Chapter 2
The Interplay of Motivation and Cognition: Challenges for Science Education Research and Practice

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Learning science at school is a complex learning task with success depending on several internal (e.g., prior knowledge, ability, personal characteristics) and external factors (e.g., teacher's competences, syllabus, classroom climate). Science education and the perception of science classes as "hard" or "difficult" are discussed by scholars, science teachers, and students for at least three decades. Research evidence shows that students do not always achieve their full potential in science classes when they are not properly motivated (Anderman & Young, 1994; Aschbacher et al., 2010; European Commission, 2007; Gilbert, 2006; Holbrook & Rannikmäe, 2014; Johnstone, 1991; Lyons, 2006; Lyons & Quinn, 2010; Osborne et al., 2003; Potvin & Hasni, 2014; Shirazi, 2017; Vossen et al., 2018). According to current research, the "negative" reputation of science in school has two reasons. First, the multifaceted and abstract nature of science, which requires motivation, effort, and higher order thinking in order to learn it meaningfully and relate it to the immediate sociocultural context. Second, the "negative" aspect is related to the ways in which science contents are transferred or taught to students. Another question is interesting in this respect, namely, do new technologies used for science education (Oliveira et al., 2019) contribute to better education (Lodge & Harrison, 2019), and what is their influence on students' motivation and their cognitive processes during science education. In order to understand these questions, one needs to thoroughly understand the processes of teaching and learning (Mayer, 2010).

This chapter aims to explore how two internal variables are affecting learning processes, i.e., students' motivation and (visual) attention. This study focuses on

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their interrelated role in teaching and learning science at school, which is a relevant problem for the current theoretical and empirical research (Braver, 2016). Moreover, it implies a responsibility for the future research and practice that are both necessary in science education of the twenty-first century (Osborne, 2013). In this chapter we focused on challenges in learning and teaching science and exposed the examples of potential problems in learning motivation in a group of dyslectic students and their difficulties in visual processing, which affect in less effective attention and motivation orientation in the learning process.

In this respect, the framework of the Partnership for 21st Century Learning (P21) lists science among the nine key subjects, and defines motivation—i.e., initiative and self-direction by means of management of goals and time, independent work, and self-directed learning—as one of the five key life and career skills (Battele for Kids, 2019). While this chapter does not provide an overall evaluation of the topic, it aims to define some relevant topics for the evaluation of factors that need to be considered for a quality science education.

Motivation in Learning

Learning motivation is a type of motivation that is expressed by students in the context of learning through their behaviours. Motivation is a psychological process (Weiner, 1992) which appears in the form of various motivational components—interests, self-concept, goals, values, attributions, challenges, or external stimuli. It energises the learning process by activating it and then guiding it until the final learning task or goal is achieved (Juriševič et al., 2012). Koballa and Glynn (2007) argue that

> the study of motivation by science education researchers attempts to explain why students strive for particular goals when learning science, how intensively they strive, how long they strive, and what feelings and emotions characterize them in this process. (p. 85)

Research shows that motivation is closely related to learning and the accompanying cognitive or metacognitive processes (Crede & Phillips, 2011; Pintrich & Schunk, 2002; Schraw et al., 2006; Tuan et al., 2005). It is related to information storage in long-term memory, its recognition, and its retrieval (Cook et al., 2015; Miendlarzewska et al., 2016; Murayama & Elliot, 2011; Murty & Dickerson, 2017; Schiefele & Rheinberg, 1997). According to Stipek (2002), learning motivation is expressed in students' attitudes towards learning and their diverse approaches to learning. Jarvela and Niemivirta (2001) argue that learning motivation advances higher forms of learning and consequentially results in better knowledge, especially at the conceptual level (see also Bomia et al., 1997; Hung-Chih et al., 2010; Linnenbrink & Pintrich, 2002; Phillips et al., 2008; Ryan & Deci, 2009; Thomas & Oldfather, 1997). Based on these findings, motivation is defined as a mediatory variable of learning performance (Linnenbrink-Garcia & Patall, 2016) that is positively, but weakly correlated to school grades; it explains around 10% of learning success, while intellectual abilities explain around 50 or 60%. Nevertheless, motivation is crucial for learning because learning cannot happen without motivation (Juriševič, 2006; Schiefele & Rheinberg, 1997).

