CHAPTER 5 : DISCUSSION OF THE FINDINGS

5.1 Discussion on the findings of Objective 1

Objective 1: ***To find out the Brain hemispheric dominance, Metacognitive awareness levels, Perceptual learning style preferences and Academic achievement levels in Biology of senior secondary school students.***

Brain hemispheric dominance of senior secondary Biology students

The findings revealed that majority of the students were left brainers (60.78%), followed by right brainers (39.20%) while there were no whole brainers (0.00%). The descriptive statistics on the basis of gender and type of study also reveal that there were more left brainers than right brainers. This undeniably shows that the majority of the participants were left brain dominant and this is congruent with the findings of Morris (2006); Fernandez (2011); Oflaz (2011); Singh (2015); Keat *et al.* (2016); Koju et al. (2019); Joven et al. (2020); Montero (2021); and Ramly et al. (2021). Left-brainers and right-brainers are individuals who consistently utilise the cognitive functions associated with the left hemisphere and right hemisphere of the brain, respectively. Furthermore, individuals who possess the ability to utilise all of the strategies employed by both right and left-brained learners equally in a balanced way are referred to as "whole brainers" (Namaziandost et al., 2020). According to Schwartz (2010), the left brain excels in analytical and logical tasks and tends to exhibit rational, quantitative, deductive, sequential, systematic, objective, rule-bound, and outcome-driven characteristics.

Biology is a science subject that requires learners to possess objectivity, rationality, systematic thinking, analytical skills, attention to detail, and deductive reasoning. These qualities are essential for effectively understanding and acquiring scientific concepts, facts, and processes in Biology. However, it is important to note that the study sample included 39.2% individuals who had creativity and imagination traits that are essential for studying Biology. According to research conducted by Dulger (2012), Humera (2015), Mansour et al. (2017), and Ayadi et al. (2019), a significant proportion of the students exhibited right-brain dominance in their studies as well. Biology necessitates both visual and verbal learning due to its use of numerous images, graphs, charts, models, and calculations. Individuals with a dominant right brain tend to effectively process information using vivid mental images, generalisations, metaphors, emotional input, and make artistic and spectacular statements (Brown, 2000). It should be noted that neither of the hemispheres are superior or inferior to one other, and their differences are only attributed to their distinct methods of information processing. Put simply, both the hemispheres can be used equally to respond, interpret, perceive, and store information, and they work together harmoniously (Yeap, 1989).

The absence of whole brained students among a total of 635 participants allows us to converge our discussion to two points: First, the negligible number of whole brained students among the group indicates that they are yet to be trained on how to effectively utilise the many functions connected with both hemispheres. Second, our education system might be such that is training students to strengthen only either of the two hemispheres, more so the left hemisphere. With regard to the this, Morris (2006) has specifically examined the instructional methods employed in educational institutions. He stated that conventional education tends to show a preference for individuals with a dominant left hemisphere of the brain. The children are also typically instructed predominantly by teachers who possess a left-brain dominance, characterised by a preference for order, sequence, reasoning, and planning. The fewer options for right-brained learners to assimilate information according to their preferences may contribute to the lower representation of right-brainers in this study. Despite significant progress, our country's education system has not yet fully embraced a non-traditional approach. Many teachers in schools still persistently depend on their comfort zone to employ traditional teaching methods (Malacapay, 2019) without first evaluating the learner's profile. There might be some students among the lot who can fulfil a learning task utilizing functions like logic, reasoning, detailed analysis etc., but there might also be students who might not be as efficient in utilizing the same functions, instead would comprehend the task better when a creative and innovative learning environment is provided to them. According to Revell (1992), our society has a tendency to value and support the left brain more than the right brain. As students progress in age, educational systems frequently prioritise the memorization of information above fostering creativity and imagination. They are becoming drawn to their left brains while their right brains are becoming less appealing.

Additionally, I address the findings of a study conducted by Saleh (2001) which propose a correlation between brain hemisphericity and several academic disciplines. The findings revealed that students studying education, communication, and law exhibited a propensity for right-hemispheric dominance, whereas those studying engineering, science, business, and commerce displayed a propensity for left hemispheric dominance. Previous studies by researchers have also revealed that individuals select their academic majors based on the alignment between the norms of these disciplinary domains and the individual's hemisphere dominance (Kolb, 1979; Rowe et al., 1992). According to various researchers, academic subjects like arts, humanities, and architecture are thought to necessitate a broader, holistic, and spatial approach, making them more appropriate for students with a dominant right brain. On the other hand, subjects like science, language and engineering focus on logic and verbal analysis, making them a better match for students with a dominant left brain (Herrman, 1982; Katz, 1983).

