STEM Revisited:

A Paradigm Shift in Teaching and Learning the Science Related Disciplines

ABSTRACT

For an appropriate way to deal with teaching and learning the Science Related Disciplines (SRD) there is an axiomatic need to accept an integrated-holistic approach both in terms of the way we regard them and of how we practice them. As a result of that need, this paper presents a multi-prong proposition to substantiate that teaching and learning of the SRD have recently undergone a paradigm shift from a Relational Literacies approach, based on searching for knowledge, and which in turn has replaced the traditional Independent Disciplines approach, based on transmitting knowledge, towards an integrated-holistic approach, bringing education into the new Integrated Competences paradigm, which is based on formulating knowledge and which should be understood as representing the confrontation of the Science Related Disciplines with the real world and its conditions.

Key Words: Paradigm shift, Integration, Classroom knowledge, Science Related Disciplines.

1. INTRODUCTION

A basic principle of epistemology is that the way scientists are approaching and practicing their disciplines is limited almost exclusively by their *"myths"*. Any judgments scientists are making are based on their myths and are revealed in their minds as reflections of the objective reality [1]. Thus, a major concern in any scientific endeavour, including the approach to teaching and learning the *science related disciplines* (a broader than STEM term to connotate the accepted natural/positive science disciplines of Mathematics, Physics, Chemistry, Biology, Computer Science, Astronomy, etc.) is the source of their myths. Science educators invariably accept the notion that science related disciplines (SRD) should satisfy certain functional conditions that qualify their nature and require systematic ways in order to satisfy basic methodological needs. As a result, it should be clear that if we are to establish the right approach in considering teaching and learning the SRD, it is necessary to face the reality of their myths, which in turn constitutes an inseparable part of our envisagement of these disciplines as well as of our methods we use in applying them in education. The question that we need to ask in the current academic, technologic and socioeconomic environment is: what are the "myths" with which we have to approach the SRD in education?

Unambiguously and categorically, this paper declares that at the centre of the approach towards teaching and learning the SRD, should be the concept of a holistic approach or of an integrated education. I suggest that this concept constitutes the source of the SRD myths not only in terms of the way these disciplines are regarded in education, but also with respect to the methods used in applying them in teaching and learning. This inevitably leads to the position that the present approach to teaching and learning the SRD, as expressed by the STEAM or STREAM concepts, which have replaced the original STEM concept, is now absolute and we find ourselves in a period where the science related disciplines are regarded and applied within an integrated education framework.

This holistic approach might be considered incompatible with the current practices in teaching and learning the SRD. But necessary educational processes such as: openness, sharing, interpersonal relationships, discourse, personal motivation, tacit over explicit knowledge, as well as the sharing and reusability of learning resources on the web cannot be addressed in the traditional (i.e. the STEM approach) or the present (i.e. the STEAM or STREAM approaches) educational practices. Nowadays for an appropriate way to deal with teaching and learning the SRD there is an axiomatic need to accept a new approach both in terms of the way we regard these disciplines in education and of how we practice their teaching and learning. However, this integrated-holistic approach should be understood as starting with an educational science confrontation and out of that phenomenological confrontation comes a question related to the teaching of the SRD, one which is too broad to be answered by any single discipline or by the independent contributions of many disciplines.

This is particularly evident in the STEM type approaches where the educators pay lip services to skill sets such as: integrate content, interpret and communicate information, engage in logical reasoning, collaborate as a team etc. [2]. But applying such standards of practice is impossible within the epistemological framework they operate, since their approach by focusing on the nature of knowledge and how students learn, relies at best on a student-centered approach. However, such skills invariably require multidimensional relationships and interdependencies of the participating disciplines, necessitating an integrated educational process, which exceeds the capabilities of the student-centered paradigm.

