Pensamiento Educativo. Revista de Investigación Educacional Latinoamericana
2022, *59*(1), 1-17

Pontificia Universidad Católica de Chile
Facultad de Educación

Articulation Between Environmental Education and Scientific Education: A Perspective From the Sustainability Competencies Developed in Initial Teacher Training

Articulación entre educación ambiental y educación científica: una mirada desde las competencias en sostenibilidad desarrolladas en la formación inicial docente

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Abstract

This paper addresses the association between socio-scientific controversies and key competencies in sustainability from science education (SE) and environmental education (EE), specifically in initial teacher training (ITT). It is suggested that new research opportunities are also obtained from the articulation between SE and EE, with those on the factors that affect the development of the key competencies outlined by Wiek et al. (2011) being particularly relevant. In order to verify this proposal, quantitative methodologies were used, which investigate the concepts of socio-scientific controversies and the relative degree of deployment of key competencies for sustainability. In order to achieve this, the BIOHEAD-citizen questionnaire and a case study test evaluated with rubrics were applied to trainee teachers to collect evidence of conceptions of controversies in various topics and the relative degree of development of three competencies, namely, systems-thinking, strategic, and normative competencies. The association of both sets of data was done with linear models, based on the score for each competency as a dependent variable. The best model obtained shows a statistically significant explanation of systems-thinking on the part of two systems of conceptions: socio-environmentally negative and socio-political religious; whereas for the other two competencies (strategic and normative) no independent variable resulted in a relevant model. These results suggest that conceptions are important for the development of key competencies, supporting the importance of a symbiotic relationship between SE and EE, the 'implications of which are discussed for ITT.

Keywords: environmental education, scientific education, sustainability competencies, socio-scientific controversies

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ISSN:0719-0409 DDI:203.262, Santiago, Chile doi: 10.7764/PEL.59.1.2022.8

Resumen

Este artículo aborda la asociación entre las controversias socio-científicas, así como las competencias clave para la sostenibilidad desde la educación en ciencias (EC) y la educación ambiental (EA), específicamente en la formación inicial docente (FID). Se propone que desde la articulación entre la EC y la EA también se obtienen nuevas oportunidades de investigación, siendo relevantes aquellas sobre los factores que afectan al desarrollo de las competencias claves de Wiek y sus colegas (2011). Para verificar lo propuesto se utilizaron metodologías cuantitativas que indagan en las concepciones de las controversias socio-científicas y en el grado relativo de despliegue de las competencias clave para la sostenibilidad. Para ello, se aplicó el cuestionario BIOHEAD-citizen y un test de caso de estudios evaluado con rúbricas a profesores y profesoras en formación respectivamente, con el fin de recopilar evidencia de las concepciones de controversias de temas variados y el grado relativo de desarrollo de las competencias en pensamiento sistémico, de estrategia y normativa. La asociación de ambos datos se realizó con modelos lineales, a partir del puntaje por competencia como variable dependiente. El mejor modelo obtenido presenta una explicación estadísticamente significativa del pensamiento sistémico por parte de dos sistemas de concepciones: socio-ambientalmente negativo y sociopolítico religioso; en cambio, para las otras dos competencias (estrategia y normativa) ninguna variable independiente resultaba en un modelo relevante. Estos resultados sugieren que las concepciones sí son importantes para el desarrollo de competencias clave, respaldando la importancia de una articulación entre la EC y la EA, cuyos alcances para la formación inicial docente son discutidos en el artículo.

Palabras clave: educación ambiental, educación científica, competencias en sostenibilidad, controversias socio-científicas

Introduction

In 2019, more than 11,000 scientists around the world signed a declaration stating that our planet is facing a climate emergency (Ripple et al., 2019), with negligible possibilities that this is being caused by non-anthropogenic factors, that is, those produced by natural systems (Santer et al., 2019). However, the denial of anthropogenic climate change in light of this situation has become increasingly common in the public debate, which is a consequence of a greater sense of insecurity and less trust in governments, industries, and experts (Smith, 2010). This is partly due to the fact that the risks faced by society are increasingly attributable to mankind and less to nature (Beck, 1992). Given this situation, it is essential to seek ways to reorganize science education (SE) and environmental education (EE), so that citizens living in a society at risk can cope with these socio-environmental problems, such as anthropogenic climate change and denialism, in order to successfully lead the way to more sustainable scenarios (Smith, 2010).

Having said that, the challenge lies in defining what these changes should be, considering that sustainability challenges are complex problems (Murphy, 2012), because the initial state, the possible operations, and the target state cannot be clearly specified (Colman, 2015). Accordingly, the common EE approach, which seeks to provide environmental information and promote certain predetermined behaviors that are more environmentally friendly, is insufficient according to research that questions its real impact (Eilam & Trop, 2012; Braun & Dierkes, 2019). From the perspective of the main current pedagogical paradigms, that goes against education and its fundamental principles (Jickling & Wals, 2008), as it is more closely related to indoctrination than

the liberation of individuals and societies. In response to this, Wals et al. (2014) recommend focusing on how to create optimal conditions and support mechanisms that enable citizens to develop in the face of possible challenges, which bears more relation to the principles associated with the four pillars of education; three of which (learning to be, learning to know, and learning to do) are of a personal nature, while the fourth (learning to live together) refers to the social sphere. Together they provide the basis for what could be called human development and lifelong learning, which are considered to be essential for education in the 21st century in the Delors report (1997) and are discussed in the publication *Rethinking Education: Towards a global common good?*, which was produced by Unesco in 2015.

