An Overview of Constructivism in the Special Needs Spectrum

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Abstract. Constructivism has dominated science education the last decades exerting great influence in that field. Nevertheless, this has not been the case for special needs sector. Indeed, few researchers have tried to extend constructivism in special needs and even fewer have investigated alternative ideas of students who lie within this spectrum. The current study tries, through literature review, to move along this line and present studies that have explored alternative ideas of students with special needs. In particular, published studies were identified through academic search engines which led to citation chasing. The collected data was read, and scrutiny analyzed leading to the final studies that were incorporated in the article. Therefore, the current article presents in a detailed and holistic view these studies that deal with alternative ideas of students with autism, learning difficulties as well as deafness about diverse physical phenomena such as mechanics, thermal phenomena, and the nature of science. Research findings suggest that these students tend to use the same alternative conceptions with those used by students of typical development, on a different frequency thought. These findings clearly support the academic belief of a holistic, inclusive education. Along this line, the findings can equip teachers with the appropriate tools to design and implement their plans based on the constructivism theory of learning in an inclusive framework. Consequently, the article fulfill to act as a motivational call for the science education community to expand research to further group of students within special needs spectrum.

1 Introduction

Natural sciences such as physics, chemistry, biology and geology have been a field of study for humans for over 2000 years. The ancient Greeks, pioneered by Aristotle, tried to study the various natural phenomena and formulate the first natural laws. Then, in the late 1600s AD, the Italian scientist Galileo Galilei proposed the scientific method, in which the experiment dominates, and which has been adopted by the entire scientific community to this day [1].

However, despite this long history of science, for decades the teaching of science has remained locked into the traditional method of the knowledge transfer model. According to this model, the teacher as an authority possesses a set of knowledge and skills that he or she

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is expected to impart to students [2]. It was in the mid-20th century when various alternative currents for science teaching that deviated from traditional teaching began to develop. The confluence of two of them contributed greatly to the development of teaching as we know it today as a distinct field of scientific research and study. The first starting current was based on the search for students' experiential mental representations and reasoning about the concepts and phenomena dealt with in science. The second starting current was based on the search for the difficulties and obstacles that students have to overcome in order to solve problems in science. The fusion of these two currents led to the creation of a new current, Constructivism, which proved to be fundamental in the development of science teaching [3].

1.1 Alternative Ideas

The title is set in bold 16-point Arial, justified. The first letter of the title should be capitalised with the rest in lower case. You should leave 22 mm of space above the title and 6 mm after the title. According to constructivism, students do not come to science classrooms as empty ‘vessels’ who have no idea about the way the natural world operates. Instead, they have their own ideas about a wide range of physical phenomena such as gravity, heat, electricity, and optics [4-8]. These ideas are formed in students' minds at a very young age, before they are even exposed to any form of instruction [9]. Various terms have been used in the international literature to describe these early ideas of students such as 'misconceptions', 'alternative ideas', 'preconceptions', 'prototypical views', 'conceptions' and 'frameworks' [10]. Researchers have assigned each of these terms a slightly different meaning and use them as appropriate. For example, the term ‘misconceptions’ is used when emphasis is given to the scientifically incorrect content of these ideas [11]. On the other hand, the term ‘preconceptions’ is used as long as the time period in which these ideas were formed is stressed, while the term ‘conceptions’ is used when the social character of these ideas is highlighted [12]. Finally, the term ‘primary views’ can be used to emphasize the widespread and generalized use of these ideas. In any case, what is of real value is the fact that regardless of the terminology used at any given time, all of these terms are used to convey children's ideas about natural phenomena that are constructed by children themselves and are incompatible with natural science [5]. For this reason, along this paper the the general term of ‘alternative ideas’ will be adopted.

