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Chilean Elementary Teachers' Beliefs about Using Agricultural Concepts to Promote Life Sciences and Mathematics Learning

Creencias de profesores de la educación básica chilena sobre el uso de conceptos ligados a la agricultura para promover el aprendizaje de ciencias naturales y matemáticas

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Abstract

In the Chilean educational system, the curricula for life sciences and mathematics promote inquiry-learning approaches over recitation for elementary school. The literature suggests that elementary teachers struggle with the inquiry approach. Integrating agricultural literacy into the natural sciences and mathematics curricula may enhance students' learning by providing a context to support students in inquiry-oriented areas such as analysis of information and interpretation of representations. To accomplish integration, it is a priority to explore the teachers' beliefs regarding agricultural literacy. The purpose of this study was to explore a group of Chilean elementary teachers' beliefs regarding the use of agriculture as an educational context to enhance students' learning in life sciences and mathematics. This study concluded that teachers believed that agricultural concepts could be integrated into some areas of the curriculum such as nutrition and healthy food and the development of mathematics skills. The next step in this study will be the formulation of a hypothesis to help researchers answer how integration could be achieved. For that purpose, an instructional approach combining a video and a serious game will be used. The scenario of the video and the board game will be an agricultural related concept known as photosynthesis.

Keywords: science education, mathematics education, teachers' beliefs, agricultural literacy, inquiry

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Resumen

En la educación básica chilena, el currículo de ciencias naturales y matemáticas promueve la indagación como método de aprendizaje por sobre la recitación. La literatura sugiere que la implementación en la sala de clases del método de indagación es un desafío para los profesores. En este contexto, la incorporación en el currículo de conceptos ligados a la agricultura podría apoyarlos en su tarea de promover el aprendizaje mediante el desarrollo de escenarios que apoyen al estudiante en áreas como el análisis de información y la interpretación de representaciones. Primero, el objetivo de este estudio fue conocer cuáles eran las creencias de los profesores chilenos sobre la incorporación de conceptos de la agricultura en el currículo. Se concluyó que las áreas del currículo que podrían incorporar conceptos ligados a la agricultura eran nutrición, alimentación saludable y desarrollo de habilidades matemáticas. Segundo, el próximo paso en este estudio será la formulación de una hipótesis para descifrar cómo alcanzar la incorporación de conceptos agrícolas al currículo de ciencias y matemáticas. Para ello, se desarrollará un método de instrucción que combina un video y un juego educacional. El escenario de estas dos herramientas será la fotosíntesis como concepto ligado a la agricultura.

Palabras clave: educación en ciencias naturales, educación en matemáticas, creencias de los profesores, educación en agricultura, indagación

Teachers' beliefs play an important role in how teachers work in the classroom. Beliefs are psychological states of minds that are formed early and persevere even against contradictions caused by reason, time, schooling or experience (Pajares, 1992). Beliefs play a key role in knowledge interpretation and cognitive monitoring as well as play a critical role in defining behavior and organizing knowledge and information (Talbot & Campbell, 2014). There are two related concepts important to mention. These are belief bias and beliefs perseverance. Beliefs bias refers to the process of making illogical conclusions to maintain our preexisting beliefs. On the other hand, belief perseverance occurs when people maintain a belief even against contradictions (Lack & Rousseau, 2016). In this document, researchers focused on beliefs perseverance herein referred to as beliefs.

Teachers' beliefs of teaching life science and mathematics in the classroom

Beliefs held by teachers about their subject matter have a direct influence on their lessons and define an implicit curriculum with regard to the nature of scientific knowledge (Brickhouse, 1990; Milner, Sondergeld, Demir, Johnson, & Czerniak, 2012; Hong & Vargas, 2015) and mathematics knowledge (Stohlmann, Moore, Cramer, & Maiorca, 2015; Lui & Bonner, 2016). What teachers believe about the content they should teach influences students' learning (Goddard, Hoy, & Hoy, 2004; Lumpe, Czerniak, Haney, & Beltyukova, 2012).

Teachers' beliefs about the effective teaching of life sciences and mathematics is influenced by the school context and the curriculum as well as their colleagues and the school administrators' opinions about what content should be taught during instruction (Bray, 2011; Milner et al., 2012). Teachers believe that an effective teaching of sciences depends on following the instructions from the textbook and showing visual aids with images from the textbook without engaging their students in the process of inquiry (Contreras, 2009; Ravanal & Quintanilla, 2012). Teachers believe that passion and coaching lead to an effective teaching of mathematics (Cortez, Fuentes, Villablanca, & Guzmán, 2013).

Also, teachers' beliefs regarding instruction are influenced by the experiences teachers have outside and within the classroom (Bray, 2011; Wan, Nicholas, & William, 2010). Teachers' beliefs of their students' goals when learning science and mathematics have a direct impact on their classroom practices (Friedrichsen, Driel, & Abell, 2011; Kupari, 2003). Teachers who hold traditional (e.g. recitation) beliefs about learning tend to focus on higher grades more than understanding concepts and procedures, in comparison to teachers who hold inquiry (e.g. class discussions) oriented beliefs (Aguirre & Speer, 1999; Stipek, Givvin, Salmon, & MacGyvers, 2001; Beswick, 2012).

There is a direct relationship between teachers' beliefs about learning and the classroom practices used by teachers to foster learning (Polly, McGee, Wang, Pugalee, & Johnson, 2013). One of those practices is the integration of different disciplines to enhance learning (Klein, 2005). Students benefit from the integration of mathematics and science (Hurley, 2001; Johnston, Walshe, & Ríordáin, 2016; Ríordáin, Johnson, & Walshe, 2016) as well as of the integration of agricultural concepts to science and mathematics. For example, students are better prepared for problem solving in science when agricultural concepts are integrated in the curriculum (Myers, Thoron & Thompson 2009). Likewise, the integration of agricultural concepts to the mathematics curriculum enhance students' learning of math content which involves the analysis, interpretation and representation of data (Selmer, Rye, Fernandez, & Trebino, 2014). The idea of learning science and mathematics through agricultural concepts is embraced in the concept of agricultural literacy presented in the following section.

