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CONSIDERING RESPONSIBLE RESEARCH AND INNOVATION IN SCIENCE EDUCATION TEACHING APPROACHES AT PRIMARY LEVEL

ANGHEL GABRIELA ALINA, GORGHIU GABRIEL

Abstract:

The paper targets to identify the potential of Responsible Research and Innovation (RRI) in the teaching-learning process specific for science education, designed to primary students (3rd and 4th forms). In this respect, a specific case study is analyzed: a unit dedicated to natural nanomaterials, having the objective of increasing the students' awareness related to the existence and usage of such materials. During the lessons, experimental approaches were introduced with the view to emphasize the nanoparticles in natural nanomaterials, but also to establish correlations between their structure and function.

The overall objective of the research was to analyze advantages and limitations of the teaching strategy which tried to consider RRI dimensions in science lessons. Specific research objectives are oriented on: analysis of the efficacy of the teaching methods used in the classroom - mostly of the 6E Model: Engage, Explore, Explain, Elaborate, Exchange, Evaluate (OS1), and analysis of the way in which RRI becomes efficiency in the educational process (OS2). The data collection process took into consideration the learning objects proposed by the teaching unit and the semi-structured interview conducted with the primary teachers. The whole analysis and the interpretation led us to the following conclusion: introducing RRI dimensions in the teaching strategy - even from early ages - positively motivates students and stimulates their active participation during the science lessons, determining so an intense process of deep learning of the related scientific content and developing of a desirable social behavior in relation to social and educational environment.

Keywords:

Responsible Research and Innovation, science education, primary level, 6E model, IRRESISTIBLE Project

JEL Classification: I21, I29

Authors:

ANGHEL GABRIELA ALINA, Valahia University of Targoviste, Romania, Email: anghelalina2002@yahoo.com
GORGHIU GABRIEL, Valahia University of Targoviste, Romania, Email: ggorghiu@yahoo.com

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Introduction

In the context of the technological progress and of the new discoveries in the area of sciences, we can notice a modification of paradigm concerning the ways of implementation of formal education, a shift in the instructive-educative process from the passive, normative education to a dynamic and active education, in which the student and the teacher become partners. Consequently, the discourse regarding the importance of education is channeled especially towards the need of shaping and developing the students' cognition, attitudes and skills, having as perspective a sustainable learning. More often, it is appreciated that the shaping of the students' skills answers to the demands imposed by the knowledge society, which is under permanent transformation.

Actual students request an education based on the acquisition of the knowledge, with a strong applicative character, but also relevant in the nowadays context, especially in the sense of the social reality. At the same time, the knowledge acquired must permit a correct management of different problems or situations they can meet in their daily life. In fact, the European educational policies encourage the need to produce an instructive-educative process able to facilitate the gain of the knowledge based on the scientific discovery. In this framework, the paradigm of formal education in the postmodern society urges for a shift of focus from the prescriptive, formative education to a pragmatic education, with a significant applicative character.

The shaping and development of "*key competencies*" is appreciated as being a need of the present education, a desideratum of education in Europe, defined as follows: "*Key competencies represent a transferable and multifunctional package of knowledge, skills and attitudes that all individuals need for personal fulfilment and development, inclusion and employment. These should have been developed by the end of compulsory school or training, and should act as a foundation for further learning as part of Lifelong Learning*" (2006/962/EC). Among the key competencies prefigured on the level of the European educational policies, it can be identified the "*basic skills in science and technologies*", with the following structure: knowledge, skills and attitudes, described specifically. Thus, in the present technological context, on the level of knowledge, it is appreciated that the students need to know: the basic principles of the natural world, the fundamental scientific concepts and methods in order to be able to understand the impact of science and technology on the natural world, the scientific progress and the limitations and risks associated in the context of the scientific theories. At the same time, it is considered necessary to be developed the skills related to: working with technological tools and equipment; using different research data in order to obtain scientific results which ensure and facilitate the transfer of knowledge. More, it is appreciated that in the context of the *basic skills in science and technologies*, the knowledge is necessary to recognize the essential features of a scientific investigation and to develop skills related to communicating conclusions.

