Gifted Education In The Enabling Sciences With A Particular Emphases On Chemistry

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ABSTRACT

The article provides syntheses and critical analyses of literature, creative insights, fruitful information, reflections on gifted education perspectives, and discusses the pertinent issues related to enabling sciences, with a particular focus on chemistry. The misconceptions among the gifted students, and a range of pedagogical approaches to resolve students' misconceptions in the sciences are discussed. The article emphasised on the development of psychosocial skills that enables the students to gain success and eminence as it is the ultimate goal of giftedness and gifted education. The implications of cultural issues on the development of students' psychosocial skills are described. The mental rotation and spatial ability that significantly affect the students in their developments of expertise and gain success in the sciences, are illustrated. The implicated issues surround the development of students' mental rotation and spatial ability are presented. The interrelationship between the mental rotation/spatial ability and the development of knowledge/skills in the sciences are discussed.

Keywords: *Gifted education, chemistry, science, misconception, mental rotation, spatial ability, psychosocial skills, culture.*

INTRODUCTION

It has been about a century that scholars, educators and researchers have been relentlessly making efforts to understand the pertinent aspects and issues encompassing giftedness and gifted education practices. However, a clear and solid definition of giftedness is yet to be articulated that has a wider acceptance or broader consensus worldwide. In gifted education, abilities are important, and the amount and source of ability, the balance of general and specific abilities, and the exact nature of specific abilities vary by talent domain. Giftedness is domain specific, and the domains of talent (viz. chemistry) have specific developmental trajectories across the life span. The psychosocial variables are important contributors to outstanding performance at every stage of talent development. The psychosocial skills of the gifted students play the greatest role during their transitions from expertise to eminence, which should be the goal of gifted education (Subotnik, Olszewski-Kubilius, & Worrell, 2011). Gifted education is strongly linked to the developmental needs of individual; and individualism is found to be embedded in gifted education (Schulz, 2005).

The nature and criteria of gifted students and their learning abilities are well studied and reported. Few common examples are: Gifted students can learn at a faster speed, and they learn the core curriculum quickly (Plunkett & Kronborg, 2007). In a mixed ability class, a gifted student can memorize as much as 12 times faster and, for complex information processing and higher order thinking, they can be 4 times faster than the slowest student (Start, 1989). Gifted students can show their performance capability in any domain of human ability at a level that is significantly higher than generally expected (Miraca U. M. Gross, 1999). Gifted students are asynchronous, their developments are uneven. They are highly emotional, and they have a higher awareness of outside world and environment. As a result, the gifted students may not find proper emotional resources to match their cognitive awareness (Hoekman, 1994; L. Silverman, 2009). Many teachers find difficulties to meet the pedagogical needs of highly gifted students in a mixed ability class. Gifted students expect their companionship with intellectual and emotional maturity. If the gifted students do not find such companionship, they may either conceal their intellectual and emotional maturity in a way that can be accepted to classmates, or they may isolate themselves, or try to adjust with age peers (M.U.M. Gross, 2004; L. K. E. Silverman, 1993). Students can be gifted in a range of knowledge domains. However, giftedness in one domain does not guarantee their gifted thinking into other domains. Some gifted students may even display underachievement and learning difficulties (Munro, 2011).

Students' misconceptions or alternative conceptions in the enabling sciences are common, and these have been widely studied. Since the last few decades researchers have addressed ranges of students' misconceptions in the sciences (D. Palmer, 1993; Tao & Gunstone, 1999), and are continuously unfolding the inherent causes and effects, the ramifications, and how those particular misconceptions that students hold can be resolved or overcome. Researchers have already identified a range of misconceptions in the enabling sciences that exist in students' minds. However, it is also research proven that like the general students, the gifted students commonly have gross misconceptions in the sciences (Greco & Greco, 1987). Students' misconceptions are generally developed from their experiences, and are shaped by a socially constructed common sense ways of describing and explaining the world (Tao & Gunstone, 1999).