Agricultural literacy as a context to enhance learning

Agriculture is a dynamic process developed by human beings who use natural resources (e.g., soil, water and solar energy) and economic resources (e.g., investments) to generate work and products that are sold in the market for consumption (FAO, 1997).

Agricultural literacy is the understanding of the importance of agriculture on the social, economic and environmental development of a society (Frick, Kahler, & Miller, 1991). Agricultural literacy includes agricultural concepts, such as nutrition and natural resources, and provided a learning scenario for students (Kemirembe, Marshall, Radhakrishna, Gurgevich, Yoder, & Ingram, 2011). It also relates to the natural environment and the participation in volunteer activities within the community to promote sustainable development and environmental awareness for students, parents, and the community that surrounds each school (Adedokun & Balschweid, 2008).

Agricultural literacy promotes the development of scientific skills through activities such as including small garden spaces and raised garden areas (FAO, 2006). For example, school garden programs assist elementary students in their ability to observe, communicate, compare, relate, order and infer when they are included in the curriculum (Mabie & Baker, 1996; Rye, Selmer, Pennington, Vanhorn, Fox & Kane, 2012).

Agricultural literacy has been used as pedagogical context to facilitate students' learning through inquiry (Thoron & Myers, 2012). Under this approach, the integration of agricultural concepts in the science curriculum supports students in the development of their problem solving skills (Myers et al., 2009). Similarly, learning mathematics by using agricultural concepts provides a context to support students in inquiry-oriented areas such as analysis, interpretation and representation of data (Selmer, Rye, Malone, Fernandez, & Trebino, 2014).

When learning science, students need a learning context that connects what they are learning in the classroom and what they are experiencing in their daily life (Sanmartí, 2011). Agricultural literacy provides authentic learning experiences that support students in the process of developing inquiry skills and it helps students to connect their learning to the real world (Knobloch, 2008). Agricultural literacy also supports instruction by providing teachers with an authentic context to teach their subjects to their students (Knobloch, Ball & Allen, 2007).

Taking into account that the Chilean curriculum for life sciences and mathematics promotes inquiry-learning over traditional teaching approaches for elementary school (Ministry of Education of Chile, 2016), the fundamental question that conducts this research is how the integration of agricultural literacy into the life sciences and mathematics curriculum could enhance learning through inquiry? The first step to accomplish integration is to explore teachers' beliefs (Pajares, 1992) regarding agricultural literacy which is the background research that represents the purpose of the present work. The discussion section states the hypothesis constructed with the results of this study. The hypothesis connects with the fundamental question and constitutes the starting point for the next study.

The purpose of this background research was to explore what a group of Chilean elementary teachers' beliefs were regarding the use of agricultural concepts as an educational context to enhance student learning in life sciences/mathematics. In other words, the phenomenon of the study was teachers' beliefs regarding the use of agricultural concepts as a context to enhance student learning in life sciences/mathematics. Three were the research questions (RQ) that guided this study and related to the phenomenon of study (Marton & Booth, 1997). They were answered by means of a semi-structured interview.

RQ1: What are the beliefs that Chilean elementary teachers hold when they teach life sciences/ mathematics in the classroom?

RQ2: What do Chilean elementary teachers know about agricultural literacy?

RQ3: Do teachers believe that they can use agricultural concepts as a venue to enhance student learning in natural science and mathematics? If so, in what ways?

Theoretical framework

This qualitative study was formatted using the interpretivist paradigm (Creswell, 2009). The process of qualitative research was inductive, with the researchers generating a pattern of meaning from the data collected (Creswell, 2009). In interpretivism, the context where the action is developed and the actors who developed that action are the focus of attention. To understand a particular social action (e.g., teaching in this study) the researchers must grasp the meanings that constitute that action (Schwandt, 2000). For that, three features of interpretivism directed this study: (1) human action is meaningful; (2) respect for and fidelity to the teachers everyday life in the classrooms; (3) from an epistemological point of view, desire to emphasize the contribution of human subjectivity to knowledge without sacrificing the objectivity of knowledge.

Within the interpretivist paradigm, the strategy of inquiry or research methodology used in this study was phenomenography (Marton, 1981). This approach aims at "description, analysis, and understanding of people's experiences" regarding the phenomenon of study (Marton, 1981, p. 180). Phenomenographers assume that the interaction between human beings and their external world determine their conceptions; and these conceptions are accessible mainly by language (Svensson, 1997). In other words, the primary assumption of phenomenographers is that conceptions are the product of an interaction between humans and their experiences with their external world. Specifically, conceptions result from a human beings thinking about his or her external world. In this particular study, the researcher used phenomenography as an approach to try to understand Chilean teachers' beliefs of teaching life sciences and mathematics. It was also used to see if teachers saw relevance in using agricultural concepts as a way to help students learn life sciences and mathematics. The research design consisted of a semi-structured interview using open-ended questions as the research method (Creswell, 2009). Figure 1 shows the framework for this study. More details in regards to the research design are explained in the following section.

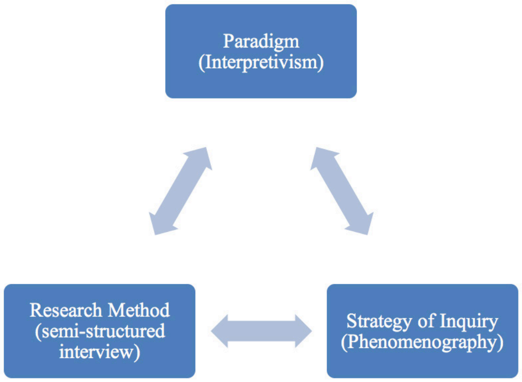

Figure 1. Framework for a qualitative research design. The interconnection of paradigm, strategy of inquiry and research method.