Within constructivism, alternative ideas play a major role in learning science. That is, the ideas that a child has about a natural phenomenon are likely to influence the way he will perceive the scientific teaching of this phenomenon [13]. As Vosniadou points out ‘the cognitive processes are influenced by the nature of individuals’ expectations based on prior knowledge and past experience’ [14]. This is in conformity with the undeniable fact that when two people have a conversation about a subject, the degree they will transform their belief is closely related to their pre-existing ideas about this subject [5]. Along this line, when a number of people read a book or hear a lecture, each one of them is likely to grasp different meanings and pay attention in different points. To quote Hewson (1981) ‘different individuals construct alternative conceptions from the same information’ [15]. Imagine a physicist and an uneducated person watching in the TV an astronomy documentary about black holes. Undoubtedly, they will perceive the information presented to them in a totally different way, as the physicist will be able to make sense of terms such as photons, protons and gravity of light while the other will not. Another example is that of a doctor and another person watching an anti-smoking advertisement. While the former will be able to fully mentalize how exactly nicotine reacts with specific vital organs and damage them, the latter is likely just to get a general idea that smoking damages our health without being able to grasp the exact way this can happen. In parallel to this, students who listen to a science teacher should try to relate what they are hearing with their pre-existing ideas in order to grasp the deeper meaning of the lecture [16]. Nevertheless, as it was stated above, students have

alternative ideas which are not in conformity with scientifically accepted ideas. Therefore, the ideas pupils have are likely to play a negative role in learning science. Constructivist theory clearly states that these ideas will probably become an obstacle in students' attempt to grasp the scientifically acceptable theories [5].

1.2 The Nature of Alternative Ideas

As it was stated above, there seems to be a consensus among science education researchers that children hold alternative ideas from a very young age which play an important role in the learning process. However, there is disagreement among them on whether these ideas form a coherent model with an internal structure and hierarchy [17-19] or are scattered ideas used on occasion by individual learners [11, 20-22]. Irrespectively of this disagreement, all of them seems to acknowledge their persistent nature. In particular, these ideas seem to be resistant to change even after a well-planned series of formal teaching [5]. As a result, a number of pupils graduate from high school without abandoning any of these informal conceptions. Vosniadou et al [23] acknowledges this point and states that the majority of adults who are not practicing science in a professional manner, do not grasp the meaning of basic physics concepts such as force, energy, heat and temperature. For those adults, misconceptions remain stable and unchangeable for the rest of their life. What is more alarming for science educators are the findings of research conducted in students who have enrolled in one or two years of college physics in top universities such as Harvard and MIT. Unbelievable it may be, these pupils seem to have alternative conceptions that prevent them from understanding basic physics' laws. So for example, many Harvard undergraduates explain the fact that in summer it's hotter than winter by pointing out that earth is closer to the sun at that time [14].

An indication of the strong persistency of students' misconceptions is the fact that many of them 'reflect ideas which have held sway among scientists in the past' [24]. These ideas were supposed to be scientifically acceptable and were taught to the next generations for hundreds of years. An exemplar paradigm of this is 'caloric theory' which was the prevalent theory of explaining heat transfer in the late 18th and early 19th centuries. The fluid nature of heat, which was the main idea of this theory, is commonly found as a pupils' alternative conception by science educators nowadays [25]. Another informal idea which has its roots in a theory which used to be accepted by scientists in the past is the belief that there is no force exerted to an object which is not moving. According to Aristotle, each object had its natural place. As soon as the object was placed there, no kind of force was exerted on it [16]. Of course, this is incompatible with the current acceptable Newtonian theory of mechanics. Nevertheless, it is still used by many children in their attempt to deal successfully with mechanics tasks in school science lessons [23].

1.3 Role of Alternative Ideas in Teaching

As it was stated above, according to constructivism students' alternative ideas play a primary role in the learning process. Their emergence and exploitation by the teacher are therefore considered essential in any teaching process [26, 27]. In particular, these ideas are expected to be the starting point of any teaching intervention with the sole aim of modifying them in order to make them compatible with scientific models [5]. As Carey [28] points out, 'effective teachers' always start science teaching by trying to bring out their students' pre-existing ideas in the classroom. This knowledge is a useful resource not only for the teachers but also for the students themselves, since in this way they clarify their thought processes and are encouraged to further develop their critical thinking [29]. The means by which these ideas are brought out in practice vary and mostly include group discussions, questionnaires,

individual assignments and practical activities. A particularly popular and innovative way of bringing out ideas is through drawing, in particular sketches. Unlike questionnaires and assignments, drawing often fascinates children and eloquently reflects their thoughts and feelings. Moreover, sketches can prove to be very useful tools for eliciting ideas in students who have difficulty with oral language [30].