However, in the current fast-paced and ever-changing world, when students are required to excel in various fields, it would be inappropriate to confine the functions of each brain hemisphere to specific academic courses. Time has brought about significant transformations and competition is the primary force that propels the world forward in the present era. Students should be encouraged to develop and utilise a wide range of cognitive processes in order to achieve optimal learning outcomes (Keat et al, 2016). In this regard, Koju et al (2019) suggested employing a well-balanced combination of instructional methods. This effective blend of teaching tactics encompasses several instructional approaches, resembling the Whole Brain Teaching method, which is a sort of differentiated instruction (Biffle, 2013). The Whole Brain Teaching technique has been documented in several literary works, including those by Torio & Cabrillas-Torio (2016), and Sontillano (2018). All of them concurred that it has a beneficial impact on the academic achievements of the students. Biffle (2013) proposed several teaching approaches that can be used in direct education. These techniques include: 1) Class-Yes; 2) Teach-Okay; 3) Five Classroom rules; 4) Hands and Eyes; 5) Switch; 6) Scoreboard; and 7) Mirror. Similarly, within the Hermann Whole Brain Teaching approach, certain instructional techniques encompass solitary hands-on tasks, experimentation, collaborative learning groups, and tangible exhibits (Torio & Cabrillas-Torio, 2016). Therefore, it can be inferred that the brain's dominance of learners can serve as fundamental information to enhance the delivery of classroom learning and that the weaker hemisphere be trained such that they can utilize those functions as well.

Metacognitive awareness levels of senior secondary Biology students

Research indicates that metacognition does not spontaneously emerge in all students and that teachers have a crucial role in fostering its growth, as they have the most direct influence on pupils (Davidson et al., 1995; Davidson & Sternberg, 1998). One possible explanation for the varying levels of metacognition observed in the current study sample might be the natural process of development of metacognitive awareness in students and also the teachers who might be contributing directly or indirectly to it. The rapid development of developmental and psychological sciences has significantly improved the quality of education. It has led us to understand that in terms of the advancement of metacognition, metacognitive knowledge comes before metacognitive control and metacognitive skills (Flavell, 1987). Metacognitive knowledge and Metacognitive regulation are integral components of Metacognitive awareness, which are the main areas of focus in this study. Metacognitive awareness can manifest as early as 4-6 years of age, characterised by a sense of something being wrong (Demetriou & Efklides, 1990; Blote et al., 2004). Metacognitive knowledge and regulation grow gradually over time, with it nearing maturity during adolescence after which metacognitive skills start developing (Veenman et al., 2004). This could be an additional explanation for the fact that the present study sample, including solely of adolescents aged 16-18, exhibit average, high, and extremely high levels of awareness.

Perceptual learning style preferences of Biology students

In the present study, it was found that less percentage of students showed unimodal preference, with 2.99% of students preferring visual learning style (V) only, 5.51% preferring kinesthetic style (K) only and 2.20% preferring auditory learning style (A) only. The highest preference was seen among 39.68% of students who preferred all styles, VAK as major preferences, which was followed by 30.08% and 13.54% of students who preferred VA and VK respectively.

A learning style refers to an individual's favoured approach to acquiring, analysing, and comprehending knowledge (Murray, 2004). In the present study, majority of students preferred VAK, leading us to understand that they prefer to learn Biology using a combination of learning styles. Nuzhat et al. (2013) and Ojeh et al.'s (2017) studies are in alignment with this, wherein they also found out that Biology students prefer multimodalities in learning. Saadi (2012); Avni (2011); Tanwinit & Sittiprapaporn (2010) also found similar results. The studies conducted by Ding et al. (2012), Urval et al. (2014), Kharb et al. (2013), Breckler et al. (2009), and Prithishkumar & Michael (2014) all found significant differences between unimodal and multimodal distribution. Ding et al. (2012) observed that out of a sample of 98 students, 14.3% preferred unimodal distribution while 85.7% preferred multimodal distribution. Similarly, Urval et al. (2014) found that 31% of their sample preferred unimodal distribution, while 69% preferred multimodal distribution. Kharb et al. (2013) obtained consistent findings when examining a group of one hundred medical students. Also, sixty percent of pupils, according to Breckler et al. (2009), had multimodal preferences. Lastly, Prithishkumar & Michael (2014) reported a high difference between unimodal and multimodal distribution among 91 first-year medicine students. Conversely, Suarez-Embalsado (2019) discovered a stronger inclination towards unimodality rather than multimodality. According to his research, auditory learning was the most favoured while visual-kinesthetic learning was the least favoured. Ortega et al.'s (2021) research on science students demonstrated a significant inclination towards the kinaesthetic learning style, while the visual style was the least favoured. In Malacapay's (2019) study, auditory learners were the majority with 47% of the overall sample, followed by visual and kinaesthetic learners. According to Bin Eid et al.'s (2021) research, auditory-kinesthetic was the most favoured among the students who had two modes of preference, which aligns with the findings of Aldosari et al.'s (2018) study. Additional investigations that show contrasting findings include those carried out by Almasri (2022), Balci & Çalışkan (2022), and Liu & Liu (2023).