Finally, the rational provided for supporting STEM type approaches usually take a purely utilitarian form [3] such as *"…STEM occupations are growing at 17%, while other occupations are growing at 9.8%, …STEM degree holders have a higher income even in non-STEM careers, … science, technology, engineering and mathematics workers play a key role in the sustained growth and stability of the U.S. economy*".[4]. Yet the presence of the SRD in education is necessitated mainly for providing an interdisciplinary approach, which rather than teach disciplines as separate and discrete subjects, integrates them into a cohesive-holistic learning paradigm, which represents their major educational contribution [5]. In other words, the SRD provision of knowledge is as valuable and their contribution is as important as any other discipline and not the determining factor in supporting their utilization.

From this brief introduction it should be evident that there is a need to connect education and SRD as to how we regard and practice classroom teaching and learning, towards achieving an integrated-holistic educational system. This objective represents the focus of this paper and is examined in the form of the following proposition.

2. THE PROPOSISION

The proposed new approach towards the SRD represents a multi-prong proposition expressed as follows: first, education constitutes a dialectic entity, part of which are the SRD; second education in general and the teaching and learning of the SRD in particular, are following a new educational paradigm; third the determining factor in the SRD changes observed are the result of the shifts in societal perceptions and beliefs; fourth the education paradigm shifts have been catalytic in altering the way knowledge is approached in the classroom; and fifth a constant and well defined principle has underlined all the observed changes. The proposition, as outlined, clearly indicate that in order to understand the role, the value and the impact the SRD have in education, it is imperative that we examine all these aspects:

The first aspect of the proposition is concomitant with the prevalent educational need that today's educational disciplines and especially those related to science, should provide combined, simultaneous and not fragmented competences, which cannot be dealt with unless we accept the fact that they represent different manifestations of "a whole", the ***dialectic entity*** of education, to which the SRD belong. Therefore, a holistic approach towards teaching and learning is imperative to address present and future conditions, where such disciplines represent a pivotal component.

The second aspect implies that a stepwise process of changes in teaching and learning the SRD has taken place, which was determined by the way ***education was considered and applied*** over time and which in turn was the result of the societal changes that took place. In other words, societal changes of the last few decades have been the determining factor in shaping the responses in considering and applying education and the SRD, which in turn led to educational changes that epistemologist Thomas Kuhn [6] has termed paradigm shifts. It should be noted that changing paradigms are not rare or unexpected events in education [7].

The third aspect suggests that the driving forces in the observed changes towards SRD are the result of the shifts in societal perceptions and beliefs. Indeed, it is universally accepted and well documented that societal values and goals are changing through time resulting in profound changes in all aspects of our lives, including the way teaching and learning is approached [8]. [9]. Following World War II and for many years, education, including SRD, had a ***limited value*** for society. Education was systematically downgraded and considered as just a tool in attaining other pressing societal objectives. It was only in the 1970's that the significance of education and especially of the SRD was recognized and the requirements of teaching and learning acquired a place at ***the center*** of societal interests. Finally, in the last few decades society realized that the world that surrounds us is simultaneously ecological, economic, social, technical/technological, political, cultural etc., in dialectic harmony with all aspects of the environment (natural and man-made), an integral part of which are the people and consequently their education. As a result, the new societal concerns have moved societal responses in dealing with educational problems and challenges, including SRD, towards a ***holistic*** approach.

The fourth aspect is concerned with the changes in the way knowledge in the classroom is treated and is based on the fact that epistemological arguments concerning education by necessity relate to knowledge. More specifically, dealing with classroom knowledge has changed from a mechanist way of simply ***transmitting*** knowledge contained within individual ***disciplines*** *(* i.e., the teacher instructs how water evaporates in physics and in chemistry that water is one of the physical elements), to ***searching*** for knowledge by creating ***literacies*** out of related disciplines (i.e. students in order to be familiar with phenomena and processes in physics, the necessary literacy, they have to be also familiar with certain mathematical principles), to finally ***formulating*** knowledge by instituting ***competences***, which have to include cultural, technical/technological, social, political etc. aspects as well as motivation, skills etc. The last approach is possible through the integration of all possible disciplines (i.e. the literacy related to any of the SRD or the ability to learn them is important, but learning how to learn them or have the competence for these disciplines is more fundamental).