Methodology

Research design

The research design included a semi-structured interview consisting of open-ended questions as the research method (Creswell, 2009). Semi-structured interviewing was selected as method because (1) the researchers were not going to get more than one chance to interview the teachers (Cohen & Crabtree, 2006); (2) a semi-structured interview allowed the natural flow of the conversation (Marton, 1986). The guiding questions for the semi-structured interview can be found in the Appendix A and were written by the researchers of this study based on a questionnaire developed previously (Knobloch & Ball, 2003). The original instrument collected information about elementary teachers general information (years of experience, grades, content areas), teachers' beliefs regarding integrating agriculture, and the relationship between their beliefs and the amount of agricultural topics integrated to their curriculum.

In the present study, the guiding questions written by the researchers (Appendix A) were directly related to the phenomenon of study (Marton & Booth, 1997). Specifically, questions 1, 2, and 4 answered research question 1 (RQ1); and questions 5, 6 and 7 answered research question 2 (RQ2). RQ1 and RQ2 explained research question 3 (RQ3) which embraced the phenomenon of study which was teachers' beliefs regarding the use of agricultural concepts as a context to enhance student learning in life sciences/mathematics. During individual interviews, additional questions (e.g. could you please explain more?) guided teachers to reflect about the phenomenon within the Chilean educational context.

Participants and school context

The participants were three Chilean teachers who taught to 5th to 8th grade students. Two of them taught life sciences and one teacher taught mathematics. In a phenomenographic study, the sample size is not prescriptive but the data that are collected from that sample size should allow enough information to find different conceptions regarding the phenomenon (Trigwell, 2000). Even if the sample size is three, it serves to the purpose of the study and to explore the phenomenon of study (Marton & Booth, 1997). Detailed information about the participants and the school setting is presented in Table 1. The schools were located in Santiago, the capital of Chile.

Table 1
Participants' and school setting description

Participant	Years of Teaching Experience	Specialization or Teaching Assignment	School System	Municipality in Santiago (school district)	Number of Students/ Class size
Teacher 2	4	Life Sciences	Subsidized preK-8	Macul	45
Teacher 5	30	Life Sciences	Public preK-12	Estación Central	30-35
Teacher 7	11	Mathematics	Public preK-8	Maipú	45

Teacher 2. Teacher 2 was passionate about his subject, his students' learning experiences and the school success. He was aware of the importance of teaching all the content of the national curriculum for life sciences: *"I try not to get sick…I am the only specialized science teacher in this school, then one day off means that my students would not be able to learn about the content that the curriculum has, so they would be disadvantaged in comparison with the other students from the same grade."*

Teacher 2's school belonged to a catholic congregation; however, staff, administrators and teachers were secular. This school was subsidized by the Chilean government; therefore, parents did not have to pay tuition for the education of their children. Parents were responsible for the enrollment fee and the materials that their children needed for the year. Students were at school from 8:00 am to 5:00 pm every weekday except on Fridays when they were dismissed at 2:00 pm. All students had access to free lunch if requested. The school was well maintained. Buildings had no more than two floors. There were enough open spaces that the 800 students enrolled could run and play during the break. The researcher could see from one of the yards the house where the nuns lived. The community around the school was residential, although it was located close to a busy avenue, a subway station and a shopping center; the environment inside the school was quiet except during the break when students play in the area used for outdoor play and recreation.

Teacher 5. Teacher 5 was aware about the specific needs his students had in the community where they lived. Therefore, he emphasized areas of the national curriculum for life sciences that were related to his students' needs: "*In 7th and 8th grade, students in this school are thinking of vocational schools because this school is located in a high educational needs neighborhood. Therefore, students are looking for technical and short careers than can help them to find a job easily. Then, the kind of science that I teach them is basic. My goal is that the students can use at home what I am teaching them at school.*"

Teacher 5's school was a public under municipal governance school. Therefore, parents did not have to pay tuition for the education of their children. Students were at school from 8:00 am to 5:00 pm every weekday. The school was mainly concrete with some trees distributed surrounding two central yards. Buildings had two floors. The second floor of buildings had a wide and open corridor with view to the central yard. Before 2005, this school was training students to receive a degree at the end of high school allowing them to find a technical/clerical position at the end of 12th grade. At that time, the surrounding community had low expectations for students to go to college. However, since 2005 the school educational program gave students the tools they needed to continue their education in college. The goal was to give the surrounding community more options for professional development.

Teacher 7. Teacher 7 was passionate about motivating his students to learn mathematics using a garden as a teaching context. He earned an associate degree in agronomy and he worked in agricultural related areas outside the educational system during eight years before becoming a mathematics teacher. Teacher 7's previous knowledge and his passion for teaching motivated him to build a greenhouse at his school which was called the "botanic classroom (BC)." Teacher 7 defined BC as a "*pedagogic place where students give value to their own work and develop mathematics skills…it is a reinforcement of what I teach in the classroom*." Once a week, students had activities in the BC as part of their mathematics classes. The BC was considered by Teacher 7, and the researcher, an example of integration of agriculture into the mathematics curriculum.

Teacher 7's school was a public under municipal governance school. Therefore, parents did not have to pay tuition for the education of their children. Students were at school from 8:00 am to 5:00 pm every weekday. All students have access to free lunch if requested. The school was well maintained. Buildings had no more than two floors. Like the school where teacher 2 worked, it had large open spaces where students could play during break.

In brief, the three teachers who participated in this study were passionate about their subject and it was that passion for teaching that motivated their students to learn (Cortez, Fuentes, Villablanca, & Guzmán, 2013).