The findings of this study demonstrate that Biology students have distinct perceptual learning styles, highlighting the significance of recognising and accommodating learner variety, particularly in the Biology classroom. While certain students prefer the act of jotting down notes, others may discover that actively listening to the teacher enhances their learning experience. One student may acquire knowledge more effectively through textual material, such as a textbook, whilst another student benefits more from visual aids like charts, graphs, and drawings presented by the speaker during a lecture. Some individuals may prefer to engage in auditory learning, while simultaneously benefiting from visual aids to enhance comprehension, and actively participating in practical exercises. Given the wide range of textual and visual illustrations, as well as the potential for practical work and experiments, it is crucial for teachers of Biology to remain knowledgeable and current on different approaches and tools. This will enable them to offer students more personalised learning experiences. Teachers should proficiently modify their instructional approaches to accommodate the varied requirements and inclinations of their students. Instead of exclusively depending on a single teaching approach, such as lecturing, educators should design their classes to incorporate multiple teaching techniques that are diverse in nature and can accommodate the preferences of learners.

Academic achievement levels of Biology students

The Academic achievement scores of the students revealed that 74.33% of the students were average achievers, 23.15% were high achievers and 1.10% were very high achievers. There were less number of low achievers and there were no students at all in the very low category. The investigator utilised a self developed achievement test to assess the academic performance of the pupils in Biology. The test was conducted on the pupils during the period of October to December. The test was intentionally scheduled during this specific time period because the test questions align with the Biology syllabus of Class 12, meaning that they are directly relevant to the subject matter. This is the time when the course has been fully covered and students possess comprehensive knowledge of all the topics included in the syllabus. This could be one of the reasons why there are very few pupils in the low achievement category and none in the extremely low achievement category. The majority of students have achieved average performance, but a few students have demonstrated exceptional performance.

Various other factors can also influence academic achievement. Duckworth et al. (2007) contend that achievement is the outcome of a combination of innate aptitude and effort. Put simply, academic success does not depend only on the learner's talents, but rather on the amalgamation of cognitive capacity and personality attributes. Students' academic achievement in the field of science is susceptible to a multitude of contextual, affective, and motivating factors. These comprise of workload, the quantity and intricacy of the subject matter, the task orientation and personal capabilities of the students, the efficacy and teaching capabilities of the instructor, the students' personalities, and the size of the class (Ehrenberg et al., 2008; Armstrong, 2009;

Bietenbeck, 2011; Wang & Hsieh, 2015; Kwon, 2016; Rus et al., 2016; Kirillova et al., 2017; Say & Bag, 2017; Shcherbakov et al., 2017; Abbasi et al., 2018). Given the typically abstract and complex nature of science education, effective teaching of science necessitates the careful attention and proficiency of teachers to effectively engage students and impart knowledge using tangible and comprehensible approaches. The academic achievement of scientific students can be influenced by the characteristics of their teacher, as suggested by several research (Wayne & Youngs, 2003; Clotfelter et al., 2007; Harris & Sass, 2008; Armstrong, 2009; Rockstroh, 2013). The importance of student motivation in relation to their success in science-related activities and academic pursuits has been emphasized in numerous studies (Jegede, 2007; Barmby et al., 2008; Llbao et al., 2016). The current investigation, however, focusses on three important factors which are Brain hemispheric dominance, Metacognitive awareness and Perceptual learning style preferences, the influences of which shall be discussed in the following sections based on the results obtained from the inferential statistics.