The fifth aspect is related to the fact that in the last few decades although change was the driving mode in society and all of its expressions, at the same time a constant principal has been the determining force. More specifically, changes in society and the resultant adjustments in considering and applying education as well as teaching and learning SRD have been following the same sequence in their evolution through time. The ***independentance*** of the core factors/ disciplines was replaced by their ***interaction***, which in turn was substituted by their ***union***. For example, the independent teaching of well-defined disciplines was later replaced by their interaction producing relations, interdependences and interactions in the form

of needed literacies, which finally were readjusted as their union, producing an educational entity in the form of specific competences (Fig. 1).

FIGURE 1

3. CONSIDERING EDUCATION AND SCIENCE RELATED DISCIPLINES

The way teaching and learning of the science related disciplines is viewed, by necessity follow changes in the way education is considered, which in turn are based on the way societal values are reconstructed and are considered as societal goals. Every time a political, environmental, technological and in general a societal change is happening a new educational approach is needed to educate students for the existing and future conditions. However, every time an educational change is happening a new approach is required to educate students for the pivotal and challenging science related disciplines. This implies that over time a stepwise process of changes is formulated to respond to societal, educational and SRD adjustments. In considering education and the SRD, the following three approaches were in operation (Fig. 2, considering columns).

FIGURE 2

3.1 The Traditional approach

In the first period, the minimal societal concern for education led into accepting education as a way of teaching and learning the "what' and not the "how" [12], using the least controversial approach, whereby teachers and children were busy covering what was set forth in the textbooks and workbooks. In addition, because society and other scientist had little or no interest in education, teaching and learning was the exclusive realm of educators who were the only ones that could offer the methods, techniques and knowledge to handle education. Under this perspective, every particular discipline would be concerned with its own subject area and its practitioners consider them in an exclusive manner, creating a ***monodisciplinary*** approach to education.

At the same time, the minimal societal attention to education and the monodisciplinary educational approach provided the rationale to consider SRD in a fragmented way, despite the lip service provided by the STEM proponents to the need for these disciplines to be “brought together to make proliferating their importance easier” [13]. In other words, the science aspect of education was represented individually by the separate subject matters of the disciplines related to science, technology, engineering and mathematics, which were considered as the only ones that could offer the methods, techniques and knowledge to handle such specific science dimensions. In this monodisciplinary approach science was faced by specialized teachers through their “exclusive” independent disciplinaries, creating a ***fragmented*** science education. For example, there was a distinct and clear differentiation between physics and chemistry, which were considered as two distinct subjects to be taught by teachers from different disciplines. At the same time mathematics were considered as providing the tools in teaching these disciplines and not a necessary component in understanding them and shaping their role in formulating the entity of education.

3.2 The Existing Approach

In the 1970’s, the second period, there was a strong questioning of the monodisciplinary and the fragmented approaches the educational community was following, resulting in the development of alternative ways in considering them. That challenge has been eloquently presented by Newell who wrote

that "*An academic discipline is a challenging intellectual game at best, and a sterile and meaningless exercise at worst, when it is taken out of the context of human experience, which is always too broad and complex to be captured fully by any one discipline"* [11]. More specifically, all teaching and learning needs were considered as requiring to be approached from various perspectives and concerns [14], [15]. Education was treated as if it consisted of the sum of all the distinct parts of a multidimensional cultural, political, social, environmental and economic reality that led to a ***multidisciplinary*** approach towards education.

At the same time, the increase of the societal attention and the multidisciplinary approach to education, provided the basis for an alternative consideration of the SRD. An approach based on the notion that human knowledge necessitates "abstractions" of all aspects of reality and thus learning has to be expressed in the form of a set of ***separate relations,*** interdependences and interactions, especially in the SRD, where such an approach is absolutely feasible and extremely easy to apply. In the previous example, Physics, Chemistry and Mathematics all could and were participating on equal footing in the education process, but by providing their individual contribution in a set of separate and distinct approaches.