Transcripts

The interviews were conducted and recorded in Spanish using an audio recorder. Each of the interviews lasted an average of one hour. The researcher listened to the recordings 10 times, and read through the transcripts twice along with the recordings to verify accuracy of transcription. During the transcription process the researcher divided the transcripts into sections according to questions outlined during the interview. The transcripts were translated to English by the researcher. To verify the accuracy of the translation, five minutes from each of the three transcripts were reviewed by a professional as recommended by a senior faculty with extensive experience in qualitative research.

Steps to analyze the teachers' interview

The data was analyzed by the researchers in three steps using an inductive approach: (1) Initially, the interviews were analyzed looking at the teachers individually, defining codes (initial coding) and categories (focused coding) according to Saldaña's (2009) recommendations for coding. The researchers had an open-minded view without defining predetermined categories and followed an iterative process until no more categories emerged (Marton, 1986); (2) Categories were reorganized and reconfigured to develop subthemes for each teacher first and then as a group, focused on differences and similarities between and within categories (Åkerlind, 2012); (3) The subthemes were clustered in more complex and cohesive categories (González-Ugalde, 2014) known as themes (RQ1 and RQ2) to explain the phenomenon of the study which was teachers' beliefs regarding the use of agricultural concepts as a context to enhance student learning in life sciences/mathematics (RQ3).

Coding method of qualitative data

The coding process of the transcripts was done using two coding methods: First Cycle and Second Cycle recommended by Saldaña (2009). First Cycle coding methods are those processes that happen during the initial coding of data, and are simple and direct. From the First Cycle coding method, attribute (descriptive, setting, context) and then initial (open) coding were used to organize the data collection. Second Cycle coding method is an advanced way of reorganizing and analyzing data coded through First Cycle coding method.

In this particular study, during the Second Cycle coding method, data were organized using focused coding before beginning the data analysis process. In this coding process several codes were grouped as categories. At the end of the Second Cycle coding method, categories were reorganized and reconfigured to develop a smaller number of broad categories called subthemes. The subthemes were then clustered under themes to explain the phenomenon of the study.

Attribute coding. Attribute coding is basic descriptive information of interest for qualitative analysis (Saldaña, 2009). The researchers used attribute coding to present the descriptive information of the field work setting and the participants' characteristics (Table 1).

Initial coding. Initial coding is breaking down qualitative data into discrete parts, closely examining them, and comparing them for similarities and differences (Saldaña, 2009). During the initial coding approach, the researcher divided transcripts into sections according to questions of the semi-structured interview. Initial coding provided the researchers with an analytic lead before initiating the Second Cycle coding. Four examples of initial coding are presented below.

The transcript belongs to Teacher 2. The question that the researchers asked was: What are your general experiences regarding teaching life sciences/mathematics? (Appendix A).

Example 1: "*I have had sweet and bitter experiences. Some of them were motivational experiences and others were very disappointing. For example, last year we repaired two old microscopes and the students observed blood cells for first time. They told me that they could not believe it! Then, after this experience they understood what I had been teaching them during four months of classes. They thought that what I was teaching was meaningful. They went home happy. Some of them even stayed after class*." Code: Students give value to what I teach them.

Example 2: "*In another class, they applauded at the end of the class and at the beginning I did not understand the reason. Then I realized that all the efforts of using simple but didactic techniques as paper models or color schemes were helpful as a way to bring the content of the books near the class. To know that what I am teaching to them has significance in the student's life, it is very motivating to me.*" Code: What I am teaching has significance in the student's life.

Example 3: "*The bitter thing is that I am not able to explain what I know with the format of the current curriculum. Its context is too extensive…you as a teacher have to cover the content of the curriculum without having the resources (material) to do it, and only with the lecture from the teacher is not enough*." Code: Curriculum.

Example 4: "*Before a test, I do a revision session of the content of the test. During it, students answer all my questions very well. We discuss the content, they give me arguments. However, when I take the test the results are not good; the score is low."* Code: Low retention.

Focused coding. Focused coding is a recommended way to further analyze initial codes when the researcher has more than one participant to compare. The goal of this method was to develop categories that cluster similar codes (Saldaña, 2009). Considering the previous examples, the following categories were the result of the focused coding process: (1) Motivating Experiences (codes: "Students give value to what I teach them" and "What I am teaching has significance in the student's life"); (2) Frustrating Experiences (codes: "Curriculum" and "Low retention"). Then categories were grouped as subthemes. The subthemes were clustered under themes to explain the phenomenon of the study.

Results

Results of this phenomenographic research are presented per each research question first, and then integrated to describe the phenomenon of study. As it was mentioned in the previous section, at the end of coding categories were reorganized in subthemes following the recommendations of González-Ugalde (2014). The subthemes were clustered under two themes; one theme described research question 1 (RQ1) and the other theme described research question 2 (RQ2). Both themes together aimed to explain the phenomenon of the study that gave answer to research question 3 (RQ3). The phenomenon of this study was teachers' beliefs regarding the use of agricultural concepts as a context to enhance student learning in life sciences/mathematics.

Defining Themes

Research question 1: What are the beliefs that Chilean elementary teachers hold when they teach life sciences/mathematics in the classroom?

Table 2 presents a summary of codes and categories developed after the First and Second Cycle coding as well as the subsequent subthemes. In cases where the category or the code was related to questions from the interview (Appendix A), a letter "q" and a number appeared in parenthesis. For example, question two of the interview was indicated as (q2). The grade of students was indicated next to the code, in the cases that this information was available. As a consequence of the coding process, three subthemes emerged: (a) teachers' personal experiences; (b) teachers' teaching methodology; (c) teachers' context at school. All together these subthemes described the beliefs Chilean elementary teachers hold when they teach life sciences/mathematics in the classroom.

Research question 2 (RQ2): What do Chilean elementary teachers know about agricultural literacy?