1.4 Constructivism in The Special Needs Spectrum

The last 30 years a vast variety of students that fall within the special education spectrum have gained access to typical schools [31]. Central role to this was played by the World Conference on Special Education, organized in Salamanka (June 1994) by 92 governments in partnership with The United National Educational, Scientific and Cultural Organization (UNESCO), which proposed a philosophy of respect and acceptance for all students with disabilities. In accordance with the decisions taken there, inclusive education is promoted for all students, included those that face diverse kind of disabilities such as learning difficulties, autism, emotional/behavior disorders, learning difficulties as well as deaf/blind and physically handicapped [32]. A number of other enactments and policies that have been arisen the last decades such as the 'Science for All' and the 'No Child Left Behind' act has reinforced the idea of inclusion specifically in science lessons [33].

Nevertheless, as research data explicitly show, students with disabilities face serious difficulties to accomplish success in school science and participate successfully in science activities [34]. What is more, they often underperform in standardized science assessments and consequently get lower graduation rates comparing to their peers [35, 36].

A prominent reason for this is that science education has not entered into the field of special needs while teaching of children with disabilities is rarely practiced under the prism of the theories that govern science education. Indeed, as Kaliampos [37] points out, few researchers have tried to expand constructivism into the wilderness of special needs spectrum. The current paper aspires to move along this line and present a comprehensive and detailed overview of the studies that have focused on the alternative ideas of students with special needs about different physics phenomena.

2 Research Methodology

The methodology that was used in this research was literature review. As the scope of the current article was to present an overview of the studies that deal with constructivism in the special needs spectrum, literature review was chosen as the most appropriate method. This is due to the fact that this method enables the researcher not only to confine into the fundamental and basic knowledge that embodies a specific research area but also to expand into interconnection with other research areas too. Therefore, the interconnection between two distinct research areas namely science education and special needs spectrum were sought through this method. Literature review acts as a tool of compilation and classification of other researchers regarding a specific research area [38]. Within this framework, an attempt is made of new insights and ways of interpretation to emerge. By so doing, instead of quoting everything that an author has written, the reader is encouraged to go a step further enhancing deeper conceptualization of the research area under study [39]. Along this line Hart [40] states that literature review encompasses an integrated research methodology that goes beyond the strengths of a study focuses on its possible limitations and controversies as well.

Within this study, research articles that deals with the expansion of constructivism into special needs spectrum were gathered and scrutiny analyzed. In particular, published studies were identified through academic search engines. Key words such as 'science education', 'special needs spectrum' and 'constructivism theory' were primarily used during the on-line

search. The collected data was read, re-read and used as a tool which led to the highly demanding citation chasing process. In this way, a crucial number of studies were collected leading to the final studies that were incorporated in the article. Along this line, priority was given to those studies that have at their core the exploration of alternative ideas of students with special needs about diverse physics phenomena. Such studies are presented below in a detailed and holistic view while an attempt was made to explore their results in the light of inclusive education.

3 Result

Special needs spectrum entails a number of diverse disabilities which differ both in their characteristics as well as in their intensity. As it was stated above, few researchers in science education have tried to explore the alternative ideas of students that fall into that scope and mainly students with autism, learning difficulties as well as deafness. In what follows these studies are presented.

3.1 Alternative Ideas in Autistic Adolescents

Kaliampos et al. [41] explored alternative ideas of autistic adolescents in mechanics. Autism is a severe neuro-developmental disorder with its estimated prevalence being 1% of the general population [42]. While strong evidence occurs for a genetic basis of the disorder, its etiology remains still unknown [43]. Pupils with autism are characterized by dysfunctions in two main areas: social communication and interaction and repetitive and stereotypical activities [44]. That is, those pupils face difficulty in processing and retaining verbal information often being unable to understand the social use of language as well as facial expression and gesture [45]. In addition, they exhibit profound inability in recognizing the emotional state of both themselves as well as the others around them [46]. Finally, they have not flexibility in thought facing difficulties in coping with changes in routine which inevitable leads them to adopt highly structured and disciplines life rules [47]. Nevertheless, quite interestingly, a relative high percentage of them of around 10% exhibit some islands of abilities; these are notable skills in specific fields, maths and natural sciences being among them [48-50].