By investigating tasks in science school curricula and considering the characteristics of students and their educational context, Rheinberg et al. (2000; see also Vollmeyer & Rheinberg, 2013) identified three levels on which motivation and its components influence learning: (1) the level of time investment that the student devotes to learning and to learning activities, both in the terms of its extent (duration) as well as its frequency, i.e., active learning time; (2) the level of forms and contents of learning activities by which student's efforts are negotiated in relation to activity's level of difficulty on the one hand, and on the other, learning strategies are implemented in order to motivate the student for learning and for achieving learning goals (e.g., superficial vs. deep learning); (3) the level of functional mood, which refers to the optimal psychological state of the student during learning (e.g., positive emotions, devotion, mental concentration). Rheinberg et al. (2000) further define a student's functional state as a motivational state that acts as a mediator for learning success:

> This variable refers to the learner's physiological and psychological activation and concentration during learning. Last but not least, we think that the learner's *motivational state* during learning mediates the effects that the initial learning motivation (i.e., the motivation that led the person to start learning) has on the learning outcome. As the initial learning motivation may change considerably during a long learning period, it is not tautological to regard motivational state during learning as a mediating variable for the impact of initial motivation on learning outcome. (p. 84)

The Relationship Between Motivation and Attention in Learning

Schiefele and Rheinberg (1997) hypothesise that the student's optimal functional state during learning significantly influences her/his conative functioning. The researchers compare this state with "flow", which is according to Csikszentmihalyi (1988) a state of high concentration during which a student best realises his learning abilities and achieves high learning outcomes. According to Posner and Boies (1971), such states of arousal and alertness are the first phase in the process of attention, controlled by the reticular activating system (RAS): if environmental stimuli do not result in student's arousal and alertness, learning does not occur. The phase of selection follows: this is the phase of selecting the most important stimuli, that is, directing the attention in a way that adequately and effectively eliminates distractors and maintains attention for so long and with such intensity as necessary so that the student can understand and use the learned topic. These processes are controlled by the frontal lobes. Moreover, attention allows students to plan, monitor, and regulate their thinking and learning behaviour (Barkley, 1998; Levine, 2002). The relationship between motivation and attention is therefore important for education. However, it has not yet been fully explained (Braver, 2016). Exploring this relationship can take at least two directions: first, studying the impact of motivation (rewards) on attention (Anderson & Sali, 2016; Rothkirch & Sterzer, 2016), and second, studying the role of orientative attention in motivated behaviour (Suri & Gross, 2015). If a student knows, for example, that she/he is learning for a grade or a reward, she/he will be more attentive during the learning process. It is also possible, however, that this type of instrumental behaviour is expected from a student, but she/he will not perform it despite the fact that it would be beneficial for her/him. Suri and Gross (2015) argue that in such cases the lack of attention, which does not cause arousal, is the main problem, as there is no consequential activation (energisation) present. Orientation of behaviour and motivation depends on whether the student chooses the behaviour of approaching or that of avoiding. In the background of this decision are always evaluation processes that negotiate between what is good and what is not good for the individual. These processes require attention. If a student does not pay attention to the evaluation of certain stimuli, this does not result in a motivated learning behaviour.

Early Development of Motivation

Research shows that children who live in a safe and predictable environment develop a healthy motivation system, which is based on a judgement, whether they should begin with an activity or rather avoid it, if the circumstances are threatening. Those children that live in an unpredictable and chaotic environment develop behaviours of avoidance so that their behaviours are based on fear (National Scientific Council, 2018). In behaviours of avoidance, emotions of fear or disgust are present in the amygdala. When the amygdala is activated, norepinephrine and other stress hormones, which prepare the body for a fight or a quick flight, are released. Consequentially, the heart rate increases, levels of blood sugar rise, oxygenation changes, and metabolic and digestive processes slow down (Schabel et al., 2011). Behaviours of avoidance which the child learns in early childhood also affect other life stages, mainly through problems with planning, achieving long-term goals, and motivational orientation. The likelihood of deep learning and higher forms of learning is reduced (National Scientific Council, 2018). It is important to consider this when discussing science education where well-developed cognitive abilities such as reasoning, logical thinking, remembering, understanding sequences, and different types of data integration are important.