Table 2 presents a summary of codes and categories developed after the First and Second Cycle coding as well as the subsequent subthemes. As a consequence of the coding process, two subthemes emerged: (a) teachers' definition of agriculture; (b) teachers' knowledge and views about agricultural concepts in the curriculum. Both together described Chilean elementary teachers' knowledge about agricultural literacy. As overall, teachers related the world agriculture to food production and natural resources. They had limited knowledge of agricultural literacy in the curriculum.

Table 2
Codes, categories and subthemes formulated from teachers' interview

Subtheme	Teachers' teaching methodology			Teachers' personal experiences		
	Categories					
Teachers/ Codes	Using examples of daily life (q2)	Using hand-on experiences	Making life sciences/math relevant to students (q4)	Challenge experiences (q1)	Frustrating experiences (q1)	Motivating experiences (q1)
2	Home example of science for abstract concepts: science in the kitchen; pound is quantity of something-one pound of bread; concept of mass (5th)	Team lab. work (DNA extraction), photosynthesis (starch test; 6th); make 3D model (tectonic plate; hydraulic machine; body system; 5th); microscope (blood cells; 8th)	Visiting places (museum, market, park, zoo, farm, botanic garden); limitations (substitute, missed class; delay in contents); science workshops; school projects (food pyramid, balanced diet; 5th)	Students' difficulties to imagine abstract concepts (atoms; 5th); students with special needs; Nat. curriculum: extensive; limited time & materials to teach contents	Students' low content retention; Nat. curriculum: rigid and not integrated to other disciplines; many abstract concepts	Students give value to what I have been teaching (cells); what I teach is meaningful for them; students' projects win in a local inter-school scientific fair
5	Family context and students' experiences (contraception, pregnancy,8 th); environment; abstract concept (mass); use of analogies: car v/s body (5th)	Models: electric circuit; (5th); use of microscope (cells; 7th); seed germination (5th /6th); experiment oxygen: insects with plants v/s insects without plants (5th-6th)	Visiting places (museum); community projects (planting trees, taking care of the environment; 6th); selling herbs produced by students in the market; building a garden at school	Students' difficulties to imagine and learn abstract concepts (atoms; 7th-8th); Students want to be dismissed before the class is over (7th-8th)	Nat. curriculum: extensive; limited resources (time) to cover the contents; many abstract concepts	Students use at home and in their daily lives what I teach them at school (e.g. minor electric repairs); Students' enthusiasm for learning science (5th-6th)
7	Students take the produces from Botanic classroom (BC) and eat them at home; students and parents work together building a garden at home (7th-8th)	BC: Students' excitement for working at this pedagogic place; students value their work and develop math skills (percentage; fractions, linear meter; geometry; descriptive stat)	BC is connected with planning lessons for the year; students have activities once per week or after class; they also learn about plants growth, fruits production, harvest, and organic products; and water management	Students' lower grades and difficulties to learn abstract concepts; difficulties to make connection between institution (universities-schools)	Administrators' & teachers' view of integrated education occurs in the classroom (more worksheet) and not in nature; and it is resource consuming (time, energy, money, materials)	Positive impact on students, parents and the community; students recycle at home; BC should be transversally integrated into the curriculum

Table 2 Continuation

Initial coding and focused coding: codes and categories formulated from teachers' interview

Subthemes	Teachers' context at school			Teacher's definition of agriculture	Teachers' knowledge and views about agricultural concepts in the curriculum	
			Categories			
Teachers/ Codes	Working with colleagues in projects	Working more hours than I should	School community	Defining agriculture (q6)	Views of agricultural concepts for lessons (q5)	Agricultural concepts in the national curriculum (q7)
2	Benefits: better strategies for teaching and learning; inter-school fair Limitations: time, only one specialized science teacher, resources, volunteer activity	I like my school; I work for students' success, school recognition; students are interested in learning; scientific knowledge is shared in workshops	Supportive school principal and administrator; organizing inter-school fair & intra-school activities	Food; natural resources (plants; animals); water resource is not included	Vegetable garden (food; photosynthesis); ecology garden (environment)	Agricultural concepts are not explicit in the curriculum; some units may be related to agriculture: healthy food and healthy school; productive process; nutrition (5^{th}); photosynthesis and transference of energy (6^{th}); nitrogen cycle (7^{th}); photosynthesis (8^{th})
5	Focused on social issues of surrounding community; science for learning life responsibilities and health care (7^{th}-8^{th})	Extracurricular activities such as a science club or a school garden (5^{th}-6^{th})	Changes in students' interest for science,5^{th}-8^{th}: high-they are active & like to study (5^{th}-6^{th}); later, low interest-they want to find a job (7^{th}-8^{th})	To plant & grow sustainable products from the land; food; flowers & pollination; protection of environment (forest fire, better citizen)	Hydroponic; garden at home; residential development; products should not be far from the city	Absent but needed. There is a need for a botanic topic in the national curriculum; Benefits of a garden: can be done at home; nutrition; food and health products; students' give value to their work; small groups; extracurricular
7	Training other colleagues from other schools and pre-schools; developing projects to be presented to the mayor; writing a book about how to use BC for learning by integrating the garden & math	Willing to do more to improve students' level of education; I like what I do; I feel satisfied when I see my students eating fruits produced by themselves; students' smile when they harvest; impact on parents and the community	Parents are involved; the principal is engaged; but colleagues feel comfortable with recitation	Plants growth, fruit production, harvest, organic products; soil & environmental sustainability; recycling	BC should be integrated in all classes; every open space in the school should be used for learning; connecting math & science to environmental issues	Agricultural concepts are needed in the curriculum; People do not want to engage with agricultural activities in the classroom because they simply do not understand what "learning using agriculture" is about; Elementary school is the core of the educational system to form better citizens

Description of the phenomenon of study

Research question 3: Do teachers believe that they can use agricultural concepts as a venue to enhance student learning in natural science and mathematics? If so, in what ways?