We contend that studying the conceptions of socio-scientific controversies in initial teacher training programs would enable us to explore the development of Key Competencies in Sustainability Research and Problem Solving (KCSRPS) (Wiek et al., 2011). Given the existence of systems of conceptions that hinder learning and considering that there are factors that influence the development of competencies, this paper examines the systems of conceptions of a group of future teachers as factors that are associated with a higher or lower level of development of KCSRPS. Therefore, we expect to propose certain pedagogical recommendations for ITT in SE-EE.

Theoretical Background

The most emancipatory approach of EE, which Monroe (2012) argues is theoretically comparable to education for sustainability, requires review of the existing educational guidelines stated in national educational policy in order to make changes to ITT. In the Chilean school system, EE is a transversal learning objective, but its implementation is limited to the reality of each educational establishment. In many cases, it is the responsibility of those who teach natural or social sciences. On the one hand, this is pragmatic because these teachers are the ones who lead the process of environmental discovery, since their subjects do include environmental education to a certain extent (Castro & Cifuentes, 2014), where not only knowledge can be promoted, but also skills, attitudes, and values. On the other hand, it emphasizes the notion that EE is simply another discipline and subject, concealing its interdisciplinary and holistic nature (Castillo-Retamal & Cordero-Tapia, 2019), for which teachers, at least in natural sciences, are not necessarily well prepared (Torres-Rivera et al., 2017).

One way of moving forward in terms of this need to improve the processes of science teaching and EE is to make significant changes to the direction of ITT, creating opportunities for teaching staff to have the ability to connect EE and SE, as suggested by Wals et al. (2014). This can only be done if, in addition to considering EE as emancipatory, SE is also considered to teach students about "the nature of science as a human activity and the power and limitations of scientific knowledge" (Organisation for Economic Co-operation and Development, 2009). This would make the social dimension of EE more visible and also make it easier for teachers of natural sciences, on the one hand, to lead the teaching-learning processes and, on the other, to develop the conditions at their educational establishment to comply with the transversal nature of EE, as expressed in the dimensions of the transversal learning objectives (TLOs) and in the learning objectives (LOs) of the various subjects. However, at present this remains a challenge in terms of teaching and learning methodologies in classrooms.

In the case of science education, the critical perspective of philosophy (Bruguière et al., 2014) can be emphasized, which suggests that science education should not be carried out in terms of a minimum level of scientific literacy, but instead referring to the need for a transformation in the relationship between the scientific community and the general public. In this respect, students should be prepared to address technical-scientific situations that involve great social controversy, in which there will even be disputes with pseudoscientific discourse, but it is the case that traditional science education has failed in terms of this preparation. Hodson (2011) contends that this occurs because the approach known as science, technology, and society fails to promote sufficient critical thinking.

Meanwhile, teaching that uses socio-scientific controversies, which involves various scientific fields and problematizes dilemmas that have social and scientific dimensions (Sadler, 2009), facilitates the integration of teaching on the nature of science with argumentation and moral judgments (Zeidler et al., 2005). According to Legardez and Simonneaux (2006), creating open and problematizing questions that shine light on the uncertainties inherent to complex problems, as proposed by the approach of socio-scientific controversies, would be the most appropriate way of enabling articulation with EE.

In line with this, Hodson (2011) argues that it is practically apparent that the best way to learn to face complex problems is through teaching-learning processes based on socio-scientific controversies, as long as there are appropriate levels of support and guidance. However, it is inappropriate to expect science teachers to generate this type of proposals without proper preparation in their training, because although socio-scientific controversies are sometimes adapted to be taught in schools, they are somewhat neutralized by focusing more on traditional teaching of the scientific content underlying the controversy itself (Simonneaux & Legardez, 2010). Nevertheless, socio-scientific controversies have an important role in the education of a society at risk, because they are an effort to democratize the evaluation processes carried out by experts on socio-scientific innovations whose legitimacy is questioned in the public sphere (Legardez & Simonneaux 2006). These situations of controversy and their results have, in part, generated greater concern about the risks associated with technical-scientific solutions, due to the problems caused in the past (Beck, 1992). This has a negative influence on the transition to sustainability, as it "may undermine honest acknowledgement of the fact that solutions are provisional and require continual adjustment. In other words, some of the innovations needed to deal with wicked problems require a more flexible mindset concerning risk and innovation" (Head, 2019, p. 192).

We therefore propose that the articulation between EE and SE should be through socio-scientific controversies associated with complex problems and should focus on teachers' professional competencies, defined as a functional framework of knowledge, skills, and attitudes that improve performance with regard to real-life sustainability issues, challenges, and opportunities (Rowe, 2007). In this respect, KCSRPS are important, as they promote competencies that are not addressed in traditional school and university education, but which are critical in order to address complex sustainability issues (Wiek et al., 2011). These competencies are: (i) systems-thinking, (ii) normative-ethical, (iii) anticipatory, (iv) strategic, and (v) interpersonal.

This framework was developed and designed for higher education in general and recommending it for ITT implies two conflicts. First, that training is mainly conducive to educational practice, so it requires more specific and different orientations to other university disciplines, for which adaptations have been suggested where the teaching staff should be trained in competencies and to prepare the learner (Archambault et al., 2013). Second, that this is a framework for higher education and not for lower levels, which we consider to be a limited perspective. Competencies develop continuously, as the idea of lifelong learning suggests, so they should also be addressed in school education to give future teachers a degree of familiarity with their development. It is also imperative that they are developed at the early stages, since waiting for this to take place only in higher education is naïve, and even more so if it is not clear how they are transmitted, since "key competencies can 'be learnt, but hardly be taught'" (Wiek & Lang, 2016, in Hilser, 2016). Therefore, research on both the teaching of KCSRPS and the conditions that facilitate their learning is of paramount importance. In the case of the former, research is scarce, but has gradually increased over time (Hilser, 2016), which has not been the case with the latter (Remington-Doucette et al., 2012).