In a sequence of studies, alternative ideas of 19 autistic adolescents on diverse concepts of mechanics such as forces, impetus theory and projectile motion were investigated [41, 51]. All participants were aged 12-16 years old, had a formal diagnosis of autism and were categorized as ‘average intelligent’ according to their score on WISC-III. In addition, their non-verbal age was consistent with their chronological age as it was assessed through Raven’s Standard Progressive Matrices (SPM) test [52]. For the exploration, a digital, well-structured Tool for Exploring Alternative Ideas in Autism (T.E.A.I.A.) was implemented. T.E.A.I.A. comprises a total of 24 tasks divided into 4 basic sections. Each section deals with a specific concept of mechanics and depicts comic figures in a variety of actions such as Obelix walking around carrying a menir in his coat, Mini hitting a ball with her racquet while the trajectory of the ball is depicted in the computer screen or a Smurf trying to move a stationary table without managing to succeed.

Research findings suggests that autistic adolescents hold almost the same alternative ideas with their typical development peers in mechanics. That is, they use the Acquired, Internal, Gravity and Push/pull model to deal with forces in diverse scenarios such as objects that are located in one place, objects in stable/unstable positions or objects that perform free fall [20]. In addition, they often resort to ‘impetus theory’ to deal with the force that is exerted in objects that are cast into the air [51].

However, the children's ideas differ considerably in some situations which is certainly worthy of attention. In particular, autistic adolescents do not use the push/pull model in cases where there is absence of movement. While they experience the 'physical effort' of trying to move an object, they do not count it as an exerted force in case that the object remains immovable. In addition, autistic adolescents seem to conceive 'impetus theory' in a different manner [51]. More specifically, a significant proportion of them do not adopt it at all. What is more, those who adopt it do not refer to the diminishment of the force within the launched object, an idea that hold a prominent place among typical development students. Moreover, autistic adolescents hold different alternative ideas regarding the trajectories that are expected to be followed by objects launched into the air. So, for example in the case of a flying airplane dropping a bomb, the vast majority of them predict a vertical, downward, straight path in contrast to the correct forward curve. Finally, they tend to use force models in a statistically significant more consistent way comparing to their peers. In particular, using the Monte Carlo method, a non-parametric analysis suitable for small samples (<50), between the two study groups (Group 1: $M = 8.21$, $SD = 1.93$ and Group 2: $M = 6.91$, $SD = 2.21$), a statistically significant difference for autistic adolescents compared to typical development participants ($U = 331.5$, $z = -2.39$, $p = 0.012–019$) was found in the consistency of the most frequent force model. A possible explanation of their tendency towards consistency can be relied upon Systemizing theory which counts for autistic characteristics [41].

3.2 Alternative Ideas in Pupils with Learning Difficulties

Katsidima et al. [53] investigated alternative ideas of pupils with learning difficulties in thermal phenomena. Thermal phenomena hold a prominent role in school curricula of many countries and are certainly an integral part of natural sciences. Therefore, being capable of grasping the laws that govern these phenomena at a very young age is undisputedly an advantage for studying science for all children, those with learning difficulties among them. Learning difficulties is a lifelong neurodevelopmental disorder which affects one's ability to acquire academic knowledge and skills in speaking, reading and writing as well as in mathematics [54]. Consequently, as Lee et al. [55] point out, these pupils confront difficulties related to concentrate and keep their attention focus during the teaching process as well as keep in their memory valuable information.

In Katsidima et al. [53] study, alternative ideas of 25 pupils with learning difficulties on diverse thermal phenomena such as heat, temperature and thermal expansion were explored. All participants were aged 4-7 years old and had a formal diagnosis of learning difficulties from Centre for Differential Diagnosis and Support. For the research study, a computerized Alternative Ideas Heat Exploration Tool (A.I.H.E.T.) was implemented. A.I.H.E.T. comprises a total of 5 tasks divided into 2 basic sections. The first section deals with thermal conduction while the second with thermal expansion and contraction. So, for example, a copper tube which one end is lit by a gas flame or a metal ball that get heated for a long time are depicted in the computer screen.