The phenomenon of study was defined as teachers' beliefs regarding the use of agricultural concepts as a context to enhance student learning in life sciences/mathematics. In other words, the phenomenon of study answered the question: Do teachers believe that they can use agricultural concepts as a venue to enhance student learning in natural science/mathematics? If so, in what ways do teachers believe they can use agricultural concepts as a venue to enhance student learning in natural science/mathematics? According to the analysis of the data, the phenomenon of study was influenced by two themes (1) beliefs teachers' hold when they teach life sciences/mathematics; (2) teachers' knowledge about agricultural literacy. A conceptual map was developed to visualize the findings of this study (Figure 2).

Teachers believed agricultural concepts could help students learn about life science and mathematics. Some of the venues where agricultural concepts could be integrated into their classes involved a school garden for helping students learn about food and photosynthesis. Likewise, an ecology garden could support students' learning about the environment as well as raise awareness about environmental issues.

Students could learn about health and nutrition by creating an hydroponic system in their classroom which could allow them to make observations of the plant growth when omitting essential minerals. Using analogies related to human health, students could learn about the negative effect on their health when the body does not receive their essential nutrients, promoting healthy food habits.

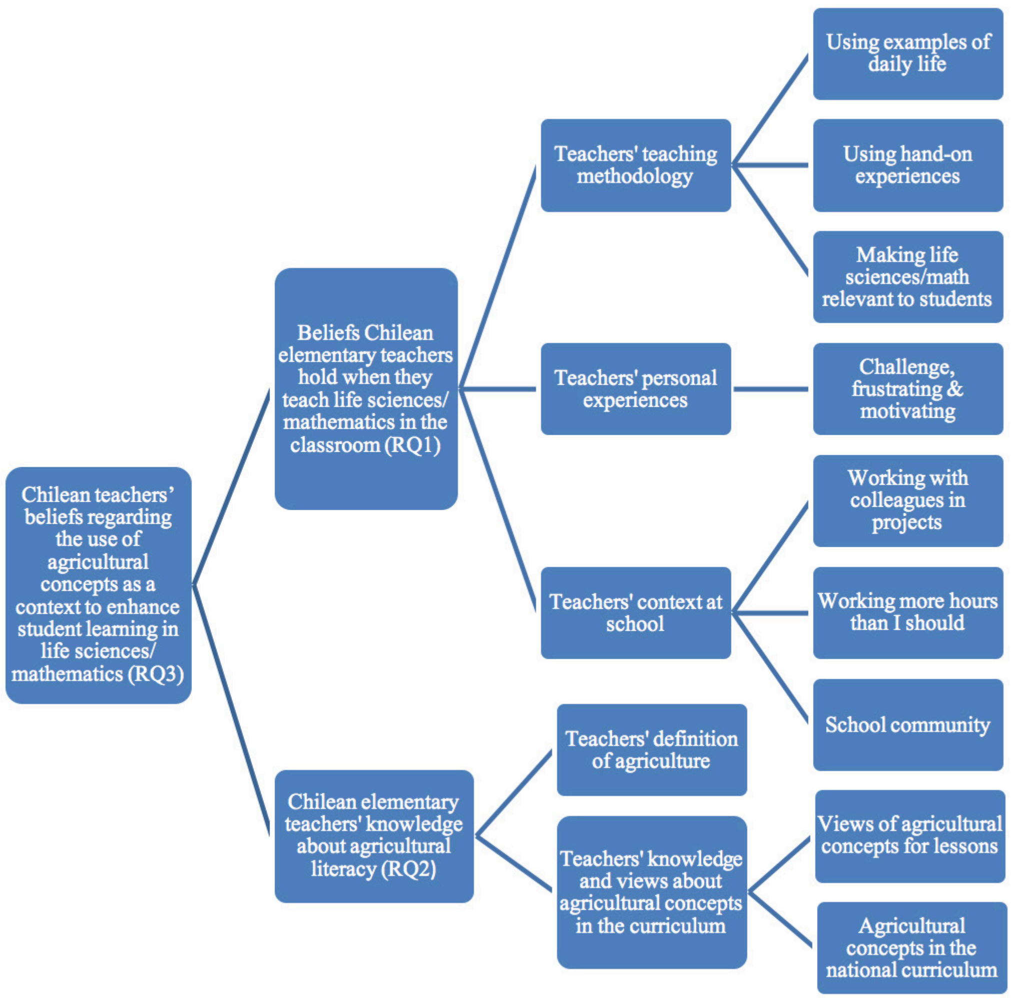

Figure 2. Concept map of the phenomenon of study.

Mathematics skills could be achieved by calculating the concentration of minerals in the solution, by building the physical structure of a garden or by collecting data about plant growth under different conditions and over the time. Descriptive statistics and graphs could enhance students' abilities to organize and communicate information in science and mathematics.

School gardens as an instructional agricultural tool to foster inquiry-learning will be discussed in the following section. However, even school gardens are tools that facilitate experiential learning and teach about nutrition, plant science, food processes, mathematics skills and environmental responsibility (Bundschu-Mooney, 2003), teachers are discouraged to use them because of the limitations and barriers to the implementation of them (Williams & Dixon, 2013).

Based on the results of this background research and the limitations in the implementation of the gardens at school, in the following section researchers proposed the use of a different instructional approach to answer the fundamental question: How the integration of agricultural literacy into the life sciences and mathematics curriculum could enhance learning through inquiry? The next step in this study will be the formulation of an hypothesis to help researchers to answer that question. The instructional approach proposed combines a video and a board game. The scenario of the video and the board game is an agricultural related concept known as photosynthesis.

Conclusions and discussions

There were three conclusions for this study: (1) Teachers' teaching methodology, school context and personal experiences are the factors that described the beliefs that Chilean elementary teachers had about teaching life sciences and mathematics in the classroom; (2) Chilean teachers related the word agriculture with food, natural resources and gardening; (3) Teachers believed that agricultural concepts could be integrated into some areas of the curriculum such as nutrition, healthy food as well as the development of mathematics skills (percentage, fractions, linear meter, geometry and descriptive statistics). The beliefs that Chilean elementary teachers hold regarding the use of agricultural concepts as a context to enhance student learning in life sciences/mathematics described the phenomenon of study.