In light of this, we suggest that teachers' conceptions of socio-scientific controversies impact KCSRPS learning and, therefore, are also relevant factors that should be considered in ITT. To our knowledge, there have been no studies on factors influencing the learning of competencies in sustainability, which is concerning. Being familiar with these conceptions enables us to assess the level of controversy, since it is important to have degrees

of tension in order to ensure that the topic is pedagogically significant (Zeidler et al., 2019). In this regard, these conceptions can be assumed to be a reflection of the status of certain aspects of KCSRPS; for example, a higher level of systems-thinking would be associated with disagreeing with reductionist conceptions such as the genetic determinism of musical geniuses. If there are cognitive conflicts that do not always improve teaching (Zohar & Aharon-Kravetsky, 2005), there may also be systems of conceptions that hamper certain learning (Astolfi & Péterfalvi, 1993, in Clément, 2010). Using the same example, a strong influence of reductionism leads to a discouraging attitude to think systemically about the controversy, because reinforcing the reductionist belief implies looking at the system from an outdated scientific perspective.

Clément (2010) contends that these conceptions can be studied as an interaction between three poles: current scientific knowledge (K), value systems (V), and social practices (P). The KVP model proposes that, in order to examine the conception of a specific topic in science didactics, elements of the psychosocial theory of social representations are used (Moscovici, 2003). The BIOHEAD-Citizen project made intensive use of this proposal with the aim of understanding how biology, health, and environmental education can promote a better citizenship, considering cognitive dimensions and socio-affective and sociodemographic variables, with the expectation of clarifying the challenges that education has to address in order to strengthen a knowledge-based society (Carvalho & Clément, 2007). With that objective in mind, the project followed two lines of research, one on the analysis of school texts and the other to identify the conceptions of teachers, both in training and in service.

The project researchers constructed, translated, and validated a questionnaire based on the KVP model, where the themes were chosen by the authors, considering that they would be potential socio-scientific controversies, such as:

- Politics and society: political views, sexism, secularism, religion.
- Genetic determinism: human behavior, intergroup differences (ethnicity) genetically-modified organisms (GMO).
- Evolution: knowledge and creationism.
- Sex education: according to minimum age of the learner by topic, roles of school and health professionals, acceptance of abortion.
- Health education: biomedical model (focused on diseases) and integral (focused on wellbeing).
- Ecology and EE: anthropomorphism, pollution and habitat destruction, attitudes towards nature and the environment, conservation.

It should be noted that although certain themes may seem obvious to some sectors of society, they are not obvious to others, so they are the ones for which science education is most crucial, without neglecting the perspective that all citizens should be educated to address these issues, because, in reality, as they are such complex questions, the debate can and should always be reopened (Zeidler et al. 2019).

The results of the project focused on teachers involved the application of the questionnaire in at least 24 countries, with more than 8,000 teachers (in training and in practice in various disciplines and at different school levels) responding to it, although it has not been applied in Chile. Since the project has been underway for a considerable number of years, there is extensive literature on its results, so we will present a brief review of the findings that are relevant to this research.

With regard to conceptions of human origin (creationism and evolution), Clément et al. (2012) found a positive correlation between creationist conceptions and genetic determinism, which, in turn, demonstrated a correlation between creationist conceptions and more authoritarian and non-secular political views. This relationship was

also linked to greater religious practice and belief in deities, which is unsurprising. In another paper, Clément et al. (2010) showed that the effect size of the teacher's discipline (natural sciences vs. language) on evolutionary conceptions is very low, except in certain countries.

With respect to sex and health education, Jourdan et al. (2012) assessed conceptions regarding two health models: the biomedical, focused on the absence of diseases (with a more negative view of health), in contrast to the integral model, focused on a multidimensional meaning of wellbeing. No findings are reported regarding interactions with other conceptions, but there were findings with respect to the specialty of science teachers. Those who taught at the basic level had more integral conceptions of health education, as opposed to secondary education teachers, who had conceptions that were closer to the biomedical model. Accordingly, the conceptions of health education were somewhat influenced by the teachers' view of their educational role in general, since it is a widespread opinion that biology teachers are focused on teaching scientific knowledge, leaving aside the other the dimensions of health.

Lastly, on nature and EE, Munoz et al. (2009) confirmed the two-dimensional structure of the model of the two main environmental values (Bogner & Wiseman, 1999), one being values for the preservation of both nature and the environment and the other being utilitarian values, that is to say, preferences for the exploitation of natural resources. So, when examining interactions with political views, the analysis suggested that those who position themselves more on the utilitarian axis report having conceptions that are close to economic liberalism. At the same time, Clément and Caravita (2011) found that the utilitarian dimension was associated with genetic determinism of gender and interethnic differences, suggesting that utilitarianism is part of an anthropocentric conception. Thus, applying the KVP model, we observe that the K pole is oriented towards scientifically obsolete knowledge and the V axis is slanted towards values that are removed from respect for diversity. With regard to the preservationist axis, Munoz et al. (2009) reported that this was strongly related to progressive political conceptions, associated with active participation in environmental activities at either individual or neighborhood level.

In the literature review presented above, we found that teacher training is a discriminating factor between different conceptions, since it was positively associated with evolutionary and integral conceptions of health. Accordingly, pure or disciplinary knowledge (e.g., of biology) does not necessarily mean that scientifically obsolete conceptions are updated or that it will improve conceptions associated with discrimination, but there may be other factors related to teacher training or work, such as the processes of reflective practice and constructivist educational theory as an important pillar of current educational paradigms.