5.2 Discussion on the findings of Objective 2

Objective 2: ***To study the Brain hemispheric dominance, Metacognitive awareness, Perceptual learning style preferences and Academic achievement in Biology of senior secondary school students with respect to gender and type of school.***

Findings with respect to gender

On investigating gender differences, it was found that gender was not associated with Brain hemispheric dominance. This finding is in line with a study conducted by Montero (2020) on Filipino senior high school students, who found out that neither gender nor age were associated with brain dominance. However, this is in contrast to the findings of Ameen (2017) and Nandhini (2017) who found out that males are mostly right brained and females are left brained and Singh et al. (2011) who found out that males were more left-brained than females. The findings suggest that the learners' brain dominance is not affected by their gender, indicating that these two factors are independent. While there is no significant correlation between brain dominance and students' gender, it is nonetheless regarded as an important factor in understanding individual differences.

The results regarding the metacognitive awareness scores and its dimensions indicate a significant difference between males and females in terms of both Metacognitive knowledge and Metacognitive control. The mean scores for both dimensions were higher for females. Female participants exhibited significantly greater scores in overall metacognitive awareness. Consequently, it may be inferred that women possess a greater understanding of their cognitive abilities and the areas in which they excel (metacognitive knowledge). Additionally, they demonstrate superior abilities in regulating and managing their own learning processes (metacognitive regulation). Metacognitive knowledge refers to the ability to understand one's own learning process and make decisions about which strategies to use, when to use them, and how to apply them effectively. Metacognitive regulation, on the other hand, involves planning, managing, monitoring, and evaluating one's learning strategies in order to optimise the learning process (Schraw and Dennison, 1994). The results align with the studies conducted by Ahmad & Sultana (2021) and Bedir & Dursun (2022), who also identified significant differences in metacognitive awareness based on gender and grade. Güneş's (2022) research findings indicates that females outperformed males in metacognitive regulation, with a statistically significant difference in scores. The author contends that women are better in using and executing their metacognitive capacities as compared to males. In Aburayash's (2021) study significant statistical disparities between males and females were found, with females scoring higher in cognitive organisation and cognitive processing. According to him, the observed result could be explained by the inclination of female students to prefer participating in structured and prearranged activities, in contrast to their male peers, and their lesser inclination to rely on instinctive decision-making. Sukarelawan & Sriyanto (2019) argue that female students exhibit greater criticality in their responses to questions and possess a high level of motivation in learning science. Consequently, they demonstrate a heightened level of focus and seriousness in their approach to learning, in contrast to male students who tend to adopt a more relaxed and laid-back attitude. In contrast, Nongtodu & Bhutia (2017), Eriyani (2020), Abiodun et al. (2021), Cetin (2021), Asy'ari et al. (2022), and Wulandari et al. (2022) discovered that there were no significant differences between males and females in terms of metacognitive knowledge and metacognitive regulation. Both genders scored similarly and neither group outperformed the other. There is a scarcity of studies that have examined the components of metacognitive awareness, thus making it challenging to make comparisons and distinctions. Nevertheless, this finding implies that educators should prioritise learners' specific metacognitive abilities since these can influence the extent to which learners derive benefits from the provided assistance.

Females outperformed males on the Biology Achievement test as well. One possible explanation could be that females have a higher level of metacognitive awareness compared to males, as discussed above. Females had better metacognitive knowledge and metacognitive regulation compared to males. Another possible reason is that females exhibit greater self-discipline (Duckworth & Seligman, 2006) and possess more developed attitudes towards learning than males (Cornwell et al., 2013) when it comes to test-taking. Additionally, studies have discovered that they tend to exhibit higher levels of conscientiousness (Schmitt et al., 2008). While previous research has not specifically examined gender differences in test-taking strategies, it has been observed that females have a neurocognitive advantage in the area of planning. Planning involves the implementation of strategies and cognitive processes to ensure the successful completion of a task, including self-monitoring, self-correction, and verification of completion (Naglieri and Rojahn, 2001). This might also be one of the reasons why they possess better metacognitive awareness than males as well along with performing better on the achievement test.