In the sense of shaping and developing attitudes, the formation of basic skills in science and technologies also targets education by developing the aspects concerning the critical appreciation and stimulating the curiosity to scientific progress, growing the interest for ethical problems and respect for security and sustainable development, from the perspective of the scientific and technological progress, through: referring to the importance of the collected information for self-purposes, for family and community, being able to be involved or participate to the process of solving actual societal problems. It is appreciated that progress in education can also be noticed in the context of the indicators concerning the school success, in relation to which, nowadays, proper explanations ensure good educational practices in the transferring of new knowledge. In this sense, it is appreciated that the implementation of integrated and innovative training strategies - that mainly use active and participative teaching methods on the student's level - successfully support learning. ,,*Few would disagree that science and innovation should be undertaken responsibly. 'Responsible innovation' intuitively feels right in sentiment, as an ideal or aspiration."(Stilgoe, Macnaghten, Gorman, Fisher and Guston (2013:p.27)*

In essence, the *Inquiry-based Science Education* model (*IBSE*) used in frameworks of teaching strategies for "Sciences" area, successfully answers to the students' learning needs. This can be linked to the students' specific behavior in relation to the learning activities implemented in classroom. In this respect, a sustainable education answers to the students' needs, coming in-line with the "*digital generation*" expectations: attention turned to the aspects which interest the youngers directly, and tendency to understand the real senses, with connections to social reality. In this framework, we consider good educational practices those specific teaching actions which guide the learning towards shaping the students' skills. Those must directly stimulate the students' interest in learning by discovery. In this respect, the practical aspects presented in correlation with the paradigm of *Responsible Research and Innovation* (*RRI*) represent a facilitator of sustainable education.

The RRI role in education and its place in the instructive-educative process has been discussed relatively recently. ,,*Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products(in order to allow a proper embedding of scientific and technological advances in our society*)."(Von Schomberg, 2011).

The European educational policies accentuate the discourse on the need to situate RRI on the level of the educational practices among the teaching and training strategies used for different areas in school. According to the European definition of the RRI paradigm, "*it refers to the comprehensive approach of proceeding in research and innovation, in ways that allow all stakeholders that are involved in the processes of research and innovation at an early stage (A) to obtain relevant knowledge on the consequences of the outcomes of their actions and on the range of options open to* *them, and (B) to effectively evaluate both outcomes and options in terms of societal needs and moral values, and (C) to use those considerations (under A and B) as functional requirements for design and development of new research, products and services*" (EC, 2013, p. 3).

RRI in education is described in the context of formal, non-formal or informal instructive-educative activities based on scientific inquiry. The promote of learning activities that integrate RRI in the teaching strategies, appears as an important preparation for the education based on scientific knowledge (Gorghiu, Anghel, & Ion, 2015, p. 601).

The "Sciences" area and the curricular design in the context of embracing the IBSE strategy

At the level of the primary school, the curricular design for the "Sciences" area is described in the context of the actual practices, based on the integration of educational activities. In this context, the raise of the students' interest for the surrounding world imposes the adoption of certain investigative approaches guided by the logic of demonstration and critical argumentation. The lessons have been designed as informational package, adapted to the students' age and rely on the method of observation of the natural world with its characteristic elements, phenomena and processes. The philosophy of the instructive-educative process represents a certain stage, promoting the necessary knowledge for a specific scientific approach. Actually, by studying the "Sciences" area, beyond the aspects related to the acquisition of new knowledge, the target is to shape and develop the capacities and skills of experimentation and exploration of the reality, using specific tools and procedures. At the same time, what is targeted is related to the aspects directed to the development of the future adults' interest and responsibility for the maintaining of a balanced life-friendly natural environment.

Those aspects facilitate the way to innovation in relation to the learning topics. I this respect, the IBSE teaching strategy supports a sustainable learning process. But what is the IBSE model and how is it substantiated at the level of primary school educational practices?

In the educational practice, the IBSE model identifies itself as an educational model described in the context of a teaching strategy taking place in six stages/steps (according to some authors in seven stages/steps). This teaching model involves the realization of certain educational activities, oriented to the engagement of the students in educational activities seen as "investigative"-type. The aim of the implementation of this model is to favor a learning based on scientific discovery. In this context, the student's active involvement becomes an essential condition. In the framework of the educational activities profitably using the IBSE educational model, its specific stages are offered by a 6E model: *Engage*, *Explore*, *Explain*, *Elaborate*, *Exchange* and *Evaluate*.