In current situation, science educators are facing enormous challenges (Batterham, 2000; Mohammad A. Chowdhury, 2013, 2014; Kiemer, Gröschner, Pehmer, & Seidel, 2015; Tytler, 2007) around the globe as students' motivation and interest in the sciences are decreasing at an alarming level. In recent years, students' interest and motivation in STEM (Science, Technology, Engineering and Math) subjects has dropped significantly throughout secondary education (Kiemer et al., 2015). Tytler's science education study (2007) revealed that Australian science education is currently in severe crisis, where students are increasingly developing negative attitude to science over the secondary school years. A decreasing participation is evident in post compulsory science subjects as well as shortage of science qualified people in the workforce, and qualified science teachers (Tytler, 2007).

Gifted students are often intrinsically interested in science, however under the prevailing curriculum, dull routine, recall-based assessment, and a lack of meaningful learning experiences may turn the gifted students away from sciences (Watters, 2003). In order to prevent it, school systems need to provide a challenging and meaningful learning experiences to our gifted students. In this context, Batterham (2000) pointed out the root causes of the current declining trend of interest in science education; and he highlighted the almost desperate state of undergraduate science education in Australia, particularly in the enabling sciences, such as, mathematics, physics, and chemistry. The brightest and best minded students are not attracted to scientific careers in part because of the poor rewards in science, and also the experiences they endure in schools, do not help to motivate them (Batterham, 2000).

A recent parliamentary paper of the Victorian state government of Australia (Parliament of Victoria, 2012) revealed that there are up to 85 000 gifted students only in the Victorian state schools in Australia. The report acknowledged that under the present circumstances, these children are neglected by the current education system that largely assumes that all students learn at the same rate and in the same way. These gifted students are frequently frustrated and disengaged due to the highly unsatisfactory picture of the gifted education system across the entire state. Apart from societal misconceptions, misunderstanding and a lack of support of gifted education, the other important factors such as, lack of gifted education provisions, poor understanding in the utilisation of the correct pedagogical approaches to gifted students, and students' declining motivation and interest in the sciences, are all contributing to the poor gifted education systems or provisions that exist in Australia, and around the globe.

This article provides syntheses and critical analyses of literature, creative insights, fruitful information, reflections on gifted education perspectives, and the pertinent issues related to sciences, chemistry in particular. The misconceptions in science/chemistry among the gifted students are discussed. A range of pedagogical approaches are discussed that may help to resolve students' misconceptions in sciences. The article emphasised on the development of psychosocial skills among the students to gain success and eminence. The implications of cultural issues on the development of students' psychosocial skills are described. Mental rotation and spatial ability are discussed as the important factors that significantly affect the students in their developments of expertise, and gain ultimate success in the particular domain of enabling sciences such as, chemistry. The implicated issues surround the misconceptions in sciences, and the development of students' mental rotation and spatial ability are presented. The interrelationship between students' mental rotation/spatial ability and development of knowledge/skills in the sciences are discussed as it is evident that the improved abilities in spatial/mental rotation significantly impact on gaining enhanced knowledge and skills, and was manifested by various research outcomes. The information and discussions presented in this article may be helpful to teachers, educators, researchers, scholars, curriculum developers, schools, and STEM education.

Effective pedagogy and outside-of-school programs to improve knowledge, learning, motivation, and interest in science/chemistry

An elementary school-based chemistry study found that children do not see chemistry as encompassing the world around them. Many students cannot classify the materials into the categories of solids, liquids, gases or elements, compounds and mixtures; and students cannot grasp the conceptual understanding of these terms. Chemistry appears as fragmented to children. And as a result it is found that by the fourth grade of their school, children perceive the science or chemistry as dull and boring, and tend to avoid the subject (Gabel, 1985). Some young children have subconscious fears of chemistry which are sometimes transferred to them by their teachers; and many children have never had a meaningful or pleasant exposure to science (Greco & Greco, 1987). Thus it is necessary that when science and chemistry are taught to the elementary school students, a proper nurturing, non-threatening and enjoyable environment is ensured. In this respect, Gabel (1985) suggested that students should be allowed more on observation than reading and listening; conceptual ideas need to be taught during any experimentation; macroscopic properties to be presented more than microscopic characteristics, and both simple process skills as well as integrated science process skills should be taught to them (Gabel, 1985).