3.3 The New Approach

In the last few decades, the third period, society by accepting that our world has to be approached as a dialectic entity, has realized that today's multidisciplinary approach to education and the existence of separate approaches of the disciplines related to science cannot be acceptable anymore. A different teaching and learning approach is required in order to express the multidimensional relationships and interdependencies of all the disciplines that participate in the education process, which is the "whole". As a result, an ***interdisciplinary*** approach is required towards education. An approach that has to be simultaneously cultural, technical/technological, social, political etc., in dialectic harmony and respecting all aspects of teaching and learning an integral part of which are all disciplines and all education stakeholders.

In terms of the SRD at this period, the societal acceptance of the need to consider the world in a dialectic manner and the interdisciplinary approach to education, have led towards an ***integrated*** approach. This approach expresses the integration of all possible disciplines and their learning actors and processes in order to overcome the compartmentalization of knowledge, which presently is unacceptable. That is, there are no distinct boundaries between Physics and Chemistry, in the same way that we cannot determine where Science stops and Technology starts. In addition, no discipline can be considered as not belonging or have the ability to contribute to SRD. For example, in STEM the case was made to add the Arts and lately Reading and Writing, while Linder has written that "Geography is STEM!" [16]. That is, SRD should be considered as encompassing all disciplines, as none of the disciplines alone would offer a responsive to present needs approach, without contributions from other disciplines.

4. PRACTICING EDUCATION AND SCIENCE RELATED DISCIPLINES

The way educational tools are utilized in teaching and learning depend on the attitudes and the way society regards education. That is, changes in societal values and goals lead into changes in the way newly developed pedagogical concepts are practiced and reinforced. Moreover, every time a societal change is taking place and a new educational practice is formulated, a new methodological adjustment in teaching and learning the SRD is required in order to properly educate students in these fundamental disciplines, whose importance keeps increasing. This implies that over three time periods a distinct

process of changes has taken place in the way the SRD have alter their application mode in response to societal shifts and educational adjustments. In terms of the way we have apply education and the SRD, the following three approaches were the most profound (Fig. 2, practicing columns).

4.1 The Traditional Instructional Approach

In the first period, the use of tools utilized in teaching and learning depended on the attitudes and mind set of the education stakeholders and the way they practiced education, which in turn represented their adjustment to societal changes. In the traditional instruction approach the basic societal tenant of education as socially non-important activity resulted in a very simple classroom instruction mode**:** the teacher, the only responsible for educating students, transmits information to them who passively listen and acquire facts. Pedagogically, in this approach the subject matter and teaching methods are based on a well-defined instruction-based curriculum. This has led to the well-known and long-lasting traditional ***Teacher- Centered Instructing,*** which was focused on the simple transmission of a well-defined discipline's subject matter.

During the same period teaching and learning of the SRD was also a curriculum approach based on the idea of educating students in specific SRD disciplines (i.e. the focus of STEM was to improve the teaching of four specific disciplines: Science, Technology, Engineering and Mathematics). Every SRD discipline through its "exclusive" subject matter has been providing a fragmented and descriptive learning process (the way students can learn SRD), which was facilitated by the ***traditional instructional*** approach.

4.2 The Present Instructional Approach

In the 70's, the second period, the educational community had strongly questioned the Teacher-Centred Instructing and the discrete discipline approach to education, resulting in the development of alternative ways in formulating them. Following the changes in societal goals and the way classroom education was approached there was an intense push towards creating engaging learning environments that provide students with meaningful learning experiences from various forms of learning relationships, which are the result of discipline interactions. Under this perspective, education was treated as if it consisted of the sum of all the distinct combination of disciplines expressing the multidimensional reality. This corresponds to a ***Student-Centered Learning*** education which involves not only learning (practices, motivation, achievements etc.) but also the learner (backgrounds, talents, interests, capacities, and needs, etc.).

