Science education for sustainability: can a Power Point-based workshop induce a related conceptual change in science teachers?

Educación en ciencias para la sostenibilidad: ¿pueden talleres basados en PP inducir un cambio conceptual en maestros de ciencias?

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Abstract

Targeting at advancing science education for sustainability (SES) via a purposed paradigm shift—from teaching to "know" – to learning to "think"- a Power Point (PP)-based interactive workshop was presented in an international conference on education research. The study, here presented, investigates the value and effectiveness of a 3 hours' workshop for making a perceptual change in science teachers. The SES-related Higher-order Cognitive Skills (HOCS) epistemology was presented in a workshop; illustrating its conceptual framework, educational potential for science teaching and contribution to science education. This paper reports the results of a formative evaluation case-study concerning the extent to which the goals of the 'SES workshop' were attained. Accordingly, we have examined the workshop participants' pre-post perceptions of the workshop, their educational objectives and ongoing teaching/assessment strategies. The participants showed no change related to collaboration issues, or their feelings about the topics discussed during the short-term workshop. However, (a) an interesting induced shift was found concerning their perception of the integration of science-technology-environment-society (STES) issues, while focusing on the implementation of HOCS in science teaching and learning; and (b) the workshop participants became more open to SES-related paradigms shift from Lower-order Cognitive Skills (LOCS) teaching to HOCS learning.

Key words: *Higher-Order Cognitive Skills (HOCS)· Perceptions· PP-based Workshop · Science Education for Sustainability (SES) · Science-Technology-Environment-Society (STES)*

Resumen

La tarea es hacer avanzar la educación científica para la sostenibilidad (SES) a través de un paradigma propuesto de desplazamiento de la enseñanza al "saber" - para aprender a "pensar" – usando el taller interactivo basado en PP. El estudio, que aquí se presenta, investiga el valor y la eficacia de un taller de 3 horas para hacer un cambio de percepción de los profesores de ciencias. Las habilidades cognitivas (HOCS) y la epistemología de habilidades cognitivas (HOCS) relacionadas con el SES de orden superior se presentó en un taller; ilustrando su marco conceptual para la enseñanza de la ciencia y la contribución a la educación científica. Este texto presenta los resultados de una evaluación de estudio de caso formativo en relación con el grado en que se han alcanzado los objetivos del taller de SES. En consecuencia, hemos examinado las percepciones de los participantes del pre- y post taller, sus objetivos educativos y estrategias de enseñanza / evaluación en curso. Los participantes no mostraron cambios relacionados con temas de colaboración, o sus sentimientos acerca de los temas tratados durante el taller a corto plazo. Sin embargo, se encontró un cambio interesante inducido sobre su percepción de la integración de las cuestiones de ciencia-tecnología-sociedad-medio ambiente, mientras se centra en la aplicación de HOCS en didáctica de la ciencia; y (b) la participacion en el taller se hizo más abierto a los paradigmas relacionados con el SES, cambiar habilidades cognitivas de orden inferior de enseñanza (LOCS) para el aprendizaje HOCS.
Palabras clave: *habilidades cognitivas de orden superior (HOCS), percepciones, taller basado en PP, ciencias de la educación para la sostenibilidad (SES), ciencia-tecnología-sociedad-medio ambiente (STES).}*

INTRODUCTION

The current educational system has an instructional framework with the objective of advancing students up the class ladder based on passing disciplinary algorithmic knowledge tests. Modern society is based on science, technology, economy, knowledge and advanced networked information and communication technologies (ICTs). For years there has been a gap between the reality of this modern society and the practices of the educational system.

A major issue of concern in contemporary science education is the existing disconnection between the teaching - strategies, assessment methodologies and learning outcomes at the secondary and higher education - and real world economical, political, and scientific-technological, social issues (Barak et al., 2007a; NRC, 2003; Zoller, 1993). Understanding of concepts and principles underlying current sustainability-related real world issues, demands awareness, compelling the integration of real-world elements into science, STES, STEM teaching and learning science education for sustainability (SES). However, the integration of new classroom practices is dependent on the instructor's ability and will to experiment and implement innovations and/or alternatives to the conventional/traditional educational methodologies. As far as science teaching is concerned, such changes are difficult. Studies show that the integration of new practices is a complex process that consists of promises as well as barriers (Davis, 2003).