Chemistry is an interrelated web of concepts, practical skills, models and facts. Students who will learn chemistry are required to gain explorative skills with identified thinking tools that help them to explore questions in the sciences, and hence understand chemistry better (Chemistry, 2012). The highly abstract nature of chemistry is itself a barrier for many students to comprehend the subject, and even at the undergraduate level (Ware, 2001). Gabel reported (1999) that teachers generally try explicitly by integrating macroscopic, sub-microscopic and the symbolic phenomena as proposed by Johnstone (Johnstone, 1991) to explain the abstract nature of chemistry. However, research (Gabel, 1999) shows that in many cases and, because of the improper integration of these three phenomena, it can make the chemistry obscure to students' understanding. Thus to improve students' understanding of chemistry, chowdhury (2013) emphasized that the maximum effort that is required in various areas of chemistry education are based on both the classroom and laboratory practices. It was suggested (Mohammad A. Chowdhury, 2013) that the basic emphasis should be given on the way how students can learn chemistry; gain knowledge, be motivated and inspired to apply the knowledge in real life. Students want to see the applications of science or chemistry in real-life situations, and various practical implications that make sense to them such as, experience in industrial settings and dealing with various problem solving issues. Thus it is important to relate chemistry to real-life situations and various practical implications that are interesting and relevant to them. And such practical implications in real life will effectively lead the students to get interested in chemistry. Both in higher secondary and undergraduate curricula, the chemistry concepts are taught theoretically, and these are mostly confined to the classroom learning environment, which does not allow the students to perceive and learn chemistry in a real-life situation (Mohammad A. Chowdhury, 2013). If the students are able to know and understand how science and chemistry are contributing to the improvement of human conditions or environments, it can provide them a motivational spirit to learn science and chemistry.

Several studies for the gifted and talented elementary students on the outside-of-school chemistry laboratory programs were reported that particularly aimed for grades 4-7 children. In these programs, each selected student was given a laboratory note book and was provided a special environment where the tools and chemicals of the senior college students were allowed them to use. It revealed that these students were actively involved and enjoyed the program; students' vocabularies had grown quite noticeably, and the questions and observations that the students recorded in their notebooks showed numerous improvements and sophistication. Participating students were able to link their own experiments much better than the set procedures with an occasional suggestions from the teachers. These students were able to vary the experiment to test their predictions or answer the questions. After completion of the programs, all participated students were excited about chemistry, and showed their interest to take a more advanced class (Carlson, 1988; Howard, Barnes, & Hollingsworth, 1989).

In another study, Farrell et al. (1988) reported their experience from an enrichment program in the area of sciences that was aimed for the bright and talented high school students. The program focused on the laboratory components of organic chemistry and team project activities. The chemistry laboratory allowed the students to work with concepts (viz. 'ferrocene' chemistry) and sophisticated instruments (viz. flash column chromatography, infra-red, UV-Visible and NMR spectroscopy) that were significantly advanced than those normally found in a high school environment. It was found that 90% of the males and 79% of the females who participated in the program were mainly from the urban areas. And the program concept showed its effectiveness in promoting students' interests from both rural and urban areas to pursue their careers in sciences. The outcome of the program showed that the selected students of that program expressed their enthusiasm for science in a number of ways. Students actively promoted the science/chemistry education in their home school districts. Beyond that initiatives these students further selected the schools that have strong technical programs for their advanced education, and effectively pursued their careers in the areas of sciences (Farrell, Pfeil, & Caretto, 1988).

Gifted students in science and chemistry are expected to display their expertise by the time they reach at the secondary level in school. The common expectations from the gifted students of gaining their expertise in chemistry or science have been highlighted by the Royal Society of Chemistry. In general, these aspects are also common to other subject areas which include good independent learning skills, the ability to make links to other knowledge and concepts, communication skills, teamwork skills, generic study skills, higher order thinking skills e.g., critical and creative thinking, metacognition and problem solving abilities (Chemistry, 2012).

Misconceptions in the sciences

The fundamental premises of students' misconceptions lie at the early stages of schooling when children are in the process of building their own world view. At this stage, students require adequate attention, support and assistance to learn, understand, and construct the scientific knowledge presented to them. If the children do not find adequate support and assistance to properly capture the scientific knowledge, it may lead them to develop misconceptions in many contents of the sciences. These conceived notion of misconceptions may remain in their minds while they advance to the higher grade in school. Thus it is quite necessary that these misconceptions are resolved or eliminated identifying them right at the beginning. If the misconceptions among the students are successfully resolved at the earlier stage, it helps the students to capture the fundamental principles, laws and models related to that context without any significant difficulties when those students are progressed at their advanced level.