In terms of the SRD, in the second period the societal changes and the alternative to the traditional educational classroom approaches, led towards a new form of teaching and learning. This new approach was based on the fact that knowledge of the SRD necessitates "abstractions" of various aspects of other disciplines and thus learning has to be expressed in the form of a set of relations, interdependences and interactions between disciplines. In addition, the present SRD instruction approach by emphasizing the importance of interrelationships and interactions in fostering learning resources, requires the creation of participatory learning experiences. In other words, it is based on ***Constructivism*** [17], or how students learn to construct their own understanding and knowledge of the world and not on Constructionism [18], the theory that learners construct mental models to understand the world around them, which raises several questions and whose discussion is beyond the subject of this paper.

4.3 The New Instructional Approach

In the previous periods, the disciplines involved in the instructional approach were considered by the education community as independent and sometimes conflicting pedagogical forces. However, the literature and experience show that such an approach is clearly scientifically shallow, logically unsound and mainly lacking the necessary integration required in the complicated and dialectic present day scientific, societal and educational environment [11]. That is, mathematics is a necessity in transferring knowledge in physics, in the same way that teaching and learning physics cannot ignore subjects such as reading and writing [19]. By accepting such an instructional approach, where all subject matters are integrated and available to all students provide the instructional tools that can address the distinct learning needs, interests, aspirations, or cultural backgrounds of individual students or simply provide ***personalized*** instruction. In addition, what separates the new instructional approach from the presently used one, is the **blended** learning environment it can provide, which shows students how scientific methods can be applied to everyday life, by enabling them to confront the world through interrelations and interdependencies in the form of competences [20].

In terms of the SRD, in the third period, serious questions have been raised regarding the presently used instruction approach. Science educational stakeholders have finally begun to realize that the skills required in SRD should include arts and crafts, reading and writing, visual thinking, modeling etc. as access points for guiding student inquiry, dialogue, and critical thinking. It is evident that in SRD all disciplines are teaching and learning factors in the pedagogical process. Because all disciplines, including SRD, are closely interrelated, complementary and not conflicting they have to be integrated into a new ***holistic*** instructing approach.

4 PARADIGM SHIFTS

These changes and their resultant implications are of paramount importance in understanding the formulation of the paradigm shifts that have taken place during the last several decades. They basically are addressing the way **knowledge is transmitted** in the classroom during three distinct time periods (Fig. 2, paradigm column). More specifically, in the first period, teaching and learning was focused on the transmission of knowledge, determined by the chosen by the teacher specific discipline. In addition, the subject matter studied was remote from the daily concerns and interests of the children, but instead it had to follow the orthodoxy of the discipline's pedagogical concepts as they were set forth in the textbooks and the curriculum. The result has been the formulation of the ***Independent Disciplines*** paradigm, whose main SRD teaching tool has been the teachers' instruction (Fig. 2, first row).

During the second period, education was directed towards searching for knowledge by following a literacy approach in the classroom. The use of the term literacy follows UNESCO's definition, which refers to students' "ability to identify, understand, interpret, create, communicate and compute" [21], which are associated with varying contexts or disciplines. The result has been the formulation of the ***Relational Literacies*** paradigm, which utilizes the SRD to search for knowledge by focusing on both the individual learners (their heredity, perspectives, backgrounds, talents, interests, capacities, and needs) and on learning itself (the best available for all learners), in order to achieve literacies, which represents a step-wise improvement over the traditional paradigm (Fig. 2, second row).

In the final period, teaching and learning is focused toward formulating knowledge by instituting competences. Students are trained to construct their own knowledge of the world, by experiencing things including their cultural, technical/technological, social, political etc. aspects and reflecting on them. Moreover, students by questioning themselves and their strategies, become "experts" on their own learning, providing them with the necessary tools in the classroom to keep learning or *learn how to learn*.

Such an approach is leading towards the new ***Integrated Competences*** paradigm. which in opposition to the previous paradigms provides prescriptive and not descriptive learning or the way students should learn. (Fig. 2, third row).