With respect to Science education, it has been suggested that instructors should be more aware of educational research and that there is a need to develop adequate professional development programs that will bridge the gap between science education research and classroom practice (Barak et al., 2007b; Barak, 2014). It was also suggested that teachers should be primarily involved in educational initiatives in order to ensure the success of educational reforms *(*Baylor & Ritchie, 2002; Tal et al., 2001). Teachers' professional development in workshops is one of many ways of addressing science teachers' educational perceptions, confidence, competence, and *willingness* to integrate new teaching strategies and methodologies (Yang & Liu, 2004).

In this paper we describe a HOCS-based SES (Zoller, 1993, 1999, 2012) workshop conducted in the framework of a national and international science education conference. The workshop's essence; i.e., educational perspectives, conceptions, goals, and its contribution to the participating science teachers and researchers are here presented. The outcomes of this case study have been used by the researchers to decide whether and to what extent a change in the workshop's science education participants' perceptions have been induced.

RATIONALE, PHILOSOPHY AND CONCEPTUAL FRAMEWORK

The development of students' learning via higher-order cognitive skills (HOCS)-promoting teaching is a continuous overriding challenge for many educators and researchers in science education (Zoller, 1993, 2012; Zoller & Levy Nahum, 2012; Zoller & Pushkin, 2007; Zoller & Tsaparlis, 1997). This paper focuses on the paradigm shift from algorithmic teaching to 'know' to-HOCS-promoting learning to 'think', while dealing with the relevant educational systems, teaching strategies, learning and assessment methods.

A major driving force in the current effort, worldwide, in reforming science education is the conviction of many that it is vital for our students to develop their HOCS capability in order to enable them to actively function and meaningfully participate in the relevant decision making processes within the context of complex science-technology-environment-society (STES) interfaces of multi-cultural societies. Indeed, science education reforms, worldwide, explicitly request science teachers to modify their teaching strategies by shifting the emphasis from the traditional lower-order cognitive skills (LOCS) rote-learning, to inquiry-based HOCS-learning, situated in relevant real-world phenomena (Zoller, 1993, 1999; Zoller et al., 1995; Zoller & Levy Nahum, 2012).

HOCS is conceptualized as a non-algorithmic complex multi-component conceptual framework of reflective, reasonable, and rational systemic evaluative thinking, focusing on deciding what to believe and do, or not to do, to be followed by a responsible action, accordingly (Zoller, 1993, 2000).

In this Power Point workshop-related paper, we envision HOCS as an '*umbrella'* encompassing various overlapping and interwoven forms of cognitive capabilities (Figure 1) such as critical thinking, system thinking, question-asking, evaluative thinking, decision making, problem solving and, most important, transfer (Levy Nahum et al., 2009; Zoller, 2012; Zoller & Levy Nahum, 2012). Thus, for example, critical thinking (Barak et al., 2007a; Ennis, 2002), and lateral (system) thinking (de Bono, 1976) involve uncertainty, application of multiple criteria, reflection, and self-regulation (Resnick, 1987) and are all interwoven components within the HOCS framework (Zoller, 1993; Zoller et al., 2014).

Figure 1 illustrates, schematically, the complex conceptual model of HOCS. The model refers to interrelated *generic* (non-content specific) cognitive capabilities, always make sense *in context*, primarily the science-technology-environment-society. It is a non-directional super-ordinate model, not specifically ordered nor linearly hierarchical. The LOCS components of basic cognitive capabilities are inherently embedded in the various components of the HOCS model.

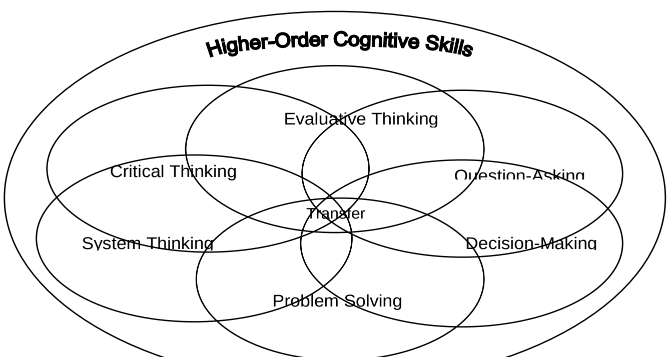

Fig. 1 The guiding conceptual model of HOCS in the context of science education (Zoller & Levy Nahum, 2012)

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The "HOCS approach" to teaching, learning and assessment continues a comprehensive educational "world outlook" which has been and continues to be implemented in different settings in different modifications, worldwide, particularly in STES education in the multidisciplinary STES interfaces contexts. This includes, among others, novel teaching strategies, assessment methodologies and learning strategies, purposed for the development of students' HOCS; i.e., their capabilities of System Thinking, Evaluative Thinking, Decision Making, Problem Solving and Transfer. Thus, active research and evidence-based practice of HOCS-oriented teaching, assessment and learning constitutes a methodology of choice for effective teaching and learning for sustainability.