The general objective of this paper is to explore the interactions between the conceptions of trainee science teachers on the themes of the BIOHEAD questionnaire and the relative degree of development of the KCSRPS, with the aim of providing pedagogical guidelines for ITT in EE and SE. Specifically, we will examine the conceptions of students of pedagogy in elementary education according to the measuring instruments (BIOHEAD and KCSRPS), we will determine the relative degree of development of the KCSRPS, and we will establish associations between the conceptions found and the relative degree of development of the KCSRPS.

Methodological Framework

Description of the sample

A questionnaire was applied in five universities in Santiago, Chile. As shown in Table 1, the participants were 120 students from programs in general pedagogy in elementary education who had completed between three and seven semesters. With regard to the sample, it should be noted that the composition of the subjects is somewhat

homogeneous in terms of gender, since only one in eight were men, a proportion that is certainly representative of the national situation, since 87% of teaching staff in elementary education are women (Ramírez, 2016). Similarly, although the age range was from 18 to 52 years old, the vast majority (90%) were at least 23 years old.

Meanwhile, the sample group is quite heterogeneous in terms of affiliation, as the number of subjects from two of the participating universities was almost double that of the rest of the total sample. As the number of years of study increases, the number of subjects decreases, as shown by the retention indicators typical of a university trajectory. At the same time, the subjects or specialties they were studying varied in combinations of two, the most common being Language and Mathematics (39%), although most were not yet studying their specialty (41%). Those studying specialties in Language and Social Sciences or Mathematics and Natural Sciences were a minority (7% and 5%, respectively), as were those specializing only in Mathematics (3%) or Language (5%).

Table 1
Number of respondents by year of study and university

University	2nd	3rd	4th	Total
San Sebastián	6	12	-	18
Santiago de Chile	4	4	5	13
Católica Silva Henríquez	15	4	-	19
Diego Portales	32	-	-	32
Alberto Hurtado	-	21	17	38
Total	57	41	22	120

Source: Prepared by the authors.

The questionnaire carried out for the BIOHEAD-Citizen project mentioned previously consists of 181 items, of which 40 are on sociodemographic variables (age, subject, year of study, gender, among others) and the rest are Likert-type questions with 4 or 5 levels, with the exception of some that are multiple choice. The results were tabulated according to the questionnaire's own coding system. As the items that could be controversial are the main topic of interest, we proceeded to look at the level of consensus among all subjects using the Tastle and Wierman (2006) consensus-dissension index. As the depiction of the consensus distribution suggests a bimodal distribution, we used mixed-model analyses (Scrucca et al., 2016) that allowed us to isolate two classes. Subsequently, the data were transformed into indicator variables, so that each item was extended to as many binary variables as the levels on its scale. Since this amplifies the number of variables, the CorEx algorithm was used, as its authors have shown that it can handle data with more variables per sample (See Steeg & Galstyan, 2015). This results in latent variables that group the responses by items, so we use the number of latent variables that reaches the maximum value of total dependence extracted.

The next step is to determine the relative degree of development of KCSRPS. In this respect, it should be underlined that there is still a need to establish valid assessment methodologies for this instrument (Cebrián et al., 2020). Specifically, case study evaluations are a promising and increasingly common approach in EE (Scholz et al., 2006). Conveniently, Remington-Doucette et al. (2012) constructed a rubric-assessed test to determine the relative degree of development of the KCSRPS: systems-thinking (ST), normative, and strategic.

Considering this, and following the work of Remington-Doucette et al. (2012), in ST the ability to identify and prioritize challenges through the economic, environmental, and social domains was assessed, as well as the ability to identify the values relevant to a sustainability challenge. With regard to the other competencies, the analysis was focused on the aspects that are similar to them, so their joint operationalization was under the conflict resolution (CR) construct. Similarly, we assessed the ability to identify potential conflicts between the priorities necessary to resolve the challenge and the ability to imagine realistic strategies to resolve the previous conflicts. The final product was a test consisting of reading case studies to answer open-ended questions and a rubric with a total of five criteria, with a scale from 0 (none) to 4 (exceptional).

In order to use the test described above, it was necessary to translate the entire questionnaire and adapt the rubric. Adaptation was necessary because the criteria were not applicable without an inaccessible list of possible correct answers. The criteria were thus reconstructed analytically, considering the spheres of sustainability, an in-depth review of the case study, and the paper by Remington-Doucette et al. (2012). The rubric was subjected to expert validation and pilot assessment. The ST criteria evaluate: (1) difficulties identified by dimension of sustainability, (2) prioritization of difficulties in an interrelated manner, and (3) identification of values. The CR criteria evaluate: (1) the tradeoffs of values for proposed benefits, (2) the identification of conflicts involved in resolving the previous difficulties, (3) and the recommendations proposed to resolve the conflicts. It should be noted that, for each criterion, quantities are assessed according to the quality of the responses.

The final evaluation of the samples was discussed in pairs until the score was agreed, which did not present any significant difficulties. Once the scores were obtained, the Kendall correlations between all the criteria were tested, correcting for the false positive rate. The final score for both constructs was then established as the average of the three criteria corresponding to each construct and Pearson's correlation was tested. The calculation of classical psychometric statistics such as Cronbach's alpha was not carried out, since not only have its shortcomings been suggested as a reason for ceasing its use (Sijtsma, 2009; Revelle, 2018), but also because its assumptions are not possible in the construct of a competency. Specifically, the items must measure the same single latent variable, where the covariance between items is constant across all pairs of items, which is an unrealistic assumption in practice (Sijtsma, 2009) and even more so with competencies, which are a network of skills, knowledge, and attitudes.

