun, 2016). Enyedy et al. (2012) mentions participatory simulations, in which students make and evaluate rules that underlie a simulation, and Siry, Ziegler and Max (2012) argues that children’s ‘science-related talk’ often is ‘at the origin’ of ‘standardized canonical discourse’ (314). Unsurprisingly, *engage* is another central word this theme; children’s engagement is instrumental for their exploration.

*Development* is characterised by two main connections: *starting* → *point* and *concept* → *develop(ment)*. In line with Dewey, the starting point of exploration in this position is seen as the child’s interest (e.g. Bruce and Casey, 2012) and exploration (e.g. Enyedy et al., 2012). Conceptual development is seen as a long-term endeavour (Decristian et al., 2015; Gropen et al., 2017), which may involve many aspects, such as children developing and exploring their own explanations, models and concepts. At the same time, children are seen as developing beings - a point that we believe is captured by McNerney and Hall (2017, 207):

For scientific thinking to develop through children’s exploratory play and observations, children should, at some stage, be able to interpret and make sense of their experiences so that they can gain a better understanding of the world around them.

*Allow student expressiveness* is built on the network connection *allow →* *student* andrepresents the varied ways in which children as active learners are allowed hands-on experiences, participation in socio-dramatic role play, or even to initiate and lead the inquiry activity (Enyedy et al., 2012; Hollingsworth and Vandermaas-Peeler, 2017). In addition, *Allow student expressiveness* mirrors the challenges of ECEIBSE found in *Share with others*; finding alternative ways to encourage young children to express and visualise their own thinking can be an important element of ECIBSE (Eckhoff, 2017). Specific media include visual arts media, drawings, use of play doh, and digital photography (Eckhoff 2017; Enyedy et al. 2012; Fridberg, Thulin and Redfors 2018; Leuchter, Saalbach abd Hardy, 2014).

The strong connection from *Young child explores* to *Surrounding world* resembles what children should explore; the strongest link in *Surrounding world* goes from *world* to *around*. The S*urrounding world* includes the material, natural, social and individual world. Thus, we interpret the link from *Young child explores* to *Surrounding world* as a prescription of what should be explored. *Young child explores* also has a strong connection to *Experiential education* in Figure 3. The strongest connection in the theme is *early* → *childhood*, and *childhood* additionally links to *teacher* and *education*. Furthermore, links make up the chain *experiential* → *education →* *context*. Taken together with our reading of the theoretical excerpts, we see this theme as representative of the broader educational context for ECIBSE that emphasises the young child’s exploration, experience-making and reflection.

## Connections between the three theoretical positions

Diagram

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***Figure 4.*** A map of the three theoretical positions described above. Each coloured circle represents one of the three positions we have identified; they are collections of the themes with corresponding colours in Figure 3. The arrows represent the collected connections from themes representing one position to themes representing another position.

In summary, our analysis finds three distinct but connected theoretical positions (see Figure 4), and each theoretical position is comprised of a number of interconnected themes. The connections (represented by arrows) between positions stem from the combined number of linguistic connections from words in one theme to words in another. The link from *Modelling scientific practice* to *Child exploration* is mainly due to the direct connection from *Instructional models and evidence* to *Young child explores*. This connection, in turn, is due to links in the final linguistic network (‘linguistic links’) that highlight how theoretical excerpts connect instructional models as a way of engaging children in exploration. The connection from *Developing Competencies* to *Child Exploration* is mainly due to the connection from *Problem solving* to *Young child explores*. This connection relies on multiple linguistic links which highlight the need to think about the emotional, physical, intellectual, technical and social environment during problem solving. The connection from *Developing competencies* to *Modelling scientific practice* is mainly due to the connection from *Process skill* to *Instructional models and evidence*. The linguistic links responsible for this connection bring together a learner’s ability to justify, argue, and connect theoretical ideas and knowledge using evidence.

# Discussion

Our discussion falls into two parts. First, we discuss how our illustrative results relate to ECIBSE literature. Next, we shall discuss our developed methodology.

## Discussion of the ECIBSE example of thematic network analysis

Many of Dewey’s original ideas of inquiry and tensions between these ideas are also present in recent theoretical expositions of empirical articles. The idea of phases is prevalent and can be traced to Dewey (2013), and we find intricate relations which can be related to a philosophy of experience. For instance, Dewey’s categories of situation and interaction are present in multiple themes, both as hands-on experiences when modelling scientific practices and in children’s exploration of the surrounding world. However, we find that the tension is not as simple as the tension between traditional and progressive education (Dewey, 2015). However, we do recognise a tension between science practice and child exploration; in the theoretical excerpts from empirical literature, children’s emotions, genuine curiosity and affect are not tightly linked to scientific practices.

The current tension between ECIBSE as scientific practice and child-centred experiential education has been addressed recently by others (e.g., Dobber et al. 2017; McGuigan and Russel, 2018; Larimore, 2020). Each of these works identifies this tension, but from different perspectives and with different solutions. Dobber et al. (2017) articulate a tension between student directed and teacher directed inquiry and identify different regulatory approaches, metacognitive, cognitive, and social for the teacher that could be used to mediate between the directions. Larimore (2020) argues for a holistic approach where ‘frequent play-based experiences with phenomena [from the children’s] everyday lives’ help ‘figuring out’ science (709). We believe that our findings highlight a way of thinking about this tension, which is related to but different from both of these approaches.