THE SCIENCE EDUCATION FOR SUSTAINABILITY (SES) WORKSHOP

The SES workshop was conducted at one annual conference of NARST (National Association of Research in Science Teaching). The guiding rationale of the workshop was based on the paradigm shift now occurring in people and in their societies' world outlooks. This includes effects on policies, economy, emerging scientific, technological and environmental research and, consequently, on science-STES and education at large. Some paradigm shifts are selected and presented in table 1 below (Zoller, 1993, 2012; Zoller et al., 2014; Zoller & Scholz, 2004).

Table 1 Selected SES-related paradigms shifts in contemporary research and STES/STEM-oriented science education (Zoller, 2012)

From:	To:
Technological, economical, and social growth at all cost…	Sustainable development
Reductionism; i.e., dealing with in-vitro isolated, highly controlled, components	Dealing with uncontrolled, in-vivo complex systems
Disciplinarity teaching (biology, chemistry, physics…)	Problem solving-decision making-oriented, systemic interdisciplinarity
Technological feasibility	Economical-societal feasibility
Scientific inquiry (per se)	Socially accountable, responsible and environmentally sound R & D
Algorithmic lower-order cognitive skills (LOCS) teaching	"HOCS Learning"
"Reductionist" thinking	System/lateral/moral and creative thinking
Teaching to "know"	Learning to think
Teacher-centered, authoritative, frontal instruction	Student-centered, real world, project/research-oriented team learning, ET assisted

Accordingly, persistent implicit-to-explicit shift in teaching and assessment, in tandem with accompanying related active research, is expected to promote the shift from 'algorithmic teaching' to "Know" – to HOCS LEARNING to "Think" for sustainability in science/STES/ STEM and IT-SES.

This PP, ICT-based workshop focused on exemplary practice of "how to do this" through active participation of all involved in the following guided design-type (3 hours) workshop schedule:

1. Introduction:
1.1 Philosophy and rationale.
1.2 The paradigm shifts in science, technology, research and science/STES/STEM Education.
2. Discussion: What does/should STES-EP (economy-policy) - oriented science/SES education take?:
2.1 Targeted main goals.
2.2 Related teaching strategies; selected research-based examples.
2.3 HOCS-promoting assessment methodologies.
3. Lower vs. Higher-order cognitive skills (LOCS vs. HOCS):
3.1 LOCS- vs. HOCS-type questions, teaching and assessment strategies – in science education.
3.2 Illustrative examples and analysis.
3.3 Participants' groups work: Development of examples (relevant to participants).
4. Exemplary STES-oriented courses, curricula and examinations for sustainability:
4.1 Short presentations by organizer and workshop participants.
4.2 Tandem action research and HOCS promoting SES; selected illustrative examples.
5. HOCS-promoting assessment in science/STES education:
5.1 HOCS-promoting exam questions.
5.2 Assessment of students' question-asking, decision-making, problem-solving, critical thinking, and system thinking capabilities.
5.3 Relevant examples; to be worked out and presented by participants (as time permits).
6. Conclusions:
6.1 Science education for sustainability (SES): What does/should it take?
6.2 Research/Practice-based conclusions.

From a constructivist perspective, science teachers' conceptions of science and the way they teach it is a result of the way they were taught in their schools (Hewson & Hewson, 1988). The methods by which science teachers were taught and instructed are often inconsistent with contemporary SES-STES/STEM educational approaches and, therefore, a related appropriate change is required. Such a change on the part of science teachers requires the research-based development and implementation of HOCS-based new curricula and a corresponding adaptation of new teaching, learning and assessment methods that foster the related paradigms shift (Leou et al., 2006; Tal et al., 2001; Zoller, 2013; Zoller et al., 1995; Zoller & Levy Nahum, 2012).

OBJECTIVES AND METHODOLOGY

The case study presented here is aimed at investigating to what extent the goals of this SES workshop have been achieved, focusing on the participants' educational perceptions, objectives, teaching, learning and assessment strategies. Such a short pre-post study design was expected to facilitate the evaluation of the workshop's effectiveness, thus obtaining feedback for a fine tuning future implementations. The specific research questions were:

Did participation in the workshop affect participants:

1. Educational objectives?
2. Teaching, learning and/or assessment strategies?
3. Attainment of *their* educational goals?