Many gifted children have little knowledge about the meaning of science. Children begin to learn science with preconceived notions about scientific matters where most of these notions are misconceptions, and children often retain their misconceptions (Woods, 1994). Misconception is very resistant to change, and represents a major challenge to science educators (D. H. Palmer & Flanagan, 1997). Many students including the gifted hold misconceptions because these students fail to integrate accurate scientific knowledge with their own personal knowledge of the world. Students view the scientific knowledge as separate and distinct from their personal knowledge (Kyle Jr., 1989). Students will hold a particular alternative view, and will not change their ideas unless these students become dissatisfied with the existing conditions, and the scientific conceptions presented to them are intelligible, appear plausible and useful in a variety of new situations (Posner, Strike, Hewson, & Gertzog, 1982). Thus it pivotal that an effective curriculum, teaching, and nurturing practices with appropriate pedagogical tools are applied to eradicate students' misconceptions in sciences. This way it helps the students building their own world view with an ability to construct a proper scientific knowledge without any error.

Students' misconceptions in the sciences are quite common which cover a broad range of areas. Teachers and science educators are constantly facing the challenges as to how the correct scientific concept and explanation can be presented to their students overcoming any particular misconception/s that students may hold surround that content knowledge. Few particular examples of the misconceptions that are related to the key concepts of mass, velocity, acceleration, and force are as follows where students constantly struggle to gain correct explanations**:** Some students believe that speed of an object decreases even though the net force acting upon it is zero. Many students find difficulties visualising and comprehending a frictionless world (Gauld, 1998). Some students believe that there is a linear relationship between force and velocity instead of force and acceleration, hence they expect a constant velocity from a constant force (Eryilmaz, 2002). Some students struggle in understanding the interaction between the opposite forces (Gunstone & White, 1981).

During teaching instruction, many students could be vacillated between the misconceptions and the scientific conceptions from one context to another which may create obstacles for them in gaining and understanding the correct scientific explanation. In one study (Gunstone & White, 1981), it was found that the students with different ages (year 6 and year 10 groups) who had misconceptions in 'motion-implies-force' displayed their conceptual changing pattern in conceptualising the situations presented to them despite the fact that these students demonstrated their metacognitive ability of the process by describing and reflecting upon their change of view. In another study (Tao & Gunstone, 1999) that was performed on the process of students' conceptual change about 'force and motion', used computer simulation programs and Predict-Observe-Explain (POE) tasks. This study revealed that during the teachers' instruction, many students were vacillated between misconceptions and scientific conceptions from one context to another which indicated that their conceptual change was context-dependent and unstable. Few students who achieved context-independent and stable conceptual change were able to perceive the commonalities, and accepted the generality of scientific conceptions across the contexts. Thus a pattern of conceptual change (from context-dependent to context-independent through a generalisation process) was identified. This study supports the idea that the teachers may encourage their students in appreciating the generality of scientific conceptions, which may help to improve the understanding, and avoid misconceptions.

Resolving misconceptions in the sciences

If the gifted students are appropriately challenged, it is most likely that these students will display their latent abilities (Plunkett & Kronborg, 2007), and well performances. Thus in order to eliminate the misconceptions in sciences, students including the gifted should be challenged for their misconceptions using proper teaching techniques and instructions. The most effective strategy to resolve the misconceptions among students is to apply the scientific principles in a useful way that ultimately helps to resolve misconceptions. Students' conceptual change in any scientific context is more likely to occur if any alternative is presented to them in a plausible manner. The plausibility of concepts being taught to the students increases their ability to gain the correct concept if any justification is provided (Gauld, 1998) for the ideas behind, which the students already possess.