The “*Engage*” stage is characterized by educational activities stimulating the students’ interest on the proposed topic (for example: watching relevant movies in relation to the selected topic, visiting specific exhibitions, meeting specialists from the scientific domains etc.). During this stage, the teacher’s role is to orient the students to the identification of the best and most relevant information able to stimulate their active involvement in the learning process. It represents the stage of identification of the learning object.

The second stage - “*Explore*” - is developed around the activities of exploration / investigation of the subject being learnt. In this setting, the students formulate questions, elaborate hypotheses, make preliminary investigations, analyze and interpret certain scientific data. At this moment of the lesson, the teacher’s role is to facilitate the correct interpretation and understanding of the collected data. The teaching activities proposed in this stage are mostly experimental activities and documentation ones, with the view to contribute successfully to the learning by cooperation.

During the “*Explain*” stage, the scientific information - collected at the level of the student group - is disseminated to the whole class, in order to being completed, restructured, correlated and validated. During this stage, the students have in view especially the received feedback and the social and scientific importance of the collected data. During this stage, it is important to have a process of content clarification, having as main objective to make proper the knowledge transfer.

During the “*Elaborate*” stage, the students’ activity has also to be focused on RRI specific problems. It is the stage of consulting scientific experts in order to know better the subject and the set of problems that deal with it. The heuristic teaching strategies successfully facilitate the learning by guided discovery. This strategy model takes “*the form of a bilateral communication, of a conversation, in whose framework the teacher/expert acts on the students by verbal requirements, and the students react by offering answers”* (Albulescu, & Albulescu, 2000, p. 125.). The participation of specialists can be realized either face-to-face or by the means of virtual tools (e-learning platforms, blogs, social media).

During the “*Exchange*” stage, one of the students’ and teachers’ important tasks is to design learning products explicitly reflecting the object and set of problems dealt with the proposed topic. In this case, multiple variants can be identified: designing an exhibition based on posters, video-clips, replicas, and other types of products. They can address a public similar to that of its designers, or even the large public.

In the “*Evaluate*” stage, the activities are guided and directed by the teacher to the assessment of what has been learnt. In this sense, the students are evaluated in order to check the extent to which they obtained sustainable acquisitions, from the perspective of the pre-set aims. The evaluation is a combined one: self-evaluation and inter-evaluation, by using on-line tests, portfolios, projects, questionnaires, interviews, opinion surveys.

The teaching approach using the IBSE strategy has in view the integration of those stages in the context of considering the following procedural aspects: proposing/presenting the problem to be investigated, organizing the problem data and reviewing the necessary data, formulating questions, determining the responsibilities at the group level involved in the scientific investigation, identifying the necessary resources, performing the necessary experiments, analyzing the results, drafting a preliminary report, presenting the solutions. This teaching strategy model is realized taking into account the RRI principles: participation/involvement, gender equality, science education, accessibility, ethics and governance.

Proposed activities for primary school students (the case of "*Natural nanomaterials*" Unit)

The teaching activities subsumed under the topic of "*Natural nanomaterials*" had the aim to increase the students' awareness concerning the existence of such materials and how those *natural nano-elements* could be emphasized in practice. In this respect, the unit (spread in four lessons of 1 hour each) proposed to perform the following specific activities: (a) experimentally highlighting the milk and gelatin nanostructure; (b) using laboratory instruments and equipment, but also the computer for studying such materials; (c) analyzing and interpreting the observations / data resulted as part of the investigative activity; (d) explaining the structural changes in the molecules; (e) emphasizing on the importance of structural changes in the analyzed materials; (f) exemplifying concrete life situations in which nanomaterials can be used (mainly related to milk processing: yogurts, cheese etc.); (g) communicating - in writing and verbally - the results of the investigative approach, using adequate scientific terminology; (h) analyzing the benefits and the limitations of the use of natural nanomaterials and nanotechnologies; (i) manifesting a responsible attitude towards the industrial use (in food industry) of such products, considering the need to promote healthy products for people's lives; (j) expressing a personal perspective regarding the importance of the social actors' involvement in the scientific research related to the area of nanoscience.