Males and females, however, did not show significant differences in case of perceptual learning style preferences. Their results for visual, auditory, and kinesthetic learning preferences were similar, suggesting that gender does not have an impact on the learning style they employ when studying Biology. The results align closely with the conclusions drawn by Abidoye & Olorundare (2020), Bin Eid et al. (2021), and Ortega Torres et al. (2021), who also observed no significant gender disparities in perceptual learning styles. The former conducted the study on medical students, while the latter conducted it on secondary science students. This is consistent with a previous study conducted by Chouhan et al. (2023) on Biology students who observed similar findings. The absence of significant differences between the two genders could potentially be attributed to the findings illustrated in Figure 4.3.1. The majority of the study sample acquire knowledge in Biology by employing all three types of learning styles (VAK). Regardless of gender, they have a strong affinity for multimodal learning. Contrarily, Wahyuni et al. (2023) revealed different findings, showing significant differences in the participants' learning styles. Females majorly favoured the kinesthetic learning approach, whilst men showed a greater preference for group learning. Their preferences for visual and auditory modalities were similar. However, it is important to note that understanding the learning patterns of female and male students has a good impact on their ability to learn the subject. They will possess the capacity to arrange information and manage strategies for the purpose of learning and obtaining knowledge (Magdalena, 2015). Moreover, the academic performance of students and their educational achievements can be enhanced if teachers tailor the instructional process to align with the students' learning styles (Graf et al., 2010).

Findings with respect to type of school

On investigating whether differences exist between government and private school students on the variables being studied, it was found that Brain dominance was not associated with type of school. This finding is in line with a study conducted by Avoodaiammal (2018), who found out that there was no difference in brain dominance among government, self-financed and government-aided college students. There are very less studies on brain dominance based on demographic variables, especially with regard to type of school, which makes it difficult to compare and contrast the current finding with other findings. Nevertheless, in contrast to the above findings, Rajalakshmi (2015); Beulah (2016) in their studies among higher secondary students found out that students studying in government schools had significantly greater left and right brain hemisphericity than the government-aided and private school students. In contrast, Nandhini and Subramanian (2021) discovered that students attending private schools exhibited markedly greater right brain dominance. They state that private schools employ many activities to actively involve their pupils, so enhancing the reputation and recognition of the institution. These exercises, together with other instructional tactics, collectively train the majority of their cognitive skills. However, in the present study, it was found that brain hemispheric dominance patterns were similar for both government and private school students and it cannot be ascertained that students from a particular type of school will show a particular type of brain dominance.

The findings on the metacognitive awareness scores and its dimensions showed that there exist no significant differences between government and private school students for Metacognitive knowledge but significant differences exist for Metacognitive regulation. The findings of Vaijayanthi (2012); Jaleel & Premachandran (2016) and Perry et al. (2019); Sangeetha and Govindan (2022) found out no differences between the two groups of students in their studies. However, Jagadeeswari & Chandrasekaran (2014); Rajesh (2021) found out that government school students had significantly higher metacognitive awareness than private school students. They state that, in the context of their area, government school students don't have enough facilities in schools to learn as much as private school students do. Consequently, they exert significant effort independently, employing various strategies as necessary in order to acquire knowledge. As adolescents acquire knowledge through various independent ways, their ability to comprehend their own learning process improves. According to Jagadeeswari and Chandrasekaran (2014), students who have a wide variety of strategies at their disposal and understand when and how to use them are more equipped to adapt their approaches to certain situations. Nevertheless, our present investigation reveals that government school students have better metacognitive regulation, meaning they can plan, monitor, manage and evaluate their learning processes better than private school students. They are similar on the metacognitive knowledge scores, implying that both groups "know" or possess the knowledge about when and why to use certain learning strategies when it comes to regulating then government school students are found to be a little better. When it comes to perceptual learning styles, both groups exhibited similar mean scores for both groups. The Sikkim government has made persistent efforts throughout the years to enhance the calibre of education imparted by the government schools. While the facilities of government schools may not be as impressive as that of private schools, they have made every effort to ensure the provision of high-quality education. They have made sure to provide the basic essentials of ICT to the schools. Currently, students from both government and private schools have the opportunity to directly compete against one another. Government school pupils are also excelling in several fields, much like their counterparts from private institutions. One possible explanation for the similar scores in perceptual learning style preferences among these individuals is that they are all Biology students and both groups learn Biology utilising multimodal styles.

The academic achievement scores, however, show a significant difference between government and private school students, with the mean scores favouring the government school students more. This contradicts the findings of Rajalakshmi (2015), who discovered that students in private schools outperformed government school students. She contends that private schools employ and involve their students in diverse educational activities with the intention of considering them as mere instruments for achieving high grades, in order to enhance the reputation and prestige of the school. Manichander (2015) discovered that private school students outperform government school students due to superior infrastructure, committed young teachers, and exceptional teaching strategies. These advantages enable private school students to achieve higher academic performance.