In many cases, during the classroom teaching practice, the conceptual change discussion is an effective way to eliminate a number of misconceptions in many particular areas of sciences that students hold. This methodology has found to be successful that significantly improves students' achievements of gaining the correct concept about the sciences, force & motion, for example (Eryilmaz, 2002). In another similar approach (D. Palmer, 1993) it was suggested that the students' understanding of scientific and non-scientific aspects are required to be taken into account, and then students should be encouraged to reflect upon the facts as to whether there is any relationship does exist between these two aspects. From that relationship, students are able to find the differences that sharpen their critical thinking abilities, and improve their critical scientific understanding, and hence students can draw their conclusive knowledge with a clear understanding of the scientific facts and evidences. Thus this way of approach is also effective to eliminate misconceptions in many areas of sciences that students may hold.

Gauld (1998) also suggested that when the students are in the process of conceptualising and acquiring knowledge of any important scientific context, then the teachers can provide the historical justifications and illustrations encompassing that context, and try to convince them in a plausible manner with many propositions and arguments around that context (Gauld, 1998). This area of approach has positive implications of particular area of sciences such as, global warming or any environmental issue related scientific topics.

Finally, the combination of the observation-based and the scientific principle-based approach (Yin, 2012) is probably the most effective technique to eliminate students' misconceptions in sciences. The observation-based approach which involves the POE (Predict-Observe-Explain) activities can be insufficient due to inherent limitations as some phenomena of the science may be difficult to observe; some observations may be counteracted with other evidences or distorted or can be biased with the previously held ideas. The principle-based approach helps students to practice the abstract thinking skills and to appreciate the fruitfulness of scientific principles. If the objects being involved in science teaching are available for demonstration, the teacher may employ a POE activity; ask the students to discuss the questions first, and then demonstrate them what happens related to that object. Teachers may then ask the students to examine different predictions, and highlight the advantages of scientific conception over misconception. This way observation-based approach supports the prediction guided by the scientific principles rather than by the misconceptions, and eventually it helps to remove students' misconceptions in the sciences.

Psychosocial skills development

In education, gifted education in particular, less emphasis is given on the development of psychosocial skills among the students, which is paramount for all students to gain success that effectively lead to display their eminence in any domain of education. Thus considering the facts of intense emotional nature, asynchronous characteristics, and uneven types of development that are observed among the gifted individuals, it is necessary that an enjoyable, friendly, non-threatening, and supportive learning environment is ensured in the classroom for all students including the gifted that can facilitate all students to develop their psychosocial skills.

In the day-to-day classroom practices, where a dynamic teacher-student interactions take place on a regular basis, a proper nurturing practice is quite important. In this case, teachers' interpersonal behaviour and personalities will have profound impact on students' attitudes towards science/chemistry. Thus to establish a unique and enjoyable learning atmosphere, a more open-ended learning environment is necessary for the students since an open-endedness and material environment are significant predictors of gifted students' positive attitudes to science/chemistry (Quek Choon, Wong, & Fraser, 2005).

When the development of students' psychosocial skills are considered, it is very important to address the cultural issues such as, 'cross-cultural border crossing' in science education and science teaching (Phelan, Davidson, & Cao, 1991) where students require assistance or support. It especially applies to the students who are from different cultural backgrounds. In the daily life, students regularly experience their interactions between students' life-world culture and the culture of school science which may often be conflicting due to cultural-clashes, and this may lead to a painful cognitive conflict that students want to overcome. This conflict may create obstacles for those particular students to gaining their success in the sciences (Costa, 1995; Jegede & Aikenhead, 1999; Phelan et al., 1991). These cognitive conflicts are created with indigenous or non-western knowledge base brought into the classroom, and may occur in the arena of students' own culture or in the realm of their beliefs or attitudes (Mohammad A. Chowdhury, 2016). These particular students generally undergo a mental and cultural ecdysis (Jegede, 1995) while resolving these conflicts. As the current school science projects only one world view i.e. western view (Jegede, 1995), hence the non-western students find difficulties, especially in a western environment, in learning science in a meaningful way. This is because these students constantly face an extra obstacle in their understanding and learning of science concept as they have to resolve their cognitive conflicts while they learn science.