The assessment tool consisted of almost identical pre-post questionnaires, requesting the workshops participants to self-reflect on six items and state their: (a) objectives for attending this SES workshop; (b) expectations from the workshop; (c) educational objectives, (d) perceptions of science teaching and assessment strategies, (e) attainment level of their pre-workshop educational goals; and (f) their comments (see Appendix).

Twenty four science education teachers/researchers participated in the workshop, eighteen of which, asserted over 290 comments and responses in the pre- and post-questionnaires. These statements were analyzed via a two step process: *First, they were analyzed qualitatively and* each statement was singly categorized. *Second,* each category was assigned with a numerical code, enabling the calculation of their frequencies and percentages. *T*he data was jointly analyzed by two experienced science education researchers for establishing research trustworthiness, achieving an inter-rater reliability of 84%.

RESULTS AND DISCUSSION

The participants' responses to the questionnaires' items have been categorized, each of which has been assigned a numerical code and quantitatively analyzed. This was followed by the selection of "representative" participants' statements and their categorization. The percentage of the pre-post response statements of the workshop's participants in each category, and the participants' responses percentage by categories are represented in Figure 2 and Table 2, respectively. Analysis of the workshops participants' self-reflection statements concerning their educational objectives, teaching/assessment strategies, and perceptions related to the HOCS-related SES PP-workshop revealed four categories of their statements made: *Global, Collaboration, Informational*, and *Emotional*: The *Global* category included all statements that were related to the integration of STES issues, focusing on the implementation of HOCS such as question asking, critical and system thinking, decision making and problem solving (Zoller, 2012; Zoller & Pushkin, 2007). The *Collaboration* category included all statements that were related to groups interactions and knowledge/information sharing. The *Informational* category included statements concerning the information that the participants expected to gain in the workshops which focused on LOCS. All statements that were related to the participants' or their students' feelings, were assigned to the *Emotional* category.

All statements could either be related to the participants' own educational needs; i.e., 'Teacher-Centered' (TC), or to her/his students' needs; i.e., 'Student-Centered' (SC). A random selection of the participants' self-reflection 'statements' and the corresponding assigned categories are presented in Table 2.

QUANTITATIVE FINDINGS

Analysis of the statements, of the workshop participants and their distribution, in the various categories, concerning their SES-related educational objectives (Table 2), revealed that Informational, 'Teacher-Centered' (TC)-1 and 'Student-Centered' (SC)-2 comments received the highest percentages in the pre-questionnaire (56% and 30% respectively), whereas Global 'Teacher-Centered' (TC) and 'Student-Centered' (SC) comments (35% and 45% respectively) received the highest percentages in the post-questionnaire (Figure 2). A Wilcoxon test for non-parametric data indicated statistically significant differences between pre-and post-category distribution for 'Global-SC' ($Z=-2.8$, $p<0.01$) and 'Global-TC' ($Z=-2.8$, $p<0.01$). A border statistically significant differences were found between pre-and post-category distribution for 'Informational-TC' ($Z=-1.8$, $p=0.06$). The results implication is threefold: first, the science education researchers/teachers participants attended the workshop mainly for "informational reasons"; namely, to learn more (with colleagues) about STES & HOCS-science teaching and assessment in the framework of the newly emerging approach for science/STES teaching and education. Second, the workshop appears to increase the participants' belief in and importance of integration STES issues, --via the implementation of HOCS such as question asking, critical and system thinking, decision making and problem solving in their science teaching. Third, it appears that the workshop participants underwent a conceptual shift concerning the significance of STES and the related teaching and learning to "think" in science education.