A new teaching and learning the SRD paradigm has emerged, which is based on the two pillars on how learning is considered and is practiced and can be defined as the process in answering pedagogical questions, solving teaching problems or addressing learning topics utilizing SRD and which cannot be dealt with adequately by the traditional and the presently used educational paradigms. This new Integrated Competences paradigm draws on various perspectives that express multidimensional relations and interdependencies of the elements that constitute or represent specific aspects or parts of the SRD. Because of the present day societal and educational needs and the nature of the SRD all aspects reflecting on them have to be considered in order for integrations and not mechanistic sums to be achieved. It is through the execution of a holistic approach, based on a new SRD perspective and in dialectic harmony with the competences from various subjects that nowadays education has to be approached. This necessity has been recognized for some time, but unfortunately educational inertia cannot be easily overcome. For example, the Nobel laureate and physicist William D. Phillips in his biography wrote "*I enjoyed and profited from well-taught science and math classes, but in retrospect, I can see that the classes that emphasized language and writing skills were just as important for the development of my scientific career as were science and math"* [22]. In sum, the competence paradigm represents a one-way educational street in teaching and learning the SRD.

5 CONCLUSIONS

The starting point for this paper has been the recognition of the difficulty scientist trained in the 20th or the 21st century are having in understanding how to account the physical world in education, which has to take into account the basic principles of the ancient Greek philosopher Aristotle [23]. In other words, we can no longer look for precursors of modern ideas in teaching and learning without stressing the social and philosophical character of education.

Within this framework the previous discussion clearly validates Ryan and Bauman claim that "*We are in a time of emergence when the best advice is to observe and to be sensitive to areas from which change is emerging.*" [24]. Indeed, in the relative recent past changes in societal values towards education (from ignoring it, to bringing it at the center of societal priorities and to considering it as a dialectic entity) have led to changes: first, on how we consider education (from monodisciplinary, to multidisciplinary and to interdisciplinary) and SRD (from fragmented, to separate relations and to integrated); and second on how we practice education (from teacher-centered, to student-centered and to personalized/blended learning) and SRD (from disciplines, to literacies and to competences).

The new paradigm is characterized by its integrated nature, which is a quality that has generated many scientific discussions. Arguments against any integrated approach rest on a conceptual confusion expressed by professor Benson who has stated: "*integrated studies are a fool's project, propounding equations where all terms are unknown*" [25]. However, the Integrated Competences paradigm as a connection between integration, interdisciplinarity and personalized learning, should be understood as representing the confrontation of the SRD with the real world, be it a pedagogical, a societal, a teaching, a learning or any other issue. But out of this phenomenological confrontation rises a situation which is too broad to be handled by a mono or a multidisciplinary approach as well as by a teacher-centred or student- centred method, with no regard for the holistic nature of that world. That is, the purpose of the Integrated Competences paradigm is more than just to address questions that transect discipline

boundaries or integrate subjects or methods in achieving teaching and learning. It involves an articulate spectrum of principles to help the education system to determine when and how to confront the world by seeking out a holistic approach to interrelations and interdependencies, that can be achieved with the use of SRD in the form of their competences.

In sum, in the last few decades there have been two pedagogic shifts from the traditional ***Independent Disciplines*** paradigm, to presently used ***Relational Literacies*** paradigm, bringing education to the ***Integrated Competences*** paradigm. But most importantly, which is the thesis and contribution of this paper, is that the new paradigm in teaching and learning the Science Related Disciplines is necessary to overcome the scientifically shallow and mainly lacking the necessary integration present paradigm, in order to meet the complicated and dialectic present day scientific, societal and educational environment. Therefore, the integrated competences paradigm is here to stay and followed by all, if we are going to educate students for the complex and challenging present and future needs [26], [27].

REFERENCES

1. Furtado C. The Economic Growth of Brazil: A Survey from Colonial to Modern Times. Los Angeles: University of California Press; 1963.

2. Rouse M. STEM (science, technology, engineering, and mathematics). Whatls.com. Accessed 19 April 2019. Available: https://whatis.techtarget.com/definition/STEM-science-technology-engineering-and-mathematics

3.Langdon D. et al. STEM: Good Jobs Now and For the Future. U.S. Department of Commerce. Accessed 19 April 2019. Available: https://www.researchgate.net/publication/292321547.