Up until now it not clear yet as to how the gifted students use their adaptation strategies to overcome their cultural borders or obstacles while travelling on a daily basis across three common domains (i.e., family, peers and school). But it is certain that the students in general who are from different cultural backgrounds, experience this cognitive conflict or psychological pain that affect their psychosocial norms. Thus it is essentially required to resolve these conflicts, make students cultural transition easier, and remove the psychological pain that those students experience. This conflicting situation that students experience is more prominent in a pluralistic society where multiculturalism is an essential component of the social fabric. Thus many students within a multicultural environment experience serious problems of their cognitive conflicts between those two worlds which evidently affect their science learning, and certainly affect their developments of acquiring psychosocial skills.

Finally, as the certain specific and essential abilities (viz. metacognitive skills, learning skills, thinking skills, knowledge, and motivation) among the students are the basis to develop their expertise in any domain of education (Sternberg, 1998), then arguably, apart from these abilities, the development of psychosocial skills among the students are the most important factor that should be considered in the school education (Mohammad A. Chowdhury, 2016). The underlying reason is that students' psychosocial skills are the pre-requisite for their success in all domains (Subotnik et al., 2011) including the STEM subjects, and these skills-set will effectively lead the students to achieve their eminence, which is the ultimate goal of giftedness (Subotnik et al., 2011).

SUMMARY

Gifted students may hold misconceptions in science and chemistry. The combined observation-based and scientific principle-based approach is the most effective technique to eradicate students' misconceptions in science and chemistry. Proper nurturing, pleasant and non-threatening environment may help to reverse students' demotivation and disengagements in science and chemistry. Emphasis should be given on the way how students can learn science/chemistry, get motivated and are inspired to learn more about science/chemistry, and how students can apply their knowledge in real life. The outside-of-school chemistry laboratory programs designed for the gifted and talented students in both elementary and secondary levels are very effective to inspire the students and enhance their interest and motivation in chemistry. Emphasis should be given on the development of metacognitive skills, learning skills, thinking skills, knowledge, and motivation to become expertise in science/chemistry. In order to gain ultimate success and eminence in science/chemistry, students should develop their psychosocial skills. The cultural issues pertaining to students' experience in cultural-clashes are essential to address in science education and science teaching.

Mental rotation / Spatial ability in the sciences

In the sciences, chemistry in particular, students need to gain appropriate scientific knowledge, spatial awareness, and frequently exercise the following aspects to develop their expertise that enables the students to visualize (three dimensions, models etc.) the objects under study. Students should gain the ability to choose the appropriate model to utilize, and they should be able to apply the abstract models, use the published data and verify the limitations found in the models, and hence students should be able to effectively evaluate the usefulness or the reliability of the models and the data in hand. Students are required to acquire practical and investigative skills, gain breadth and depth of knowledge in science/chemistry with an ability to apply the fundamental concepts of science or chemistry to novel situations, and also acquire mathematical skills to apply to a chemical or scientific context (Chemistry, 2012).

Mental rotation is one spatial task, and is not inherently numerical or quantitative in nature (Prescott, Gavrilescu, Cunnington, O'Boyle, & Egan, 2010). Humans can accurately measure two-dimensional (2-D) images of a three-dimensional (3-D) object which represent the same 3-D shape despite changes in the 2-D object's orientation (Stransky, Wilcox, & Dubrowski, 2010). Mental rotation is a hypothetical psychological operation in which a mental image is rotated around some axis in a three-dimensional space (Zacks, 2008). Although individual differences in intelligence and spatial ability are associated with the proficiency in mental rotation, however the relationship between the spatial activities and the mental rotation is complex (von Károlyi, 2013), and it is not clearly understood. Individual's mental rotation skill may vary according to his or her spatial aptitude. However, upon active interventions such as, practice, training, and specific spatial experiences may enhance the mental rotation skills and performances in the STEM domains (von Károlyi, 2013). In general, the mental rotation ability can be improved, and the effects of mental rotation training may transfer to different mental rotation tasks (Stransky et al., 2010).