With the latent variables of the conceptions, the competency score is subjected to a final regression analysis, assuming that the most statistically plausible model involves the use of predictors that are theoretically significant. Therefore, the competency score will be dependent variables, while the latent variables of the conceptions would be the independent variables, together with the aforementioned variables. Selection of the linear regression model was based on the Bayesian information criterion (BIC), through an exhaustive search of all the possible combinations of independent variables and second-order interactions (specific coefficient for the product of only two predictors). Complementary statistical tests were also performed to see whether the hypotheses associated with the linear regression assumptions are not rejected: normality and heteroscedasticity of the residuals (Shapiro-Wilk and Brausch-Pagan tests, respectively), predictors without multicollinearity (determining the variance inflation factor), and correlation with the residuals. It was therefore tested (with Kruskal-Wallis) that the latter differ between the groups of the covariates in years of education and university, in order to assess whether the marginal effect of the covariates persists in the dependent variable, since the sample may have a relevant level of dependence. In that case, the regression step would be repeated to use mixed models and solve the problem of non-independence.

Finally, the sampling protocol was applied by course cohorts in a block of classes facilitated by the teacher in charge of the course. To do this, it was considered that the sample universe would be the students of general pedagogy in elementary education from different schools in the Metropolitan Region. The selection of the sample was non-probabilistic (Martínez-Mesa et al., 2016), since convenience was the main factor for choosing

universities, and the sampling effort was quite limited, because it was carried out only during October 2018. Intentionality was another factor, because we sought to sample universities with a diverse context and with curricula that included at least two science subjects, in order to analyze their respective didactic strategies.

Results and Discussion

Analysis of the BIOHEAD questionnaire

With regard to the consensus, the value ranges from 0% to 100% (full dissension and consensus, respectively). In general, there is a slight consensus between all items, as the mean is approximately 61% (SD=14%). Observation of the histogram in Figure 1 shows that the empirical distribution of consensus does not approach any pure distribution function, although the two peaks (close to 0.5 and 0.7 of the abscissa) suggest a mixed distribution. We tested five distribution models based on the Gaussian distribution; one unmixed (null model) and two with two- or three-component mixed models: one restricted to the components having equal variances and the other not. The two-component mixed model of equal variances was chosen as it showed the best goodness of fit. These mixed components are considered to be subtypes of the data (Scrucca et al., 2016), so those with the lowest and highest values were interpreted as items in dissension and in consensus, respectively (Figure 1).

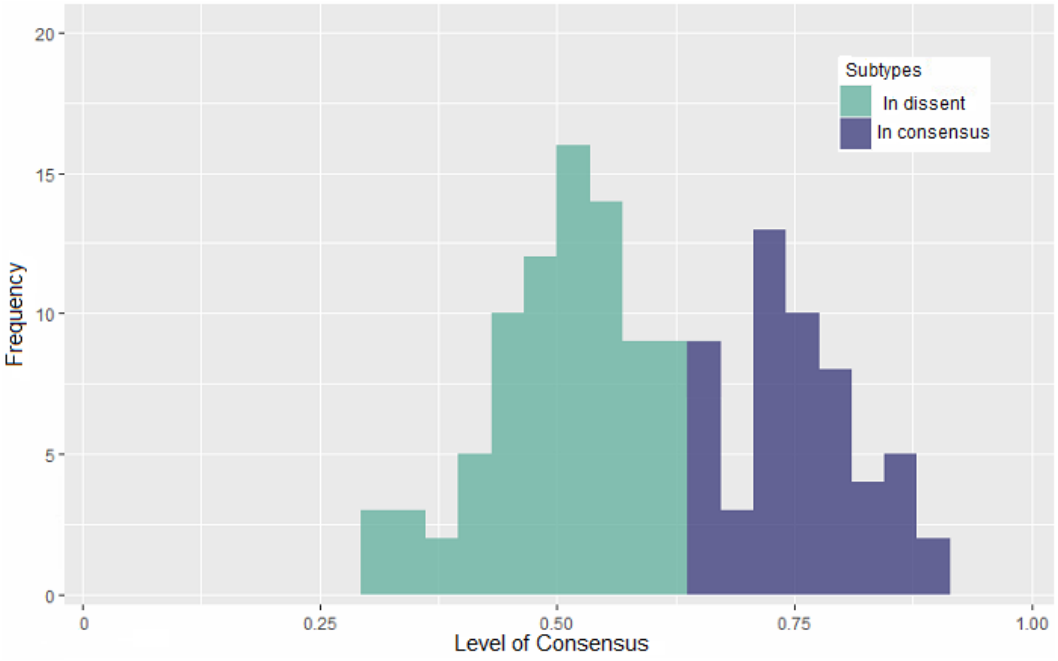


Figure 1. *Histogram of the consensus index for the items in the questionnaire on conceptions*

Source: Prepared by the authors.