Research findings of this study also suggests that pupils with learning difficulties have similar alternative ideas with their typical development peers in thermal phenomena. In particular, they tend to interpret the conduction of heat via a substance which has the capability to move through the material. Along this line, they predict that the end of a copper tube will be heated as soon as the other end is lit by a gas flame. In addition, they often hold the view that the temperature of an object is closely related to the material itself. In accordance with the above, a metal spoon is naturally cold while a wooden spoon is naturally hot. Finally, pupils with learning difficulties deals in a correct manner with the expected increase in the volume of a heated sphere even if they rarely refer to notions such as expansion or contraction [53].

3.3 Alternative Ideas in Students with Deafness

Florentino et al. [56] studied alternative ideas of a group of deaf students about the nature of science. Deafness is a hearing impairment which affects one's capability to receive sound in all of its forms. Subsequently, conceptions of those children are totally and exclusively received through vision. To overcome their linguistic specificity, the deaf community have developed diverse official sign languages across the world (i.e. Libras in Brazil, BISINDO in Indonesia, BSL in British, GSL in Greece ect). Nevertheless, as literature clearly shows, there still exists concrete barriers in science teaching in deaf education that should be addressed [57].

In Florentino et al. [56] study alternative ideas of five deaf students about the way they imagine science were investigated. The participants were aged 12-14 years old and had a good understanding of Libras, the official Brazilian sign language. Students' drawings were used as a tool for data collection. In particular, the deaf students were asked to draw a picture about the way they perceive science, and then they were asked to explain, in Libras, their drawing.

Research findings suggests that alternative ideas of deaf students regarding nature of science could be divided into three broad categories which are the planetary-spatial view, the science mediated by the internet view and the atypical view. Regarding the first category, students referred to science in terms of 'discovery'. Therefore, they drew stars, sun, moon as well as a rocket and an astronaut in the role of scientist. Quite interestingly they pointed out specific equipment for human safety such as a helmet and a breathing mask. With regard to the second category, the deaf students mainly referred to chemistry and the role of experiments. Along this line they drew a laboratory which contained various elements such as microscope, cell, bone, DNA, recycling and vaccines. Finally, in the third category it was depicted an atypical view of science which was clearly alluded to video-games characters [56].

4 Conclusion

The research evidence to date suggests that students who lie in the special needs spectrum hold similar alternative ideas with their typical development peers. In particular, research suggests that while autistic adolescents and pupils with learning difficulties as well as students with deafness have some specific ideas regarding diverse physical phenomena, in general they seem to share common ground. This finding inevitably supports the concept of inclusion in science education [36, 58]. As soon as the students with and without special needs have the same alternative ideas, the argument goes, constructivism theory can be applied in classes which are aparted from both of them. In essence, this is the general spirit of inclusion. As Aucoin and Berger [59] point out, within the scope of inclusion, all students irrespectively of their abilities hold the same rights in education and should equally take part in school science teaching procedures.

Undoubtedly, teachers should take into account the specificities of each child and try to modify and enrich their strategies in order to meet his/her needs [60]. Nevertheless, the fact that all children seem to hold the same alternative ideas clearly makes this goal look more feasible. Indeed, the starting point of the teaching intervention would be the same for all while the process of modifying them in order to become compatible with scientific models could be implemented with specialized techniques that include the special needs spectrum. Therefore, equal opportunities for all pupils will arise in science education within the concept of a holistic, inclusive education [61].

Undoubtedly, research data is still confined and certainly its findings should be treated with caution. Further research is needed in order to explore in-depth the alternative ideas of

students that lie into special needs spectrum. Particularly, research should be extended in two directions, that is to cover more cases of children with special needs as well as more physical phenomena such as electromagnetism, optics, air etc. Having done this, the academic belief of inclusion in science education will be reinforced and enriched with practices that could be implemented in teaching process.

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