Crone and Dahl (2012) found that children who have been emotionally neglected or abused develop an increased susceptibility to social exclusion, especially during adolescence. Positive feedback from important others, including teachers, positively influences their motivational orientation. If in learning an adolescent exhibits a low motivational orientation towards a particular goal, positive feedback can strengthen her/his feeling that she/he is on the right path, and conversely, if an adolescent exhibits a high motivational orientation, critical feedback is more efficient, because it points towards the difference between where she/he currently stands, and where she/he aims to arrive (Fishback et al., 2010). Both motivational orientations, the one oriented towards the expected reward and the one oriented away from threats or dangers, are important for survival. Regulation of motivation depends on the coordination of molecules (peptides, hormones, neurotransmitters) that integrate different signals in the decision-making function (Simpson & Balsam, 2016). Those processes evolve in a supportive environment. However, when both types of motivational orientations are not balanced, over-rewarding or over-avoiding can produce a number of unwanted results, for example, attention deficit hyperactivity disorder, attention deficit disorder, depression, anxiety, substance abuse, and post-traumatic stress disorder (Kasch et al., 2002; Meyer et al., 1999; Muris et al., 2001) as well as other mental disorders (Simpson & Balsam, 2016).

Neural System of Motivation

In recent decades, researchers of cognitive neuroscience use non-invasive methods to explain the neurological basis of motivation. Understanding classical and modern research findings is important for understanding the school setting, especially when discussing about motivational topics and the importance of rewarding, punishing, or asserting repercussions. Using meta-analysis, Cameron and Pierce (1994) found that an individual's interpretation of praise and reward is important. If it is perceived as control over one's actions, it negatively affects internal motivational orientation. If it is perceived as information about one's ability and is understood as recognition of efforts, it can have a positive effect. In his early research, Deci (1971) argued that under certain conditions rewards are not suitable as they reduce learning motivation. Deci et al. (1999) and Lepper et al. (1973) found that external rewards negatively influence internal motivational orientation, especially when intriguing challenges are concerned. Hence, they suggest that external rewards are not always beneficial in learning because the promise of a reward activates the dopamine system and stimulates the performance of an activity, which seems worthy of learning and interesting in terms of gaining new experiences. Fastrich et al. (2018) and McGillivray et al. (2015) also found that tasks, which promote internal motivational orientation, are already interesting so that rewarding is not necessary or may even be harmful. The short-term effect of rewards influences further recognition of those circumstances that lead to an award (Adcock et al., 2006; Murty et al., 2012, 2013). Murayama et al. (2010) also found that internal motivational orientation undermines the prediction of introducing external rewards. This reduces the activation in the striatum, which is the part of the neural network responsible for the reward. As preliminary research, Murayama (2018) found that striatum is related to personal decisions, risk-taking, and the need for curiosity. This proves that internally conditioned "rewards" play a central role in deciding which activity an individual will choose. Murayama and Kitagami (2014) argued that monetary rewards could improve learning. This activates the hippocampus, which creates a neural network that forms the basis for rewarding (Adcock et al., 2006). Regarding external motivational orientation, Schiller et al. (2009) discovered an increased activity in the posterior cingulate cortex, which is activated in decision-making and in social judgement contexts. Lee et al. (2012) found differences in the activation of brain structures when an individual is internally or externally motivated. With regard to the intrinsic motivational orientation, activity in the insular cortex was identified. Insular cortex is responsible for emotional processing in decision-making contexts (Bechara & Damasio, 2005) and is associated with hedonic emotions. Di Domenico and Ryan (2017) suggested that intrinsic motivational orientation is phylogenetically conditioned and that it includes the dopamine system. They found that intrinsic motivational orientation produces patterns of activity in large neural networks, namely, those neural networks that support detection of recognition, attention control, and self-referential cognition.