The researcher would also like to discuss more about the current finding wherein government school students performed better on the basis of what she observed while conducting her field work in various private and government schools. She noted that the majority of classrooms in private schools in Sikkim at the senior secondary level are well furnished with various teaching aids, especially overhead projectors and computers. However, after conducting surveys in many government schools, it was seen that the academic standards in Sikkim surpass the common perception of government institutions. Government school children possess the same level of competence as their counterparts in private schools. Indeed, it is possible that this group of students exhibited more zeal and grit, hence potentially contributing to their better performance in the present study. Grit encompasses the qualities of perseverance, passion, and commitment that students possess in order to achieve a long-term objective (Duckworth, 2016). Given that a significant portion of students in government schools in Sikkim originate from modest backgrounds, achieving academic proficiency is their sole means of securing admission to higher education institutions within the state. Private school students typically do not face significant challenges in terms of affordability, as the majority of them come from affluent families that have the means to finance their education in any location, including overseas. Another observation made by the teacher during the administration of the achievement test was the level of concentration displayed by the pupils from government schools. The government school students exhibited a higher level of attention to detail when composing their responses in contrast to the students from private schools. The researcher greatly values this aspect of their work. Also, another possible explanation for government school students performing better in the test than private school students would be, as mentioned earlier, the former demonstrating higher metacognitive regulation mean scores than the latter.

Having better metacognitive regulation entails having better ability to plan, monitor, debug, and evaluate. They must have employed these strategies more effectively than their counterparts when approaching the test.

5.3 Discussion on the findings of Objective 3

Objective 3: ***To study the Brain hemispheric dominance, Metacognitive awareness and Perceptual learning style preferences of senior secondary school students with respect to their Academic achievement levels.***

The finding on the Brain hemispheric dominance (left and right) of students with respect to their Academic achievement levels as given in Table 4.3.1.1. showed that there is no association between the two variables. This implies that whether a student is left brained or right brained has no association with whether that student is a very high achiever, high, average or low achiever. Arabmofrad et al. (2021) also found a similar finding wherein brain dominance was not associated with academic achievement. Conversely, Ramly (2021) conducted a recent study on students specialising in animation and applied sciences, revealing that Science students exhibited left-brain dominance, whilst Animation students demonstrated right-brain dominance and excelled in their respective fields of study. They assert that individuals with a dominant left hemisphere of the brain, known for their analytical and logical thinking, excelled in applied sciences. Conversely, those with a dominant right hemisphere, known for their intuition, creativity, and imagination, excelled in the field of animation. Lavach (1991) also found that students studying natural science exhibited a left-hemispheric cognitive style, while students studying Humanities displayed a predilection for right-hemispheric dominance. Despite Biology being a scientific discipline, previous research (Fernandez, 2011; Özyel, 2016; Mansour et al., 2017; Joven et al., 2020; Montero, 2021) has yielded conflicting results regarding the academic performance of the brain hemispheres. However, our current study reveals that both groups of students perform equally well. In his study, Walesh (2015) discovered that engineers, who are typically left-brained, also possess the ability to think creatively and innovatively, as well as actively pursue opportunities. This can also be related to the current finding. While it is true that most Biology students are left-brained, the presence of both left and right-brained students across all achievement levels indicates that Biology students are also capable of meeting the creative and imaginative requirements of the subject. This is corroborated by additional studies, such as the research conducted by Ayadi et al. (2019), Wei & Sulaiman (2018), and Yazgan & Sahin (2018). These studies also concluded that there is no significant difference in academic achievement between students who are left-brained and those who are right-brained. The presence of learners with diverse brain dominances in the classroom is inevitable. This study emphasises the importance of determining learners' brain dominance as it is expected to have a significant impact on their choice of strategy use (Özyel, 2016).

When assessing the metacognitive awareness of students on the basis of their academic achievement levels as shown in Tables 4.3.1.3. and 4.3.1.4., it was found that there are significant differences among the very high, high, average and low achievers on their metacognitive awareness levels. Significant differences are found among all the academic achievement levels in case of both metacognitive dimensions. Simply put, both metacognitive knowledge and metacognitive regulation scores are found to increase with the increase in academic levels. This clearly indicates that there is a linear positive relationship between metacognitive awareness and academic achievement as shown in recent studies conducted by Ashfaq et al. (2022); Aydin & Mocan (2022); Ahmad & Sultana (2021); Akkurt (2021); Oyovwi & Iroriteraye-Adjekpovu (2021); Samuel & Okonkwo (2021); Arami & Wiyarsi (2020); Oyelekan et al. (2019); Cook Jr (2018); Hakeem et al. (2017) on Science students; Bedir & Dursun (2022); Souhila (2022); Bećirović et al. (2021); Mäkipää et al. (2021) on English students; Tak et al. (2022); Bulut (2021); Baltaci et al. (2016) on Maths students; and Sawhney & Bansal (2015); Ward & Butler (2019); Çetin (2021); Ihor & Ruslana (2021) on students in general (without considering their subject backgrounds). Prior studies have also demonstrated the importance of metacognitive awareness in learning. They have found that learners who exhibit high levels of metacognition are more strategic (Garner, 1989), more inclined to use problem-solving heuristics (Artzt & Armour-Thomas, 1992), and better at predicting their test scores (Vadhan & Stander, 1994).