For reaching the proposed objectives, experimental approaches have been designed, to highlight nanoparticles in natural nanomaterials and to establish the correlation between structure and function. By means of those activities, the students expressed their opinion regarding to the use of nanotechnology. In this framework, it has been appreciated that students were encouraged to develop a responsible attitude to the maintaining of their fellows' health state. The module took place by means of four lessons (L) as follows: "*Description of the proposed natural nanomaterials (milk and gelatin), emphasizing their physical properties and familiarization with a series of notions to be used later on*" (L1); "*Highlighting the effect of the interaction between milk and the citric acid*" (L2); "*Implications of the use of nanotechnology (with specific applications for milk and gelatin), for a civic and moral responsibility of the students*" (L3); "*Designing of a mini-exhibition with posters or Power Point presentations* *promoting the novelties in the area of nanotechnology, together with the launching of a blog called:* "*Choose healthy eating!*" (L4).

The teaching activities involve a profitable use of the basic knowledge of chemistry, physics, biology and even civic culture. Their development has been realized via investigative approaches such as determinations, experiments, interpretations and debates. Those educational activities allow the students to manifest their civic sense and an adequate attitude to the present problems of the society (in conjunction with health, research, civism). The following types of teaching strategies have been proposed: inductive, deductive and heuristic, in order to shape and develop the students' exploration and investigation, communication and efficient group working, analysis and synthesis, but also evaluation skills. In this framework, the students have the possibility to become aware of the need to respect the ethical principles and values in the research-innovation approach.

Research methodology

The aim is to identify the RRI potential in the teaching-learning process specific for science education, designed for primary school students (3^{rd} and 4^{th} forms).

The target group is composed by students who find themselves in the primary educational cycle, in the 3rd and 4th grades and who were instructed in the direction of training cognitive and functionally actionable competences, on the natural nano–material theme, which has been approached during the "Natural Nano-materials" module. The target group is composed of heterogeneous educational groups which include boys and girls (42 – 20, in 3rd grade and 22 students which come from the 4th grade), with ages between 9 and 12, from urban schools. The instruction activities were coordinated by the guiding teachers of these classes, who are also a part of the educational experts group in the framework of the "Irresitible" project.

In this respect, a specific case related to the study of natural nanomaterials is analyzed, having the aim to increase the students' awareness related to the existence and usage of such materials. During the lessons, experimental approaches have been introduced in order to emphasize the nanoparticles in natural nanomaterials, but also to establish correlations between their structure and function.

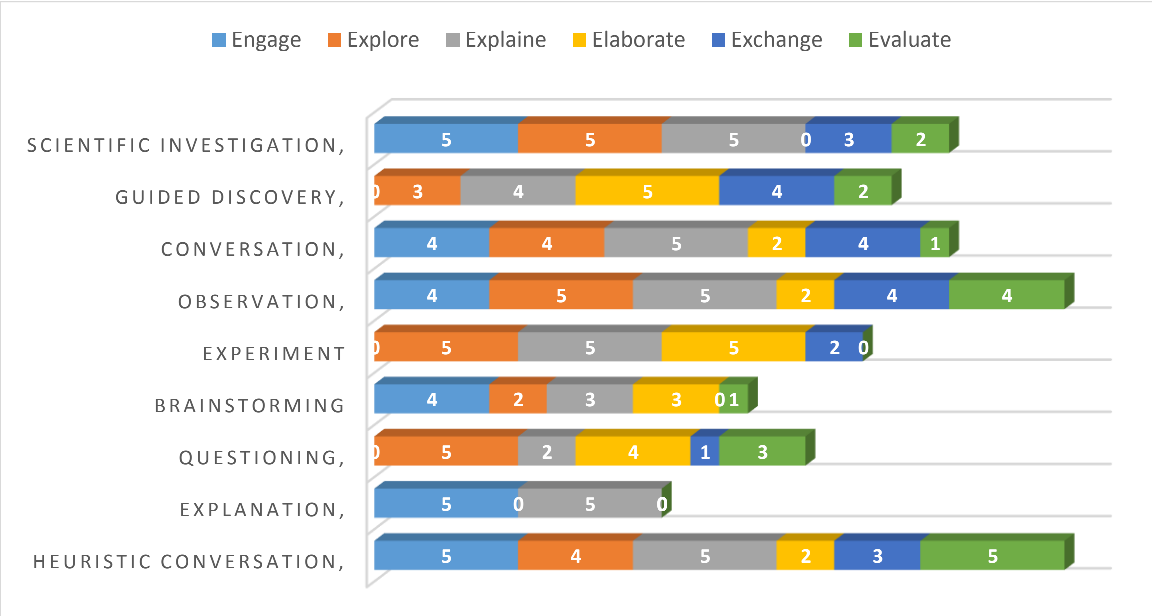
The overall objective of the research was to analyze advantages and limitations of the teaching strategy which tried to consider RRI dimensions in science lessons. Specific research objectives are oriented to: *analysis of the efficacy of the teaching methods used in the classroom* - mostly of the *IBSE - 6E Model*: *Engage, Explore, Explain, Elaborate, Exchange, Evaluate* (*OS1*), and *analysis of the way RRI becomes efficiency in the educational process* (*OS2*).