Table 2 Post-questionnaire topics and examples of participant's self-reflection Statements and their assigned category

Topic	Participants' self-reflection statements	Assigned category
1. Objectives for attending the SES workshop	"Explore with colleagues ideas and challenges abut STES and environmental ideas".	Collaboration/ Teacher-centered
2. Main expectations from SES workshop	"To know strategies for sustainable science education and HOCS-assessment".	Informational /Student-centered
3. Educational objectives	"To impart enthusiasm and capacity for life-long learning in my students".	Emotional/Student-centered
4. Extent of the attainment of educational objectives	"Encouraging students' discussions about the nature of science in the context of STES".	Global /Student-centered

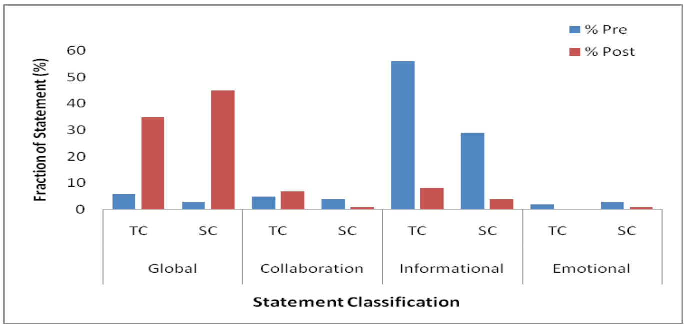

Fig. 2 Participants' self-reflection: categories and percentage of pre-post statements

Table 3 presents the category percentages of the workshop participants' responses in the pre- and post-questionnaires, wherein N represents the number of statements written for each topic, and the numbers in the following rows are the percentage of responses. Each row sums up to 100%.

Thus, similarly to Figure 2, Table 3 indicates that the workshop participants' main objectives in attending the HOCS-SES workshop were the 'Informational-TC' reasons (75%); namely, the participants were mostly interested in learning the instructional, teaching aspects associated with HOCS-based teaching in SES. However, in their post-questionnaire, the 'Informational-TC' reasons, dropped to 24% and the participants' main objectives in attending the SES workshop were within the 'Global-SC' category (44%).

Thus, the participants' main post workshop expectations, were less related to informational and collaboration issues (both 14%) and more to global issues (46%), (in comparison to their corresponding response in the

Table 3 Workshop's participants' percentagewise responses by categories

Topics	Survey (N)	Categories: Global TC (%)	Global SC (%)	Collaboration TC (%)	Collaboration SC (%)	Informational TC (%)	Informational SC (%)	Emotional TC (%)	Emotional SC (%)
1. Objectives for attending workshop	Pre (32)	6	-	9	-	75	3	6	-
	Post (25)	44	12	20	-	24	-	-	-
2. Main expectations of SES workshop	Pre (33)	3	-	15	-	76	6	-	-
	Post (28)	46	14	14	4	14	7	-	-
3. Educational Objectives	Pre (33)	7	9	-	-	52	26	-	7
	Post (27)	30	59	-	-	-	7	-	4
4. Teaching & assessment strategies	Pre (34)	15	3	3	9	44	15	3	9
	Post (25)	32	64	-	-	-	4	-	-
5. Extent of attaining educational objectives	Pre (29)	-	3	-	10	34	52	-	-
	Post (25)	24	76	-	-	-	-	-	-

N – The number of statements asserted by the 19 participants for each topic
SC – Student-Centered; TC – Teacher-Centered

pre-questionnaire). This result suggests a post workshop growing interest among the participants to integrate STES aspects in their teaching via focusing on the implementation of HOCS. As one participant expressed at the end of the workshop: *"Exploring STES and environmental education in science teaching practice; "gathering resource"*, or "*learn integration techniques – the importance of multiple integrations – society, technology, etc. in science learning and students' engagement*".

The above results suggest that (1) the participants' perceptions of teaching and assessment strategies were mainly 'Informational-TC' in the pre-questionnaires (44%); and 'Global-SC' on the post-test (64%); suggesting that the participant's perceptions of HOCS teaching and assessment strategies were 'positively' enhanced. Similar results were found in participants' perception of the attainment of their educational objectives; namely, the percentage of the 'Global-SC' statements reached 76%, typified by the statement: *"students give importance to recycling of products and reduce consumption", or "students start to analyze and evaluate results of experiments or happenings in the world*".

Finally, in their additional comments, the workshop participants wrote that they found the workshop "thought provoking" and "very interesting". Moreover, few suggested that more research should be conducted to support the claims made in the workshop concerning HOCS promotion in SES.

CONCLUSIONS AND IMPLICATIONS

Science education that addresses issues relevant to global sustainability will, most likely, require restructuring science and STES/STEM education, at all levels, and in accord, science teachers professional development programs, particularly in respect to SES (Zoller, 2012, 2013). Thus, an important challenge for contemporary science education at all levels is the development and implementation of instructional practices that will foster students' HOCS capabilities of solving interdisciplinary, poorly-structured complex problems. Our and others' related longitudinal research and, in accord, implemented practice, provide some fundamental insights into the way HOCS-STES-related issues are to be implemented in science teaching, assessment and learning for sustainability.