Self-Determination in Learning

Motivation is one of the most important research topics due to its importance in various areas of human life. In the field of education, various concepts connected with motivation have been studied (e.g., self-efficacy, academic emotions, self-regulation), and various theoretical models were developed in order to explain the relationship between motivation, learning, and learning performance. Examples of such theories include Attributional Theory, Expectancy-Value Theory, Achievement Goal Theory, and Self-Determination Theory (see Hidi & Renninger, 2019; Wentzel & Miele, 2016 for their review). In what follows, we focus on Self-Determination Theory in more detail, because it explains in relative detail those parts of motivation which empirical research identified as particularly relevant for learning and teaching science subjects in schools.

Self-Determination Theory (SDT). SDT (Deci & Ryan, 1985; Ryan & Deci, 2020) is a macro theory that analyses the extent to which human behaviour is self-determined. This means that it analyses the extent to which an individual independently decides to achieve their goals, and how and to what extent they reflect their thoughts during this process. SDT is hence relevant for researching the role of motivation in learning, the promotion of motivation, the evaluation of education, and encouraging students' confidence in their abilities (i.e., self-concept). SDT focuses on motivational orientations or types rather than just the amount of motivation, paying particular attention to autonomous motivation, controlled motivation, and motivation as a predictor of performance, relational, and well-being outcomes (Deci & Ryan, 2008). A common question of SDT in the framework of the school system, therefore, is the following: how to increase learning motivation in education without external pressures, and how to encourage the development of students' internal motivation?

According to the SDT, motivation can be autonomous or controlled. Students who are autonomously motivated feel an inner desire to perform the activity for which they are motivated (Deci & Ryan, 2008). The autonomy-supportive style of teaching is primarily related to a relaxing classroom atmosphere, which, according to neuropsychological research studies, is crucial for effective learning (Reeve, 2016). Education in contexts that promote autonomy also promotes internal motivational orientation (Deci et al., 1981) and internalisation (Grolnick et al., 1991). Patall et al. (2019) report that in science classes students show more genuine interest in learning if teachers are committed to supporting autonomous behaviours. Moreover, such contexts offer better conditions for conceptual learning (Grolnick et al., 1991) and creativity (Koestner et al., 1984), and further increase autonomous motivation and the perceived competences in science labs (Black & Deci, 2000). Skinner et al. (2017) found that autonomy-supportive classes are related to higher identification of students as scientists. Students who aim to choose their goals independently are more likely to achieve success by means of higher educational outcomes (Boggiano et al., 1993; Deci & Ryan, 2008; Deci et al., 1981; Fink et al., 1992; Guay et al., 2008; Juriševič et al., 2012; Toshalis & Nakkula, 2012). Ryan and Grolnick (1986) found that a student's perception of her/his own autonomy varies within a one-hour lesson. They suggested that the perception of a student's control depends on the perception of their competence, the perception of self-concept, and self-esteem. Students have different experiences in classrooms: from subordination to independence. When motivation is controlled, a student feels pressured to think, feel, or behave in a certain way. Research evidence implies that traditional external motivators in schools, such as setting deadlines for tasks (Amabile et al., 1976), supervision (Lepper & Greene, 1975; Plant & Ryan, 1985), competition (Deci et al., 1981), evaluation (Church et al., 2001), and goal-setting (Mossholder, 1980) might not increase students' internal motivation. Guay et al. (2008) found that students who primarily experience controlling motivation are more distracted, anxious, and achieve lower learning results.

Researchers of self-determination are interested in the relationship between autonomy, structure, and discipline, which is an aspect of external motivation. Eckes et al. (2016) argue that teachers most effectively encourage the development of intrinsic motivation by providing appropriate structure and promoting autonomy. Ryan (1982, 2016) emphasises the importance of feedback in providing structure and determines the appropriate relationship between autonomy and structure, which alongside appropriate social cohesion allows for a sense of security and intrinsic motivation.