4. Hom E. What is STEM education. Accessed 19 April 2019. Available: *https://www.livescience.com/43296-what-is-stem-education.html*

5. Koutsopoulos CK, Papoutsis P. School on the cloud: Transforming Education. Education Policy Analysis and Strategic Results.2016; 11(1): 31-47.

6. Kuhn TS*. The Structure of Scientific Revolutions.* Second edition. Chicago: University of Chicago Press;1970.

7. Hammersley M. Methodological Paradigms in Educational Research, British Educational Research Association on-line resource. Accessed 19 April 2019. Available: https://martynhammersley.files.wordpress.com/2013/11/methodological-paradigms-4.pdf

8. Koutsopoulos CK, Kotsanis Y. School on Cloud: Towards a paradigm shift. Themes in Science and Technology Education. 2014; 7(1): 47-62.

9. Koutsopoulos KC, Economou V. School on Cloud: Towards Unity not Uniformity in Education. British Journal of Education, Society and Behavioral Science. 2016; 16(1) 1-11: 2016.

10. Ralph Ross, "The Nature of the Transdisciplinary: An Elementary Statement," in Alvin White, editor. Interdisciplinary Teaching. San Francisco: Jossey Bass; 1981).

11. Newell W. The case for Interdisciplinary Studies: Response to Professor Benson's Five Arguments. Issues in Interdisciplinary Studies.1983;2(2):1-19.

12. Goodlad J. A place called school. New York: McGraw-Hill Book Company; 1984.

13. U.S department of Education. Science, Technology, Engineering and Math: Education for Global Leadership. Accessed 19 April 2019. Available: https://www.ed.gov/Stem

14. Anderson ES. The School District Role in Educational Change: A Review of the Literature, ICEC Working Paper. 2003;1. Accessed 4 March 2019. Accessed 19 April 2019. Available: http://fcis.oise.utoronto.ca/~icec/workpaper2.pdf

15. Godwin L, Kaplan S. Designing e-Learning Environments: Lessons from an Online Workshop. Innovate: Journal of Online Education. 2008; 4(4). Accessed 19 April 2019. Available: https://nsuworks.nova.edu/innovate/vol4/iss4/1

16. Linder E. Geography is STEM: Augmenting Reality to Convey Physical Geography and Remote Sensing in Class. EUROGEO conference, Paris, France, 2019.

17. Cakir M. Constructivist Approaches to Learning in Science and Their Implications for Science Pedagogy: A Literature Review. International Journal of Environmental and Science Education. 2008; 3(4):193-206.

18. Papert S, Harel I. Constructionism. New York (NY): Ablex Publishing Corporation;1991.

19. Debroy A. What is STREAM Education and Why it is Gaining Popularity? Accessed 19 April 2019. Available: http://edtechreview.in/trends-insights/insights/2968-what-is-stream-education

20. Kotsanis Y. Models of Competences for the real and digital world. In Koutsopoulos at al. Editors. Handbook of Research on Educational Design and Cloud Computing in Modern Classroom Settings: Hersley, PA: IGI Global Publications; 2019.

21. UNESCO. Understanding Literacy. In: Education for All: The Global Monitoring Report. Paris: UNESCO Report;2016. Accessed 19 April 2019. Available: gem-report-2017.unesco.org/en/current-report/

22. Phillps W. Biography. Accessed 19 April 2019. Available: https://old.nobelprize.org/nobel_prizes/physics/laureates/1997/phillips-bio.html

23. Duarte S. Aristotle's Theology and its Relation to the Science of Being *qua* Being' Apeiron. 2014; 40: 267–318

24. Ryan C, Bauman K. Educational Attainment in the United States: 2015 Population Characteristics. U S Departments of Commerce, Current Population Reports, P20-578; 2016.