Since traditional science teaching was shown by research to result in mainly LOCS level gain, the persistent integration of HOCS-promoting teaching, targeting at learning to *think*, will not only challenge students, but also will contribute, meaningfully, to the LOCS-to-HOCS paradigm shift as is research evidenced (Zoller, 1993, 1999, 2012; Zoller et al., 1995; Zoller & Levy Nahum, 2012; Zoller & Tsaparlis, 1997).

All of the above reflects on the importance of translating research into applicable and manageable instructional HOCS-promoting strategies, thus strengthening students' conceptualization of science principles and their capabilities of transfer in the SES context. We, the authors, believe that this goal can and should be achieved.

This short study integrated quantitative and qualitative research methods in order to get a response concerning the related teachers' points of view and attitudes. The pre-post workshop questionnaire, which was distributed to the participants, enabled the researchers to learn about the participants' attitude changes as a result of their participation in the workshop, regarding the teaching-learning-assessment process and the potential strategies for the development of HOCS in the context of SES.

Although this in-service teachers' professional development was done in the form of a short term workshop, it enabled the participants to reflect on their prior teaching in real-time.

The findings show that a certain change did take place as a result of the participant's active involvement in the workshop. We found that in the two categories -- the 'Global-TC' and the 'Global SC', as well as 'Informational-TC' and the 'Informational-SC' -- there are, clearly, significant differences: the Global increased and the Informational decreased. This finding is compatible with the main goals of the workshop—inducing a shift: from teaching to know' to learning to think', particularly in the context of SES. Thus, the emerging conclusion is that the workshop did affected the workshop's participants' STES-HOCS-SES-related conceptualisation, attitudes and points of view. Ultimately, they were satisfied with the workshop and, hopefully, will involve HOCS in their teaching and research.

In conclusion: given the above induced shift in the workshop's participants' perceptions of HOCS in science research, teaching and learning, the workshop participants became more open to the SES-related paradigms shift from 'LOCS teaching' to 'HOCS learning'. Thus, similar PP-based workshops may serve as initiators of this and related shifts in the context of science teaching and learning for sustainability.

Limitations

The main limitation of this study is its short duration which, in turn, dedicated very short pre-post time duration between the administration of the questionnaire. Adding to that the small number of workshop's participants, requires the limitation of the research-based conclusions. Yet, the potential of PP-based workshops for inducing particular conceptual change in the STES-SES context is apparent.

Appendix: SES Workshop Self-Reflection Pre-Post Questionnaire

1. State 2 of your main objectives for attending active participation in this SES workshop:

1.1 ____

____

1.2 ____

____

2. Specify 2 of your main *expectations* of this workshop:

2.1 ____

____

2.2 ____

____

3. Formulate 2 of your main *educational/instructional objectives* in your teaching of
science/chemistry:

3.1 ____

____

3.2 ____

____

4. Specify 2 of your *main teaching/assessment strategies* that you are currently using in
order to achieve/attain your teaching goals as formulated in number 3:

4.1 ____

4.2 ____
____

5. Provide the evidence you have (or will have) concerning *the extent of the attainment* of your educational/instructional goals as specified in number 3:

5.1 (Objective 1): ____
____

5.2 (Objective 2) ____
____

6. Any additional comments:
____

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El trabajo cooperativo con las TIC para el tratamiento de contenidos de biología con alumnos de 14-15 años

Cooperative work through ICTs to teach biology contents

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Resumen

Se propone una metodología de trabajo por proyectos para abordar contenidos curriculares de biología y geología, con alumnos españoles de 3º ESO (14-15 años). Los contenidos se distribuyen entre subgrupos cooperativos de alumnos para ser desarrollados utilizando las TIC y con la creación de recursos digitales integrados en un padlet (muro digital) para comunicar los resultados de los proyectos. Aquí, se desarrolla un ejemplo de cómo se han trabajado los proyectos sobre los sistemas nervioso y endocrino en tres subgrupos de clase y se analizan las evaluaciones de las exposiciones de los alumnos por los compañeros y el profesor. Los resultados muestran altos niveles de resolución en relación a la calidad de sus padlets, es decir, en el tratamiento dado a los contenidos trabajados en sus proyectos, así como en su exposición y comunicación.

Palabras clave: *Aprendizaje basado en proyectos; grupos cooperativos; TIC; evaluación de la competencia digital; biología-geología; educación secundaria.*