Teachers' beliefs affect their behaviors in the classroom. Pajares (1992) recommended that teachers' beliefs should be considered before starting studies based on how their beliefs influence teachers' inquiry-oriented instruction. Considering the explanations of the phenomenon of this study and taking into account that Chilean elementary teachers struggle with the inquiry approach that the Chilean national curriculum posits (Miranda, 2003; Vergara & Miño, 2009), in this section the researchers discuss ways teachers can use agricultural concepts as venues to enhance student learning in life science and mathematics through inquiry.

Using agricultural concepts to facilitate learning of science and mathematics through inquiry-oriented activities

Definition of the inquiry-based approach. Inquiry is a learning process that involves hand-on and mind-on experiences, "something that students do, not something that is done to them" (National Research Council, 2011, p. 2). Scientific inquiry process includes several steps: (1) engaging with a scientific question; (2) participating in design of procedures; (3) giving priority to evidence; (4) formulating explanations; (5) connecting explanations to scientific knowledge; (6) communicating and justifying explanations (Quigley, Marshall, Deaton, Cook, & Padilla, 2011). In other words, in the science class, students should learn about scientific skills such as observation, inferring and experimentation and also engage in inquiring (Atar & Gallard, 2011). Students should engage in cognitive processes which refer to "describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, communicate their ideas to others" (National Research Council, 2011, p. 2) as well as "use mathematics in all aspects of scientific inquiry to improve communications and investigations" (Olson & Loucks-Horsley, 2000, p.19). Discussions about the nature of science (Capps & Crawford, 2013) and the nature of mathematics (Smith, 2016) were beyond the scope of this article.

Hands-on methods and modeling activities such as drawings, tables, and diagrams enhance students' knowledge regarding science (Powell & Wells, 2002) and mathematics (Kelly & Lesh, 2012). The inquiry-oriented approach enhances students' ability to transfer their knowledge to real life situation (National Research Council, 2011). The challenge for teachers is that inquiry learning classrooms demand more preparation than a teacher-centered classroom (e.g., recitation) in science (Anderson, 2002) and mathematics (Horton, Sloop & Marshall, 2014). Under an inquiry-oriented approach, students need time to explore a problem while the teacher acts as a facilitator supporting students in the process of finding the explanations (Marshall, Horton, & Smart, 2009).

Science and mathematics teachers are reluctant to change their teaching methodologies and promote the development of inquiry-oriented approach over traditional teaching (e.g., recitation) because of their limited pedagogical content knowledge (Appleton, 2008; Towers, 2010) and limited time and resources (Milner et al., 2012; Stipek et al., 2001). Particularly, Chilean science teachers face challenges with the inquiry approach because of the students' limited interest in science, the large class size which affects class management, and limited equipment for working in the laboratory (Vergara & Miño, 2009). In the same context, the teaching approach of the Chilean elementary mathematics teachers focuses on the procedures for problem solving more than an inquiry- oriented approach (Preiss, Larraín, & Valenzuela, 2011).

Generally, Chilean elementary teachers are discouraged by the amount of content to be covered for high-stakes tests and curriculum standards (Miranda, 2003; Vergara, 2006). Considering this information, the following section gives examples of agricultural concepts that science and mathematics teachers could integrate into the curriculum to enhance learning of science and mathematics through inquiry.

Integrating agricultural concepts into the science and mathematics curricula. Chilean elementary teachers believed that curricular areas such as nutrition, healthy food and the development of mathematics skills (percentage, fractions, linear meter, geometry and descriptive statistics) could be connected to agricultural concepts to facilitate learning. The most commonly used example of agricultural integration in the curriculum is the school garden (FAO, 2006). School gardens are tools that facilitate experiential learning and teach about nutrition, plant science, food processes, mathematics skills and environmental responsibility (Bundschu-Mooney, 2003). School gardens assist elementary students in their ability to observe, communicate, compare, relate, order and infer when they were included in the teachers' curriculum (Mabie & Baker, 1996; Williams & Dixon, 2013). Gardening promotes learning outcomes related to students' health and nutrition, and also it improves students' environmental attitude when gardening is part of the curriculum (Phibbs & Relf, 2005).

Gardens are an aspect of agricultural and environmental education that are supported by many university programs across the United States (North American Association of Environmental Education, 2016). Some examples are: Aggie Horticulture-Just for Kids (Texas A&M University Horticulture Program, 2004); Eat Your Way to Better Health (Purdue University, 2012); Got Veggies? (Wisconsin Department of Health Services, 2016); My First Garden (University of Illinois Board of Trustees, 2016); Urban Programs Resource Networks (University of Illinois, 2016); Elementary School Gardens (University of California Cooperative Extension, 2016); and Junior Master Gardener® (National Junior Master Gardener Program, 2016).

In Chile, a project known as "Biohuerto UC" is currently training teachers from different disciplines such as linguistics and special education to help use the garden as a venue to support the learning experiences for their students. "Biohuerto UC" was developed by undergraduate students from the College of Agriculture of the P. Catholic University of Chile (UC) in 2006. The goal of the Biohuerto UC project is to improve the quality of life for people who live in the city through environmental education. The learning center for this project is a garden that is used by students to cultivate fruits and vegetables, to reproduce different ecosystems, and it is also a place used for recreational and educational activities (Biohuerto UC, 2016).