25. Benson, TC. Five Arguments Against Interdisciplinary Studies. Issues. Integrative Studies. 1982; 1(4): 38-48.

26. Gialamas S, Pelonis P, Medeirod S. Metamorphosis: a collaborative leadership model to promote educational change. Thoughtful Mind, Institute for Innovation and Creativity, ACS, Athens. Accessed 19 April 2019. Available: http://issuu.com/acsathens/docs/final_publicity_book_2012/23.

27. Koutsopoulos CK, Kotsanis Y. Efficiency and Effectiveness: Need for new Paradigm. In: Williams DA, editor. Proceedings International Conference: The Future of education. Rome: Libreria Universitaria Publishing Co: 2016.

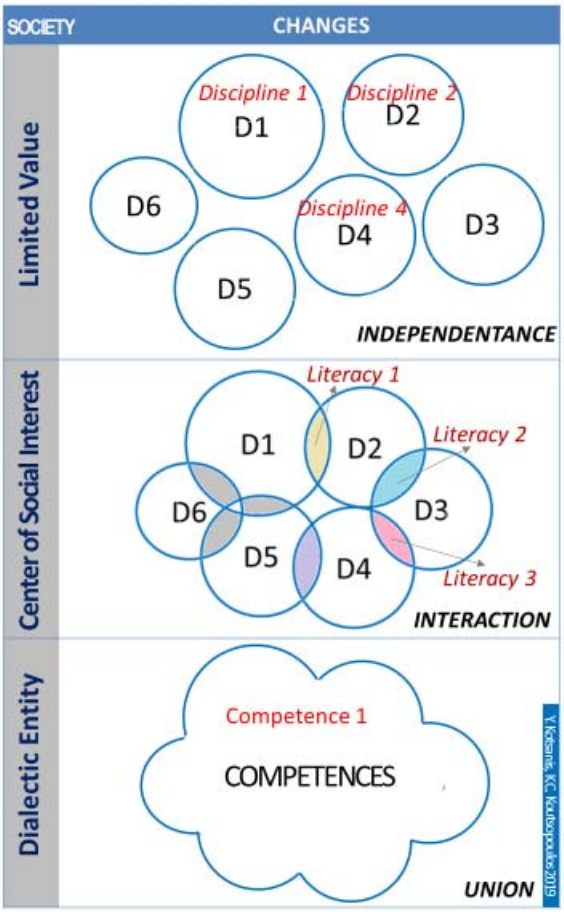
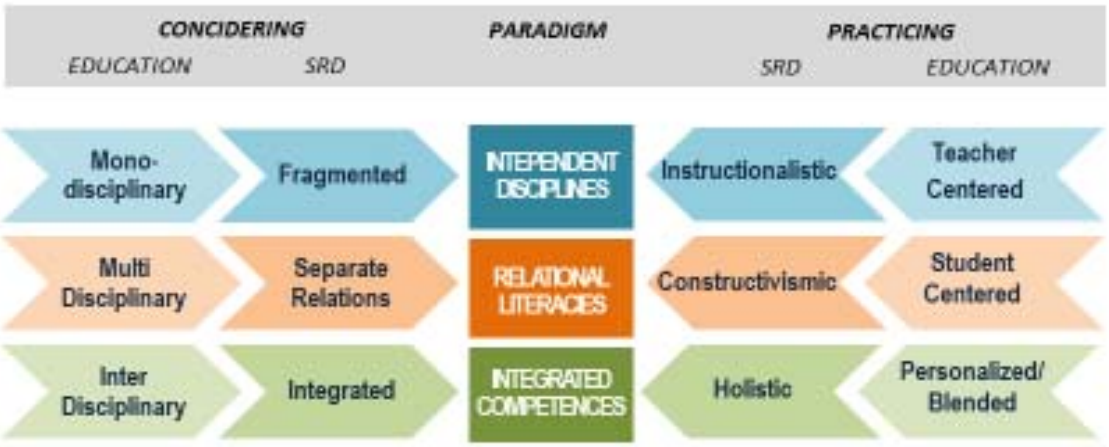


Fig. 1. The Determining Principle of Change



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488 Fig. 2. Changes in Society, Education and the SRD.