Self-Determination Theory's taxonomy of motivation. Ryan and Deci (2009, 2020) described the regulation of motivation on a five-level motivational continuum. The first level is without regulation; it is a-motivation or non-regulation. It is present when a student is not motivated for an activity and it describes the lack of intention and purpose, e.g., "Not interested in science subjects at all". A-motivation is therefore a lack of self-determination and motivation (Deci & Ryan, 2000). The individual does not act with an intention to carry out the activity. This level is often related to learned helplessness because a-motivated students feel incompetent and believe that they have no influence over the outcome (Abramson et al., 1978; Ryan & Deci, 2000). On a continuum between a-motivation and introjected regulation, feelings of failure, weak self-concept, anxiety, internal conflicts, loss of self, and consequent loss of intrinsic motivation for life, may be present (Abramson et al., 1978; Ryan & Deci, 2000). The second level is the level of external regulation, also called controlling or controlled motivation. This motivation comes from the outside, namely, from a teacher or a parent. In order to participate in an activity, the student expects to gain or avoid something in return. Both consequences are completely independent of the activity itself: the student has no influence over the external demand but carries it out because this is expected of her/him, e.g., "I study science because I have to as a student". The third level is introjected regulation, which is the first stage of internalised motivation, but is still a controlled form of motivation. The student performs an activity to maintain his self-concept and avoid feelings of shame or internal pressures, e.g., "I study science to satisfy my parents' expectations". The fourth level is identified regulation, which is the first level of autonomous motivation, meaning that the student autonomously decides whether to perform an activity or not, e.g., "I study science to get good grades". The fifth level is integrated motivation, which is the most self-determined type of external motivation. It is similar to internal motivation, but it still has instrumental value, e.g., "I study science because it is important to understand it as a prospective medical doctor", and "I study science because it is interesting to me", respectively.

The SDT describes intrinsic regulation as a "prototype of self-determination". This means that a person fully interested in an activity also has "full choice, experience of deciding what he wants and what he does not want, without a sense of coercion" (Deci & Ryan, 1991, p. 253) and is connected to herself/himself; it is a form of a completely autonomous motivation.

Challenges in Learning and Teaching Science: Examples of Potential Problems in Learning Motivation

Because learning motivation is the result of an interaction between student's personal characteristics and the educational context, it is important to identify and monitor those factors that negatively affect student's readiness for schoolwork. As mentioned, these potential problems or learning difficulties can arise from students themselves or from the environment, either educational or home environment. Two of them that concern students were chosen for the purpose of this chapter. Both are complex in nature, with a fairly high prevalence in children and youth. The first is "learned helplessness", which is of psychological nature and is learned. The second is "developmental dyslexia", which is neurologically conditioned within the context of specific learning difficulties and can prove to be a problem in visual processing that affects in learning science. Both learning difficulties exhibit an inhibitory effect on learning motivation and therefore pose a serious problem in science education for students, regardless of the level of their learning abilities.

Learned Helplessness

The phenomenon of "learned helplessness" in students (Abramson et al., 1978; Maier & Seligman, 2016) is a learned mental state conditioned by stress experiences in which the student feels that they have no control over their situation, i.e., truly no control over the circumstances or a perception that they have no control. It develops from early childhood on as a vicious circle of continuous aversive situations and can be domain- and/or person-specific. Because of the expectation that nothing can be changed, students begin to behave in a helpless manner, overlooking learning opportunities for relief or change and thus influencing overall mental health (Maier & Seligman, 2016). Koballa and Glynn (2007) describe the syndrome of learned helplessness in science education as the students' belief that academic achievement in science subjects is mostly uncontrollable, i.e.,

> Students who develop a learned helplessness are reluctant to engage in science learning. They believe they will fail, so they do not even try. Because they believe they will fail, these students do not practice and improve their science skills and abilities, so they develop cognitive deficiencies. Students with learned helplessness also have emotional problems such as depression and anxiety. (p. 90)