The data collection process took into consideration the learning objects proposed by the teaching unit and the semi-structured interview conducted with the primary school teachers. The teaching strategies adopted during the instructive educative process were described according to the constructivist learning model (Joiţa, 2009) using the following features: *cognitive learning* in relation to which the knowledge edifice relied on the interiorization of the information; and *social learning*, in relation to which the knowledge is a product of group dialogue.

Results and discussion

Concerning the analysis of the efficiency of the teaching methods used in the teaching design, it is considered that it can be measured by the evidences of teacher's perception of his/her own satisfaction regarding the used methods. It is appreciated that satisfaction in relation to the use of certain teaching methods has a positive correlation with the students' active participation in the learning process. In this sense, the evaluation of the teaching methods was realized by giving a mark, on a scale from 1 to 5, according to the students' satisfaction regarding the learning results. The distribution of the scores awarded is represented in figure 1.

Fig 1. Score related to the used teaching methods in correlation with the IBSE - 6E model



When analyzing the lessons sequences - held as part of the Unit -, the teaching methods can be gathered with specificity for each stage of the IBSE - 6E model (Table 1).

Table 1. Distribution of the used teaching methods for each model stage

Stage	**Teaching methods used in the "Natural nanomaterials" Unit**
Engage	heuristic conversation, explanation, problematizing, brainstorming
Explore	experiment, observation, conversation, guided discovery, scientific investigation, problematizing
Explain	explanation, conversation
Elaborate	explanation, case study, problematizing, debate
Exchange	conversation, explanation, case study
Evaluate	brainstorming, conversation

From the analysis of the teaching approaches - undertaken for each stage of the teaching plan and from the interviews with the teachers who coordinated the learning unit *Natural Nanomaterials* -, the following *advantages and limitations* of the proposed strategy have been identified (Table 2).

Those advantages were identified considering the teacher's perception in relation to the students' high degree of participation in the lessons. At the same time, the limitations of the used teaching strategies were identified in the context of the learning particularities, at the level of the group of students. It is appreciated that the constructivist type of learning (Jonassen, 2000) is dominant in the framework of the teaching strategies based on the IBSE model, and profitably exploiting RRI in the learning contexts.

Table 2. Advantages / Limitations of the proposed teaching strategy

Advantages		**Limitations**
Engage	The students are motivated by the presence of the inputs that stimulate the interest for learning	The activity is organized frontally; It keeps the audience passive; Use of the expository approaches
Explore	After each activity, a new product is created	Rigorous monitoring of the activities based on experimentation; It requires preparation and

		multiple resources
Explain	It produces transferable learning	The students' attention to the teacher is a short-term one
Elaborate	It encourages the development of high-level thinking skills;	Time-consuming stage;
Exchange	It develops interpersonal intelligence, team spirit, cooperation, tolerance, respect, help; it bridges the gap between theory and practice;	Difficulties in the individual evaluation of each student;
Evaluate	It assures the combination of evaluation with self-evaluation and inter-evaluation.	The activity is organized frontally.

Research conclusions

The learning model identified is profitably using the IBSE strategy and the 6E model, and successfully integrates RRI aspects at the level of the primary school groups of students (3rd and 4th grade). It is characterized by an active, constructive learning environment (idea exchanges are realized and value judgements are emitted), collaborative settings (the form of organization of the student class is the group made up of five students), where students model their knowledge. The development of the skills for each group member is mainly assured, and the students have the possibility to freely express their opinion in relation to the learning acquisitions. Such approach facilitates the recognition of the students' importance for themselves and for their fellows. More, the undertaken analyzed problems are complex, stimulating the reflection in relation to the importance of the acquired knowledge.

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