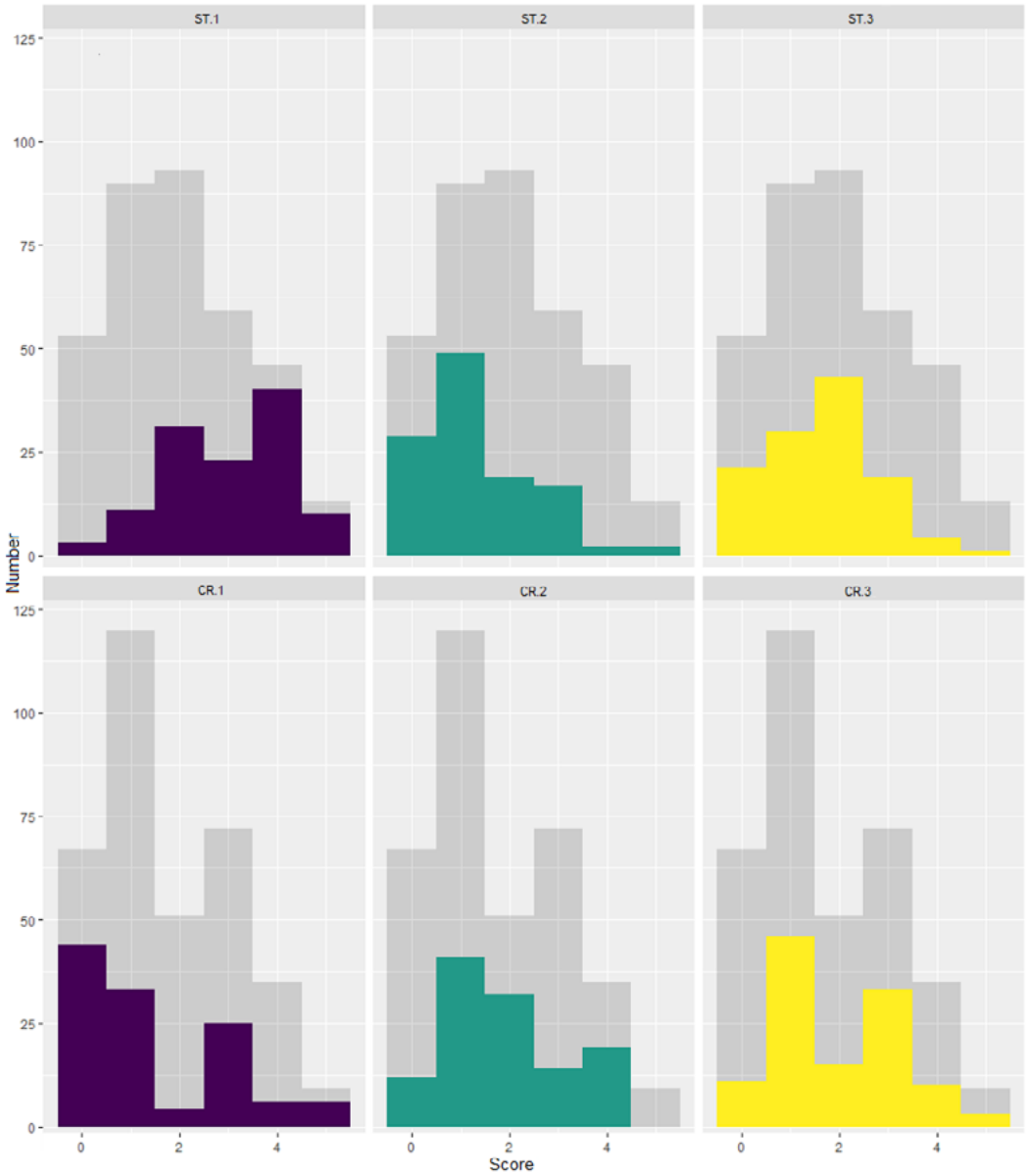
This was followed only with the subtype in dissension. It is composed of 71 items, with a consensus of less than 63% and a mean of 50% (SD=8%), that is, the majority is between slight dissension and consensus. Simply stated, the items address the environment (20 items), for example, snails can feel joy; politics and society (16), for example, religion and politics should be separate; genetic determinism (12), for example, Mozart's clones

would all be excellent musicians; creationism and evolution (11), for example, the degree of importance of God in evolution; health and sex education (5), for example, the age at which people should be taught about sexual pleasure; GMOs (4), for example, GMOs will help reduce world hunger; and acceptability of abortion (3), for example, when a couple suffers serious financial problems.

The transformation to indicator variables by response produced a matrix of 300 variables that were grouped into 11 latent variables with CorEx. Explanation of these would be extensive and beyond the scope of this article, so we will continue with the competencies. However, the latent variables associated with the competencies will be described later in this paper.

Analysis of the competencies

The score for each systems-thinking criterion is shown in Figure 2. The scores are generally moderately low, with the exception of the first criterion, in which the highest score is observed. However, the lower frequency in item 5 (identifies one or more valid difficulties by dimension: economic, environmental, and social) and item 3 (identifies several valid difficulties in two dimensions) compared with item 4 (identifies one valid difficulty in all dimensions) and item 2 (identifies one valid difficulty in two dimensions), indicate that there is a lower probability of identifying more challenges in fewer dimensions than fewer challenges in more dimensions, which allows us to infer that there is a more superficial skill in this aspect of systems-thinking or a superficial understanding of the interrelationship between human and ecological systems (Remington-Doucette et al., 2012). In both of the remaining criteria, a score of zero points stands out, suggesting that a null ability to deploy these aspects of ST was common in the sample. The correlations between the first and second criteria are not significant (t=.11; p^*>.2), which allows us to rule out that identification of difficulties was one of the main constraints in their prioritization. We therefore identify a low level of specific skills of the construct, which are associated with the analysis of complex systems. Indeed, 64% did not demonstrate this ability, since they were evaluated with one point at most, and from two points it is considered that they performed an interrelated prioritization of difficulties. In the third criterion, there was a slight improvement in performance, which could be explained by a lower level of Bloom's taxonomy (constantly used in initial teacher training for planning lessons) than in the second criterion, which would explain the differences. However, the fact that systems-thinking is less frequently deployed in the identification of values suggests lower development of the ability to integrate multiple perspectives, which is a basic requirement for ST performance in the KCSRPS framework (Wiek et al., 2011).



Note: The grey is the cumulative number per construct and not the average.

Figure 2. *Frequency of scores by criterion*

Source: Prepared by the authors.