In this way of thinking, modelling scientific practice and child exploration and experience can be moderated by the need for developing competencies. In this particular context, competency includes curiosity, emotions, skills and knowledge, as well as the will and ability to use them when relevant (Ropohl et al., 2018, 10). In this view, children’s development of competencies becomes a main goal – one that cannot be achieved without either of the two others. This does not preclude tight connections between children’s innate propensity to be curious and figure out the world by learning science (Larimore, 2020).

The theoretical positions and tensions we found in excerpts are also highlighted by McGuigan and Russel (2018). Their analysis suggests, in line with our analysis here, that early years’ practices should be linked to science approaches ‘by tracing developmental learning progressions between general behaviours and the emergence of more science-specific behaviours’ (34). They advocate for a ‘whole child framework’ that integrates these positions and suggest collaborations with practitioners to implement such a framework.

In addition, the positions warrant a discussion of what should be learned in ECE and what should be learned later in school. For example, with respect to the cognitive and executive level of development (Hollingworth and Vandermaas-Peeler, 2017), allowing the children to experience how to cooperate before asking them to discuss may be beneficial. For the same reasons, allowing children to learn to observe, classify and ask their own questions might be a part of a science-related competency to be developed before learning to draw conclusions based on evidence.

On the other hand, both McGuigan and Russel (2018) and Larimore (2020) suggest that children are capable of using both technical terms and of providing explanations of what they experience. Furthermore, Larimore may be aligned with Dewey’s idea of continuity, when suggesting ‘frequent meaningful integration of science’ for children. The quest may then be to find age-appropriate content, drawing on a world near to the child, and work frequently to foster children’s ability to unify elements of an indeterminate situation. Combined with metacognitive, conceptual and social regulation (Dobber et al., 2017), continuous negotiation between developing competencies, child exploration and modelling scientific practices might constitute such a holistic or whole-child approach.

We believe important questions remain: In what way is *Modelling scientific practice* valuable from the child's perspective? How can a *child's exploration/experience* open for qualified science experiences in early childhood? Which competencies should be developed during early childhood?

## Thematic network analysis as a review method

As stated earlier, the method presented here shares many elements with recently published methods (AUTHORS, 2019; AUTHORS *in press*), and thus shares methodological issues with methods. The issues include: whether the products of our thematic network analysis represent the text appropriately; whether and how the method is and can be scientifically rigorous; strengths and limitations; and how the method might be further strengthened. Instead of repeating those discussions here, we shall focus on issues we believe are central to this particular method.

The design and implementation of algorithmic rules are at the heart of the researcher’s decision process. These rules shape thematic networks, thereby framing the whole interpretative process. Therefore, keeping track of rules and how changing them changes network representations are essential to interpretations and the final narrative (AUTHORS, 2019). The final narrative should be consistent with themes, positions and connections in thematic maps. This begs the question: Do the final maps and narrative correspond to theoretical positions as seen by researchers in the field? In our illustrative example, we compared the positions with both early inquiry frameworks and contemporary ideas about teacher practice in inquiry and found correspondences. Another method for establishing such correspondence would be to present researchers with our findings and ask if they could recognise the theoretical positions and to judge to which position(s) their writings would correspond. This method is inspired by Von der Fehr (2016), who used it to validate respondent positions in social networks.

Our proposed method can be seen as an integration of qualitative (thematic analysis) and quantitative (network analysis) methods. We see the two as being on equal footing in the method (Johnson, Onwuegbuzie and Turner, 2007), because they iteratively inform each other throughout the process. This means that one the method can be judged against both quantitative and qualitative standards for scientific rigor. Here we focus on the quantitative concept of *reliability* and the qualitative counterpart, dependability (Golafshani, 2003). The networks and maps created with the method are reliable and reproducible, given the textual excerpts and our final procedure. However, the textual excerpts and procedure might change if different researchers had extracted and produced them. In order to increase *dependability* (Galofshani, 2003), we have iteratively and critically gone through words that we either changed or removed, and – as discussed above – compared with other sources. A further increase of *reliability* might be to have researchers work independently on different aspects of the method: selection of excerpts, selection of words to change or exclude, naming of themes; then and on several occasions meet and compare notes and then independently prepare new versions of the analyses. If researchers’ analyses converge over time, then one could say that the results were reliable.

Our example was comprised by excerpts from a limited set of papers. As such, it was a manageable data set. Depending on the aims and scope of research, both target excerpts and number of papers could vary. Had we chosen inquiry more broadly, we would have got a lot more papers, and had we focused on the abstract rather than theoretical expositions, we might have achieved a relational map of elements of studies rather than theoretical positions. With a larger set of papers or a broader scope, it might not have been feasible to read each paper and weigh every ‘algorithmic rule’ as closely as was the case here. Instead, one could draw on more of the quantitative tools available with network theory to provide overviews of data. However, following Willig (2013, 126), we argue that no reading – and indeed any interpretation – can be said to be ‘true’ or ‘right’, since language is constructive and functional. In our view then, as quantitative network tools become more ubiquitous in the analyses, the qualitative parts of the analyses should intensify as well.

# Concluding remarks

In this paper, we have shown a method for reviewing literature, which is aimed at revealing standpoints embedded in each article and which used theoretical excerpts from early childhood inquiry-based science education literature from 2008-2019 as an illustrative example. We arrived at a map and accompanying interpretations of theoretical writings in the field, which showed interwoven themes and positions relating to how young children should engage with inquiry. We used our discussion relate the map to both recent literature and Dewey’s original thoughts, arguing that thematic network analysis can mediate theoretical standpoints. We further argued that the methodology can be expanded and refined in different directions, including other textual excerpts, selection of texts and scientific rigor.

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