In addition, the Chilean government created a school environmental certification program to promote sustainable development and environmental awareness for students, parents, and the community that surrounds each school (Burgos, Perales & Gutiérrez, 2010; Chilean Council for Sustainable Development, 2016). It is this program that gave the support that Teacher 7 needed to fulfill his dream of having a botanic classroom (BC) in his school where he could use agricultural concepts to integrally teach mathematics skills to his students. In cities like Santiago, the capital of Chile, where schools have limited space or lack of access to land, containers can be utilized to create multiple small garden spaces and raised garden areas (FAO, 2006; Chile Lives Healthy, 2016).

However, there are limitations and barriers to the implementation of school gardens. First of all, the school administrator, principal and colleagues need to be on board (Williams & Dixon, 2013). In this study, Teachers 2 and 7 described the support of the school principal as vital to develop their science class and mathematics class (botanic classroom) outside the classroom at their schools.

Other barriers described by Teacher 7 were limited time and resources to take care of the school garden during summer time and weekends. Their colleagues' lack of experience and unfamiliarity with agricultural activities in general were also barriers for engaging them to use the botanic classroom to teach other disciplines (Trexler & Hikawa, 2001). The three teachers who participated in this study indicated that the curriculum constraint and the limited curriculum links of content to outdoor activities were a limitation for learning outside the classroom (Dyment, 2005).

It is in this context that researchers in this study proposed ideas about agricultural-related activities that can be done within the classroom to facilitate learning of science and mathematics through inquiry. For example, students exposed to concepts in biology through learning about poultry and daily animals were able to transfer knowledge about health to other disciplines, such as the health of their own body (Balschweid, 2002). Likewise, adaptations to different environmental conditions could be studied by using plant mutants within the classroom, but it involves expenditure of resources (Brooks, Dolan, & Tax, 2011). However, there are activities that could be done in the classroom with simple equipment such as a ruler. For example, students could growth small plants in three different pot sizes to compare how the soil volume influences plant growth, how fertilizers affect plant growth, and how plants adapt to the light length (short light length could be reached by locating plants inside the cabinet for the most part of the day). These activities relate plant growth to the abstract concepts of transformation of matter and energy (Dauer, Doherty, Freed, & Anderson, 2014) that the Chilean curriculum for science posits (Ministry of Education of Chile, 2016).

In all these experiences, the key aspects for learning through inquiry are the mechanistic procedures (e.g. making measurements and recording of data, making graphs, writing conclusions) and the reasoning (National Research Council, 2011). Engaging students in the correct set of questions help them to reach scientific reasoning (engaging with a scientific question, design of procedures and planning of experiments, gathering relevant information, formulating explanations, connecting explanations to scientific knowledge, group discussions, representation of data in a meaningful way such as graphs or diagrams, communicating and justifying explanations) (Quigley et al., 2011) as well as the mathematics reasoning (Olson & Loucks-Horsley, 2000) involved in those activities.

Examples of questions that engage students in reasoning are: Why it is important to study plant growth? Why are you choosing a specific treatment instead of others? How do you think the pot size would affect growth? How would you plan a different experiment? What does the literature inform about factors affecting plant/animal growth? What bias are you and your teammates including in this experience? What would be a meaningful way to present your data and communicate your results? What inferences could be done regarding the plant processes involved with nutrients and light from the sun? How does the experiment relate to the plant/animal metabolism? How does plant/animal metabolism relate to human health? (Grady, Dolan & Glasson, 2010; Dauer et al., 2014).

In brief, it can be concluded that agricultural concepts could be used as a context for learning through inquiry at least in those areas that the three Chilean elementary teachers interviewed in this study reported they believed. These curricular areas are nutrition, healthy food and the development of mathematics skills. Researchers also discussed about supporting students' scientific reasoning by allowing them explore an idea through investigation, and after that, apply the appropriate scientific principles that support their understanding using an agricultural context.

An important agricultural concept that could be used as a context for science and mathematics learning is photosynthesis. Based on the conclusions of this study, in the following section researchers proposed the use of an instructional approach to enhance learning of energy transformation in the context of photosynthesis through inquiry.

Future work

The following step will be the formulation of a hypothesis to help researchers to answer the fundamental question: How the integration of agricultural literacy into the life sciences and mathematics curriculum could enhance learning through inquiry? An instructional approach proposed by the researchers combines a video and a serious game. The scenario of the video and the game is an agricultural related concept known as photosynthesis. The learning outcomes for eight grade students for science and mathematics in regards to the energy transformation process are: (1) energy is transformed from one form to another one (Ministry of Education of Chile, 2016, p. 29); (2) students understand a visual representation (Ministry of Education of Chile, 2016, p. 40). The hypothesis to be investigated is: Students' knowledge of the energy transformation process in photosynthesis is enhanced by using an educational video and a serious game. Researchers will evaluate the enhanced students' knowledge by measuring students' score improvement after treatment. Researchers will be presenting the results and conclusions of this study in a future publication.

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Appendix A. Semi-structured Interview

1. What are your general experiences about teaching life sciences/mathematics?
2. Do you use examples of the daily life to teach life sciences/mathematics?
3. How do you connect the previous knowledge of the students with the community or with the content that you are teaching to them in class?
4. How do you make life sciences/mathematics relevant to your students? How do you help students to see real life examples in your subject?

Give community examples related to environment. For example:

- Going to the park during weekend.
- Water quality of the Mapocho River in Santiago.
- Hill in the middle of Santiago: going to the San Cristóbal hill for hiking and visiting the botanical garden.
- Going to the Zoo in the San Cristóbal hill.
- Community service: forestation of the Andes Mountain in Santiago (pre-cordillera).

5. Have you ever used agricultural examples in activities to try to explain one specific objective of the curriculum? If yes, what? If not, why not?

Give community examples related to environment. For example:
- Taking care of a plant at home.
- Taking care of a pet.
- Growing a plant at home.
- Raise a garden.
- Control pest of tree at home.
- Control of insects at home.

6. What is your definition of agriculture?
7. Do you think that there is a possibility/opportunity to incorporate agricultural concepts in the life science/mathematics curriculum? Why?