The scores for the conflict resolution (CR) criteria are generally lower than in ST (Figure 1). We found the worst performance in the first criterion; there was one tradeoff proposal at most, which indicates low demonstration of the normative competency, since there is a lack of ability to imagine a more sustainable future scenario (outlining what would be gained in the negotiation) and to think about what aspects of the present should be addressed to enable a transition to that scenario (specifying the values to be conceded). Evidently, proposing from whom one will receive what one proposes to gain requires sufficient strategic prowess, as it allows one to realistically recognize the barriers to change and how to overcome them (Remington-Doucette et al., 2012). These latter two points are addressed in the second and third criteria, respectively. Both showed a better performance, although no better than intermediate. The correlation between the two is (the only one that is) significant (t=.33; p*<.001),

which is to be expected, considering that successfully recognizing barriers is inherent to being able to overcome them. Conflicts between priorities are potential obstacles to the transition to sustainable scenarios and are unavoidable, not only because they involve complex (convoluted) problems, but also because of the ambiguity of sustainability (Schlottmann, 2008).

The distribution of both constructs resembles the normal distribution and the score for ST tends to be slightly higher than that for CR (Figure 3). As can be observed in the scatter plot, ST and CR have a moderately small positive correlation (t=.21; p<.05). This is because certain CR questions were based on previous responses in ST, so this result is therefore not surprising. The three competencies are also theoretically interrelated and interdependent (Wiek et al., 2011).

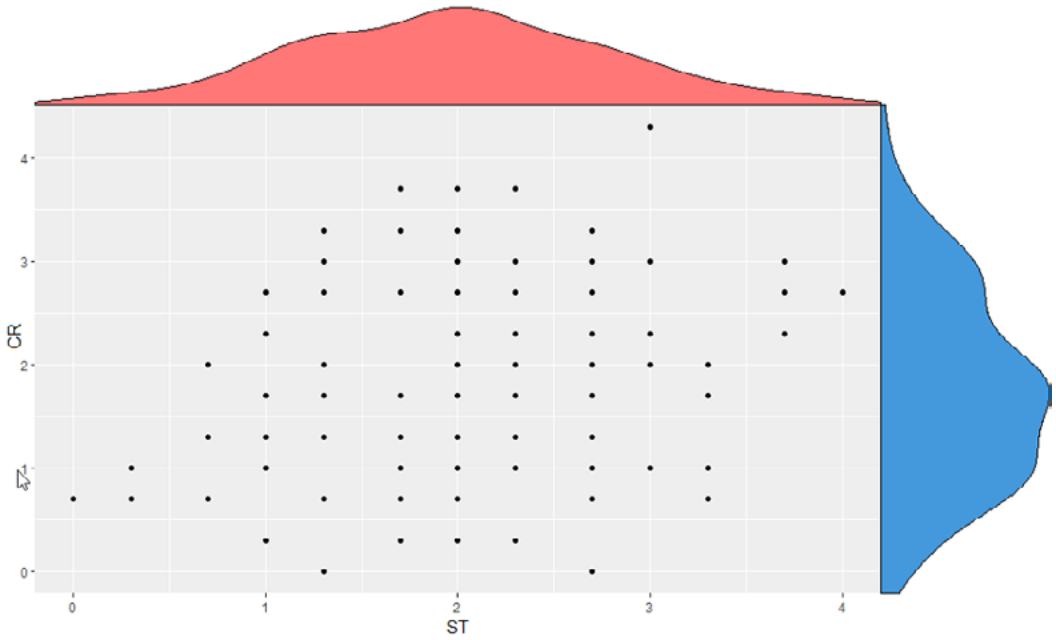


Figure 3. *Scatter plot between ST and CR, with densities of the total score horizontally and vertically, respectively.*

Source: Prepared by the authors.

Linear regression analysis

As regards ST, the best linear regression was produced with the second and fifth latent variables, in addition to their interaction. The model explains a small part of the variance and it is significant (adj-R^2 =.13; p<.001), as in the case of the intercept and the three predictors (p<.001; p<.01; p<.05; p<.05, respectively), with the effects of the latter being negative, small, and very similar (around a standardized ß of .24). As for the assumptions, all associated tests failed to reject the hypotheses underlying them and although none of the covariates had a significant effect on the residuals, mixed models were tested with university and course years as random effects, but were ruled out by likelihood-ratio tests. With respect to CR, no latent variable or covariate improved the regression compared with the null model.

The responses that are grouped in the second latent variable are negative environmental attitudes and utilitarian conceptions. There are also political views that are in full disagreement with progressive public policies and with full confidence in private security. The answers grouped in health are associated with their conception as the

absence of diseases and the subjects do not believe that health education improves the behavior of students in the school environment, which is congruent with the biomedical model. There are also responses to questions that sought to isolate the K pole, although interactions with the V pole are inevitable. Disagreeing that chimpanzees should be in the *Homo* genus due to their high genetic similarity to humans is a relatively correct response, although it could be associated with anthropocentrism, as this is related to negative and utilitarian conceptions of the environment, as well as less progressive views (Munoz et al., 2009; Clément & Caravita, 2011). The very low importance of viruses in evolution is a response with outdated scientific knowledge, which can be related to anthropocentric conceptions, since these views position human beings as superior, understanding evolution as the survival of the fittest and ignoring the complexity of the evolutionary phenomenon. In short, we arbitrarily call this group of responses a system of negative socio-environmental conceptions.