Spatial talent principally lies in the capability of understanding and reasoning the spatial relations among objects or spaces. Spatial talent is complex, multidimensional, and encompasses many combinations of abilities (von Károlyi, 2013). In recent period of time, the concept of spatial ability has gained significant attention in the area of STEM gifted education under the banner of "mental rotation" skills. Mental rotation and spatial ability has always been found with controversy ever since the 1920s for understanding the human spatial reasoning (Bodner & Guay, 1997; Zacks, 2008). However, over the period of time, the field of cognitive psychology, neuroscience and neuroimaging research have provided more insights and understanding. Spatial abilities play an important role in every major subjects of the STEM (Harle & Towns, 2011), particularly in chemistry. Mental rotation skill is quite important because of its association with specific domains of ability, and with giftedness in those domains. However, the mental rotation is not the only determinant of success in the STEM domains (von Károlyi, 2013).

Mental rotation/spatial ability is specifically necessary for many branches of chemistry (e.g., stereochemistry) due to the requirements of understanding the three-dimensional arrangement of atoms that form the structure of molecules, and the effect of this arrangement on the chemical reactions. Due to this ability, chemistry students can easily understand of configuring various structures, stereoisomers (viz. enantiomers, diastereomers), and chirality of the molecules they study.

Interrelationship between mental rotation/spatial ability and development of knowledge/skills in the sciences

Apparently there is no solid research-based evidence that describes as to how students' mental rotation or spatial ability contribute to the extent of either increasing or eliminating misconceptions in the sciences. But it is clearly evident from research that the increase of mental rotation/spatial ability certainly improves the practical skills, knowledge and understanding of the subjects in certain disciplines such as, enabling sciences or advanced sciences viz. chemistry, medical surgery, dentistry and architectural science. If students' mental rotation/spatial abilities are increased through teaching or training, then these students can easily apply their skills more efficiently than the students who have limited or poor mental rotation and spatial ability or lack of teaching and training imparted to them. Hence it is quite rational to depict that the improvement of metal rotation/spatial ability of students in certain specific disciplines will certainly help students to improve their understanding about the content knowledge and enhance practical skills, and effectively these abilities will help eliminate the misconceptions that student may hold.

From the neurological point of view, it is not clear yet whether the human mental rotation depends only on the analog spatial representations or it depends on the motor simulation or the combination of both. Mental rotation is accompanied by the increased activity in the intraparietal sulcus and its adjacent regions, and it is a continuous transformation process performed on the analog spatial representations. Mental rotation is also accompanied by the activity in the medial superior precentral cortex. Under some conditions, humans are more likely to engage in the motor simulation to solve their mental rotation problems. So when people are engaged in this strategy, the medial/superior motor areas are activated. The evident interaction between the motor performance and the mental rotation indicates that when the motor simulation arises in the mental imagery tasks, the motor processes interact with the visuo-spatial processes (Zacks, 2008). In one research, Prescott et al. (2010) performed a comparative study between a group of mathematically gifted adolescents and a group of students with an average math ability as a control group using the mental rotation of complex three-dimensional block figures and, then probed the data using the Functional Magnetic Resonance Imaging (fMRI) technique. The fMRI data revealed that the mathematically gifted students showed enhanced intra-hemispheric frontoparietal connectivity, and effectively it enhanced the frontal connectivity between the dorsolateral prefrontal and the premotor cortex. Thus it was concluded that the gifted mathematical reasoning ability is related to the enhanced connectivity between these anterior/posterior brain regions. And such enhanced brain connectivity with a high fluid intelligence is a unique brain characteristic of the mathematics giftedness (Prescott et al., 2010). In another study, Stransky et al. (2010) examined the surgical performance among the medical professionals, which was assessed using a laparoscopic bench model. Their study revealed that the mental rotation experience contributed to a significant improvements in the performance on certain laparoscopic surgical skills. Their observations also showed that the participants who previously obtained mental rotation training performed significantly better on the mental rotation dependent surgical tasks than the participants who did not receive similar training (Stransky et al., 2010).

In the sciences, three types of abilities are evidently crucial for success, such as, mathematical, spatial, and verbal ability. Students have varied level of abilities in these three areas. Among these three areas, spatial ability is especially important in the scientific and technical domains, and plays a critical role in developing expertise in the STEM subjects. The success in many specialized professions such as, architecture, dentistry, engineering, and medicine were found to be related to the spatial ability skills (Wai, 2009). In another research (2009) where the longitudinal review was performed on the 50 years of studies among the typical and the gifted students revealed that the spatial skills are consistently associated with the success in the STEM domains and for further occupational advancements in the scientific careers. It was observed that among the students of physical sciences, the ability pattern was 0.60 standard deviations apart on the spatial ability compared to the students in humanities. Such a significant differences observed in the spatial ability level is indicative of the importance of spatial ability measures through the selection process to cast a wider net for identifying the intellectually able students in the STEM domains (Wai, 2009).