Peterson et al. (1993) further explain the characteristics of learned helplessness; the authors claim that the phenomenon has three main components. The first is contingency, which deals with the uncontrollability of the aversive situation. The second is cognition, which refers to the attributions or explanatory styles people make in relation to the situation of which they are a part (for details see Weiner, 1992). Finally, behaviour allows people to decide whether to give up or continue with the obstacle in front of them. Defined in this way, learned helplessness affects the behaviour of students in three different ways: motivational as a lack of effort, cognitive as passive attributional explanations of situations, and emotional as doubts about one's own ability to learn and consequently the decrease in their self-concept (for details see Gordon & Gordon, 2006).

Developmental Dyslexia

Among the various learning difficulties that hinder school learning, developmental dyslexia is very common (Győrfi & Smythe, 2010; Lyon et al., 2003). Due to neuropsychological and neurophysiological causes, students with dyslexia have continuing difficulties with recognising and decoding words, reading fluency, reading comprehension, pragmatic use of language, naming symbols, manipulating with abstract concepts, time-management, management of school materials, educational sources, and other learning tools (Raduly-Zorgo et al., 2010). Moreover, they have difficulties with metacognitive awareness (Klassen & Lynch, 2007; Kolić-Vehovec et al., 2014), self-observation, and self-evaluation (Gargiulo, 2015), and consequently with self-regulatory learning. In relation to their peers, they perceive themselves as less competent in reading (Soriano-Ferrer & Monte-Soriano, 2017). It seems that less developed metacognitive functions are a consequence of dyslexia (Roth, 2008), but such students can develop independent compensatory skills (Bogdanowicz et al., 2007). Reiter et al. (2004) found that students with developmental dyslexia have deficits in working memory, problem-solving, inhibition, verbal and visual fluency, that is, in cognitive functions associated with the left prefrontal cortex. Brosnan et al. (2002) found that individuals with developmental dyslexia show deficits in executive function, inhibition of distractors, recognising and determining a sequence of events, and in tasks that require the functioning of the prefrontal cortex. By constantly experiencing failure, they develop feelings of helplessness and other negative emotions; self-perception of poor learning effectiveness further affects self-concept in learning, reduces learning effectiveness, and reduces the chance of success (Mitchell, 2014; Sorrenti et al., 2019; Spafford & Grosser, 1993; Sršen Fras, 2016). Research shows that self-efficacy is significantly lower in students with developmental dyslexia than in that of their peers. They perceive themselves as less successful, incompetent, and unappreciated; because they value themselves and their abilities less, they give up faster on difficult learning tasks, and they learn only easier school topics (Bakracevic Vukman et al., 2013). Despite being successful, they may show low interest and a depressed mood (Lackaye et al., 2006). Since they have no automatisation developed, they experience greater cognitive engagement and fatigue in learning and task solving, also due to the inclusion of additional sources of attention, conscious control of the implementation, and the use of higher order cognitive functions (Magajna, 2015).

Various theories aim to explain the etiology of developmental dyslexia, from theories of phonological deficits to theories of automation disorder and to theories of visual attention deficits. Modern findings suggest that students with more severe reading difficulties have a double deficit, a phonological and a visual (Boets, 2014; Boets et al., 2007). Deficiencies in visual processing in students with developmental dyslexia are explained by two main theories. Visual Deficit Theory or Magnocellular Theory suggests that in students with developmental dyslexia, the part of the visual system, which is responsible for controlling eye movements, is hindered. Students with developmental dyslexia experience difficulties in performing precise eye movements, which are necessary for reading (Stein & Walsh, 1997; Stein, 2001, 2012). They also experience difficulties in the following areas: (1) length and direction of saccades (extremely fast eye movements), (2) verge movements in fixations of letters that form a clear image, and (3) coordination between both eyes. The Visual Attention Deficit Theory or Visual Stress Theory, on the other hand, argues that students with developmental dyslexia have difficulty perceiving individual symbols when the attention is asymmetrically distributed between the visual field and the word. This theory assumes that reading difficulties result from hypersensitivity to certain wavelengths of visible light, which results in an unstable or poor/foggy perception of symbols when reading (Wilkins et al., 2016), as well as the reading distress, which increases with the length of the text. Kriss and Evans (2005) found that students with visual stress experience blurring of text, duplication of letters, movement of symbols or words, changes in text format, or disappearance of symbols and words, which all consequently result in learning difficulties (Loew et al., 2014).