In the fifth variable there are responses on belief in and practice of a religion, as well as being slightly opposed to secularism in politics and science. There are creationist responses of course, since some answer that God is important in the evolution of species and, specifically, of humans. Although evolution is not denied and seems to be in harmony with religion, it is associated with less understanding of evolution, giving little importance to factors such as transposons and chance. There is also the conception that GMOs are contrary to nature, which could be an influence of religion on bioethical perspectives. With regard to abortion, although the responses are not strongly opposed to it, there are responses in favor and they have negative weights, so, on average, there is disapproval of freer abortion (preferring a lower limit of weeks of gestation and considering it unacceptable in cases of economic problems of the parents). The responses on health indicate a positive conception, which could be related to religion, since it also promotes behaviors that are appropriate in line with its norms. As regards political issues, there are views that reflect the current social reality, since there is a slight distrust in health and public education, as well as a preference for decision-making based on representative rather than direct democracy. The responses on the environment range from neutral attitudes to a slight lack of concern about the issue. Finally, since religion predominates in this group with regard to social and political issues, it is considered a system of socio-political-religious conceptions.

From this perspective, the systems-thinking construct assessed is negatively related to both systems of conceptions, socio-environmentally negative and socio-politically religious, where together they have a synergistic effect on ST. These results indicate that the systems only hinder the performance in ST but do not facilitate it, so they would not be part of the framework of competency in systems-thinking, but the values and social practices of each system of conceptions replace those components of the attitudinal aspects of better use of systems-thinking. The absence of findings on factors that favor systems-thinking may be due to the fact that it is not considered to be an intuitive cognitive activity (Hung, 2008) and it requires training, particularly in basic knowledge of system dynamics (Wiek et al., 2011). The CR construct did not show any relevant association in our results. This can be understood as the assessed aspects of both of the competencies involved, normative and strategic, not involving attitudes or knowledge that are reflected in the controversies.

Consequently, although our research has limitations in terms of using a relatively small sample, exploratory (not causal) experimental and statistical designs, and constructs and tests that are not (as yet) psychometrically tractable, we were able to achieve our objectives. Our results suggest that there are indeed systems of conceptions that are associated with a lower level of development of the systems-thinking competency in the KCSRPS framework; that is, it can be inferred that our data do support the stated hypothesis.

Discussion and Conclusions

According to the evidence obtained, and considering the limitations of research with this type of methodology, it is possible to argue and draw conclusions on a series of ideas and new knowledge in the educational field. The first conclusion concerns the evident articulation between SE and EE; put simply, a contemporary education in accordance with the current socio-scientific scenario inevitably implies a process of teaching and learning EE. Similarly, the provision of values and representations that are characteristic of EE naturally favor the development of scientific competencies. In this sense, it is important to use this stated relationship to eradicate linear interpretations of problems from educational systems. As observed in the results, a significant number of the variables and categories reviewed include a superficial view, where the causes and consequences are close in time and in space. However, there are situations in which causes and effects do not have such obvious connections, so it would be advisable to promote learning in the competency of systemic-thinking in teacher training and thus foster cyclical and deeper representations. In this respect, the use of controversial topics is recommended for the development of systemic thinking and reflective resolution of conflicts.

Another important aspect that emerges from the analysis of the results is the pedagogical function of future teachers and the need to be aware of the ideological role they have in their teaching activities. By action or omission, they interfere in a socio-natural system that continues to conceal the complex problems that the world is facing. It is thus proposed that there should be curricular teaching that centers on the criticism of modes of production and consumption that destroy nature and impoverish millions of human beings and which contribute to the reproduction of the ecological and social crisis. On the other hand, and as observed in the results, there is a lack of ability to imagine scenarios for a more sustainable future. In this respect, it is recommended that the prospective dimension of EE-SE be added to initial teacher training. This is linked to the ability to incorporate new approaches that consider the future dimension in the field of research and teaching, as proposed by Kong (2015) regarding the need for a profound and up-to-date (scientific and environmental) education, which should have the capacity to incorporate creativity as a reflective act in teachers' work, providing them with tools to look at the globality of world phenomena, constantly considering sustainability as a space for action that builds the future.

The development of professional competencies in ITT is complex and dynamic. It assumes principles such as coordinated and collaborative work among the teams at higher education institutions that train teachers and which should be consistent with the current standards of ITT in Chile. It recognizes the importance of training future teachers who value, respect, and teach about the environment with a critical, systemic perspective, and who are capable of solving controversial problems pedagogically. This is a space for disciplinary dialogue in which diverse institutional cultures converge. In this manner, such collaborative work would allow the emergence of disciplinary and supra-disciplinary knowledge that would enable the relationships proposed in this paper to be addressed. Accordingly, we see the university and its respective ITT programs as an opportunity to reflect on and look more deeply at the concept of competency itself (Bautista et al., 2003) and as a training space from which we can address the challenges of sustainability. ITT requires a change not only in the teaching culture (Lozano-García et al., 2008), but also in the higher education institutions themselves (Martínez & Esteban, 2005), in order to face the new phenomena affecting human beings and the planet. In the learning of competencies oriented towards SE-EE, it is important that there should be an institutional commitment and the involvement and perception of the teaching staff as key actors in the inclusion of environmentalized criteria and approaches in their respective teaching programs (Corney & Reid, 2007). Consequently, in the future, the results of this research will allow advances in the design of a curricular model that contributes to the development of scientific and environmental competencies in university education in general, requiring inputs provided by this paper to progress with a training framework that facilitates the design of new didactic methodologies that foster mechanisms which improve the development of key competencies in sustainability.

Acknowledgements: To Pierre Clément, for providing the BIOHEAD-Citizen questionnaire, and to the faculties that allowed the instruments to be applied to their students.

The original paper was received on May 22, 2020
The reviewed paper was received on October 14, 2020
The paper was accepted on November 9, 2020

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