In chemistry discipline, it is important that the students develop spatial abilities to gain representational competence and an understanding of the contents. Thus in the context of chemistry, these students require assistance to become competent in the domain-specific spatial skills to connect the particulate representation of the molecules to the conceptual and symbolic knowledge. In the process of students' learning of chemistry, the domain-specific visualisation skills help them to apply analytical techniques (Harle & Towns, 2011). In the context of chemistry, Bodner and Guay (1997) examined the relationship between spatial ability and students' performances in an introductory chemistry courses which were based on Purdue Visualization of Rotation Test (PVROT). Their investigation found a good correlations when the chemistry task had high spatial contents, and thus students were required to exercise real problem-solving skills (Bodner & Guay, 1997). The PVROT is a valid test that can measure the cognitive spatial abilities of students (Bodner & Guay, 1997), and it is being frequently used (Harle & Towns, 2011) in the chemistry. In a practical situation, chemists generally use a wide variety of methods to represent the concepts in chemistry (Harle & Towns, 2011). Chemistry and its various sub-disciplines have vast arrays of spatial contents and thus require a frequent exercises of tasks with high problem solving ability. As the students in chemistry have varied level of capabilities in their spatial and problem solving skills, it was also found that many of the students quite easily used their own and varieties of tricks (Bodner & Guay, 1997), and became successful in solving their chemistry problems.

SUMMARY

Mental rotation and spatial ability are important attributes for developing expertise in the STEM subjects. Among the general and the gifted students, these abilities can be improved with the intervention of appropriate training and exercise. In the enabling sciences (viz. chemistry), the spatial ability, more particularly, the representational or the visuo-spatial and problem solving abilities are important. As the gifted students have varied level of giftedness (viz. spatially gifted, intellectually gifted or both spatially and intellectually gifted) in the wide spectrum of ability pattern, it is thus quite important to use the mental rotation/spatial tasks in a judicial and sensitive manner (Harle & Towns, 2011; von Károlyi, 2013). The brain characteristics of the gifted students in other area of sciences viz. chemistry, are not uncovered yet by the neuro-scientific applications. It is worthwhile that future researchers may look into this matter to understand the enhanced brain connectivity, and uncover the ability profiles of the gifted students in chemistry. Again, due to the methodological complexities and the difficulties that are involved in interpreting the brain scans (von Károlyi, 2013), it is important that a care should be taken not to take any conclusive decision from the outcomes. The mental rotation and spatial ability tests may be effectively included in the regular identification process of the gifted students in science/chemistry, and in the STEM subjects.

CONCLUSIONS

The article presented syntheses and critical analyses of literature, creative insights, and gifted education perspectives related to enabling sciences with a particular focus on chemistry.

Like the general students, the gifted students also hold misconceptions in science/chemistry. The article discussed how students' misconceptions in science and chemistry can be resolved. Emphasis should be given on the development of metacognitive skills, learning skills, thinking skills, problem-solving abilities, knowledge, and on the improvement of students' motivation, engagements and interest in science/chemistry. Students' psychosocial skills are paramount to gain their ultimate success and eminence in science/chemistry. To ascertain the development of students' psychosocial skills, the cultural issues related to students' experience in cultural-clashes need to be rigorously addressed in science education and science teaching.

When the gifted students are at the intermediate level, then emphasis should be given that they acquire the integrated process, reasoning and complex skills with proper theoretical and practical instructions. The outside-of-school chemistry laboratory programs aimed for both the elementary and secondary gifted students are found quite effective.

Mental rotation and spatial ability are important for developing expertise in the STEM subjects, and these abilities can be improved with appropriate training and exercises. Spatial ability, representational or visuo-spatial and problem solving abilities are important for success in science and chemistry. Mental rotation and spatial ability tests may be included in the identification process of the gifted and talented students in STEM subjects.

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