The Development of Visual Attention

From the moment of birth, the visual system is exposed to different visual information that it cannot instantly process. Visual attention is the main function of filtering, differentiating, and selectively processing information (Amso & Scerif, 2015). Hendry et al. (2019) suggest that the development of visual attention is multifaceted and non-linear. In everyday life, main functions of attention such as orientation, selective visual attention, and processing visual information are intertwined and influenced by other cognitive components. During task solving, students differ with regard to experience, motivation, cognition, and physical abilities or deficits, while those mechanisms, which determine the success of visual attention development, may change. Visual attention encompasses several functions and processes. Hendry et al. (2019) defined four functions of attention, which are often intertwined in everyday life and are considered to be particularly important in early development. Those are: orienting towards and away from objects, selective filtering of visual inputs, processing visual information, and maintaining focus on a target. Maintaining attention, which can be associated with new information and arousal, as well as the skill of withdrawing attention, can be a mediator in the effective processing of visual information in infants up to six months of age. An increased ability of infants to control their attention means that factors of motivation can influence the recognition of a stimulus and the maintaining of attention. Although skills of executive attention continue to develop during adolescence and later, a child with neurotypical development by the end of the second year of life is able to use control mechanisms to identify and orient objects in space. With this, fundamental aspects of visual attention are established (Hendry et al., 2019).

We will present individual deficiencies in the field of perceptional skills, which significantly affect the less effective learning of science.

Types of visual processing disorder. Visual processing skills are part of a student's cognitive functioning and play an important role in interpreting and understanding visually conveyed information (Brown & Stephen, 2011). Visual processing disorders are not related to myopia, but to deficiencies in understanding visually conveyed information such as object movement, spatial relationships, and recognising the shape of symbols or their orientation. The following types of visual processing disorder were identified: (1) disorders of visual decoding, inference, and identification; (2) disorders of understanding spatial relationships and visual orientation; (3) disorders of visual discrimination; (4) visual memory disorders; (5) visual tracking disorders.

Visual decoding and identification word disorders are manifested in students with developmental dyslexia such as problems with recognising objects and symbols when they are not visible in their entirety, but only in parts.

Disorders in space orientation are manifested in students with developmental dyslexia such as shifting of symbol order in a word and digit order in a number or in a chemical formula. They are directly related to visual sensitivity for spatial relationships and sequences.

Visual discrimination disorders are manifested in students with developmental dyslexia such as mix up letters in a word, digits in a number, and having difficulty reading or scanning visual material.

Visual memory disorders are manifested in students with developmental dyslexia such as retrieving a visual image in the form of letters, numbers, words, or symbols and reading text instructions (Willows, 1998).

Visual sequencing disorders are manifested in students with developmental dyslexia such as harder to follow moving objects because the movement of both eyes is not coordinated (Schulte-Körne, 2010). Their eyes often get tired when reading (Murphy, 2004). Students with visual tracking disorders and disorders of coordinated eyes functioning use a finger or a ruler to focus their visual attention. Schulte-Körne (2010) found that unnecessary and redundant eye movement in students with developmental dyslexia occurs in situations other than reading as well.

Visual processing disorders and visual attention disorders are manifested in students with developmental dyslexia such as various types of attention disorder, such as directing and maintaining attention during specific tasks (Helland & Asbjørnesen, 2000), directing and maintaining attention over a long time period, and following fast and sequential information (Hari et al., 1999). They are more likely to be distracted by insignificant interferences during a task or activity than their peers without developmental dyslexia (Reiter et al., 2004). Compared to their peers without developmental dyslexia, students with developmental dyslexia also exhibit less substantial and quality attention (Segalowitz et al., 1992), which could result in motivational learning difficulties, as such students stop learning earlier and use simpler learning strategies.