In contrast, Hassan et al. (2022) discovered that neither of the dimensions of metacognitive awareness showed a significant correlation with academic achievement levels. This finding suggests that there is a need for corrective measures in the curriculum implementation, specifically in the teaching of metacognition. In a study conducted by Siraj et al. (2022), it was discovered that university students majoring in Chemistry had similar findings. The researchers proposed that university professors, educators, and curriculum developers should develop the Chemistry curriculum in a manner that incorporates the use of metacognition. According to the study conducted by Wulandari et al. (2022), students who possessed a high level of metacognitive awareness were likely to achieve lower GPAs, whereas those with a low level of metacognitive awareness were likely to get better GPAs. Similar findings were also reported by Abiodun et al. (2021) and Eriyani (2020).

Regarding perceptual learning styles, Tables 4.3.1.6. and 4.3.1.7. reveal significant differences between groups in terms of both visual and auditory learning styles where the mean scores of very high achievers, high achievers, and average achievers are higher than those of low achievers. However, no significant differences were observed in case of the kinesthetic learning style. Consequently, it may be inferred that kinesthetic learning is equally favoured by individuals at all levels of academic achievement when studying Biology. In his study on higher secondary students, Punjabi (2022) found that the kinesthetic learning style was more beneficial than the visual learning style, and the visual learning style more than the auditory learning style in terms of Science achievement. These findings align with the research conducted by Kopsovich (2001), Coutinho (2007), and Apipah et al. (2018). Therefore, it can be inferred that students can enhance their learning outcomes by employing kinesthetic methods in the classroom. This might be one of the reasons why in the current study as well, we find that all students prefer kinesthetic learning equally. Janštová & Míková (2019) state that Biology involves theoretical knowledge from textbooks as well as hands-on practical courses. In their survey of Biology students' learning styles, they discovered a strong inclination towards utilising live microscopy, conducting experiments, and performing dissections as the preferred methods. This clearly demonstrates the significance of kinesthetic learning, which likely contributes to its popularity among learners of all types in the Biology classroom.

5.4 Discussion on the findings of Objective 4

Objective 4: ***To study the relationship between Metacognitive awareness, Perceptual learning style preferences and Academic achievement in Biology of left brained and right brained students.***

The findings on Objective 4 showed that there existed significant positive correlations among the Metacognitive awareness, Perceptual learning style preferences and Academic achievements of Left brained and Right brained students. In order to initiate a discussion around this, I would like to emphasise the research conducted by Aburayash (2021), which examined the metacognitive awareness of students in the humanities and science fields based on their brain dominance patterns. It was found that both streams showed a higher correlation between metacognition and left-brain dominance compared to right-brain dominance. Additionally, left-brain dominance had a higher correlation with academic achievement than right-brain dominance. He posits that this could be attributed to the persistence of old teaching methods, wherein students' left-brain functions are still prioritised above their right-brain functions. Furthermore, both humanities and science students are being educated in identical conditions and using the same instructional approaches. However, for this particular study, the participants were exclusively Biology students. The results revealed a strong and positive correlation between metacognitive awareness and academic achievement in individuals with both left-brain and right-brain dominance. There were no clear distinctions in the correlation coefficients which make us believe that metacognition is better correlated with the academic achievement of left brainers than right brainers or vice versa. The correlation coefficients, signifying positive moderate correlations between Metacognitive knowledge and Academic achievement and between Metacognitive regulation and Academic achievement were similar for both left and right brainers. According to the brain theory (the neural direction), the analogy between thinking and learning, as learning is thinking, and thinking occurs in the brain cortex, whether it is on the left side or the right side of the brain (Aburayash, 2021). According to the theory of brain function (neural perspective), there is a correlation between thinking and learning. Learning is essentially a form of thinking, which takes place in the brain cortex, whether it is the left or right hemisphere of the brain (Aburayash, 2021). According to Dulger (2012), metacognition plays a crucial role in regulating the learning process, irrespective of an individual's hemispheric preferences, and benefits learners of all sorts. Therefore, regardless of their brain hemisphere dominance, both measures of metacognitive awareness were found to have a significant correlation with their academic achievement in Biology. These findings also resonate with the studies conducted by Narang and Saini (2013); Hong et al. (2015); Sawhney and Bansal (2015); İşgör (2016); Cook (2018); Shah and Modna (2022) wherein they found positive correlations between metacognitive awareness and academic achievement despite being left brainers or right brainers. Some contradictory results about the correlation between metacognition and academic achievement have also been documented. For instance, Sperling et al. (2012); Çetin (2017) and Hassan (2022) found no significant relationships between them. Mäkipää et al. (2021) found better correlation between Metacognitive knowledge and Academic achievement. Nevertheless, most studies consistently conclude that metacognition is crucial in understanding academic achievement and makes a distinct contribution (Veenman et al., 2005; Young and Fry, 2008).