Conclusions and Implications

The relationship between motivation and cognition is a complex phenomenon that is not yet fully explained, presenting a challenge for researchers and practitioners in education. This relationship has been the subject of discussion in this chapter, specifically, its relevance for science education and science classes, which are often regarded as highly demanding and thus less motivating in comparison to other school classes. By discussing the dynamics of learning motivation as well as its relationship with cognition, the focus of this chapter was twofold; first, to highlight the importance of autonomy-supportive teaching and learning for the individual student, and second, to present the examples of potential problems in motivation and/or learning outcomes conditioned by both internal and external factors of learning.

The question of the differences between students with regard to their motivational attitudes in science education remains unanswered. It would therefore be beneficial to look more closely at various aspects of teaching in future research, especially the relationship between promoting autonomy, the controlling teaching style, and establishing structure as an aspect of external motivational orientation. Students with learning difficulties should be focused on specifically as they have deficits in visual attention, visual retention of models, images, and illustrations, visual tracking of text and written instructions, visual discrimination in understanding visual information, recognition of objects and symbols due to the inability to integrate and/or synthesise visual information, and spatial relationships and orientations as shifts of symbol in a word order, digits in a number or in chemical formulas. It would be also fruitful to examine the relationship and the impact of visual attention and precise visual processing on learning motivation of students with developmental dyslexia and other types of learning difficulties in different developmental periods, especially in adolescence, which is characterised by the phenomenon of the reward sensitivity in adolescence (Casey & Galván, 2016).

Modern eye-trackers are becoming more sophisticated and transferable so that an expansion of the studied population and the improvement of early detection of developmental deficits are possible. Those deficits are, for example, autism spectrum disorders (Hendry et al., 2019) or hereditary attention deficit hyperactivity disorder (Goodwin et al., 2016). These groups of children are more exposed to the development of cognitive and behavioural problems due to early deficit in the development of attention, and they are often accompanied by developmental dyslexia (see also Sorrenti et al., 2019). Hendry et al. (2019), Putnam et al. (2006, 2008), and Rothbart et al. (2000) point out that the research and assessment of visual processing should use triangulation of sources and methods (EEG, eye-trackers, multiple observation, assessment of visual attention and visual memory, considering data gathered with questionnaires for parents who can provide insight into aspects of attention and motivation outside the laboratory setting, appropriate learning strategies in science education, etc.).

Since students with specific learning difficulties often exhibit comorbid conditions, we suggest individualised interventions for the development of self-regulation in autonomy-supportive learning settings, and with it the development of appropriate motivational skills, motivational strategies, and strategies for the development of visual perception, visual attention, and visual memory used in science to observe similarities, differences, and changes and also structured trainings that improves visual processing skills (Stevenson et al., 2013). When planning the trainings, one should consider that cognitive deficits of memory influence the use of learning self-regulation, which is important in the development of motivational and metacognitive knowledge and skills (Reid et al., 2013). At the same time, it is important to note that problems in learning motivation often arise from the lack of desire to learn and the lack of effort or willpower (Di Domenico & Ryan, 2017; Ryan & Deci, 2000, 2020; Stipek, 1996; Weiner, 1992).

The main question for the future, hence, is how to make science education more approachable to students with motivational and/or learning difficulties, how to encourage them to cope with different obstacles in learning science, how to memorise visual materials and understand the learned topics, and how to attract and retain attention while learning. The use of visual and graphic representations, posters, concept cards, cards with a marked sequence of steps for experiments, aids, schemes, and various animations in the framework of autonomy-supportive classrooms (Reeve, 2016) all affect visual memorisation, procedural knowledge and visual attention retention, and internal representation of mental images (Lodge & Harrison, 2019) and answer to the important question—how to create optimal conditions in the school environment so that students can motivate themselves. When we understand the basic interplay of motivational and cognitive processes that present the inner context for learning and teaching, we can make science education more autonomous and effective.

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