The brain serves as the core for human cognition, overseeing all learning processes. Given that metacognition controls cognition, it is crucial to understand the profound connection between the brain and metacognition. Nevertheless, it is widely understood that metacognition undergoes a development over time, similar to the development of learning styles. Learning styles, similar to abilities, are not innate. They undergo partial development as a result of environmental conditions (Otero et al., 1992). The learning style people choose is their chosen modality of acquiring knowledge (Gupta, 2017). The present investigation reveals a strong and positive correlation between the perceptual learning styles and academic achievement of the students. For both individuals who are left-brained and right-brained, there is a significant and moderate relationship between academic achievement and visual learning, between academic achievement and kinesthetic learning, as well as between academic achievement and the combination of all learning styles known as VAK. Furthermore, for both categories of students, there exists a positive but weak association between auditory learning and academic achievement. The low correlation may be attributed to the transition in learning methods from auditory to visual modes in contemporary society, primarily driven by the widespread adoption of mobile phones and online learning. Nowadays, students have a preference for visual and kinesthetic learning over auditory learning. They want to actively participate in class rather than passively sitting in one place. This is seen in their desire to observe and experience things rather than just listen. Additional research examining the relationship between perceptual learning style preferences and academic achievement has found significant associations. These studies include those of Moayyeri (2015), Wright and Stokes (2015), Van and Tran (2020), and Aburayash (2021). Fahim et al. (2021) conducted a study on Medical students and found that their highest preference was for kinesthetic and visual learning, followed by auditory learning. However, the current study revealed that their academic achievement was better when they utilised all three modalities of learning. In a study conducted by Ortega Torres (2021) on Science students, it was discovered that those students who had ARK and VARK preferences achieved significantly superior academic scores in science compared to those who had frequent SP, A, K, AK, VAK preferences. This suggests the importance of multimodal learning. This outcome is not unexpected, given the utilisation of tri- and tetramodal learning styles enables students to benefit from a wider range of learning materials. In contrast, the studies conducted by Horton et al. (2012); Awang et al. (2017); Shrestha et al. (2020); Bin Eid (2021); and Ishartono et al. (2021) did not find any significant correlation between any of the perceptual learning styles and academic performance. Chavosh and Davoudi (2016) found that only tactile and kinesthetic learning were significantly correlated with academic achievement. In their study on Biology students in Nigeria, Abidoye and Olorundare (2020) reported that there was a negative correlation between visual and kinesthetic learning and academic achievement in Biology, whereas there was a positive correlation between auditory learning and academic achievement in Biology. Rogowsky et al. (2020) argue that tailoring instruction to students' learning styles does not enhance their learning outcomes. Additionally, Papadatou-Pastou et al. (2018) criticise learning-styles based instruction as an unreliable concept for determining effective teaching methods.

Therefore, the insights we may make at this point is that it is preferable to possess something rather than having nothing at all. It is important to recognise that adapting teaching approaches in the classroom to match students' preferences is always preferable than completely disregarding them. In their concluding remarks, Lin and Tsai (2013) urge science educators to minimise the use of traditional teaching methods and instead involve students in diverse inquiry-based science learning activities in the classroom and other active approaches to increase their learning. Considering this perspective, it has been contended that teachers can enhance the effectiveness and efficiency of learning by adapting their approaches to align with the individual learning styles of their students. This awareness of learning style distinctions enables teachers to better cater to the preferences of their students (Vaughn & Baker, 2008; Romanelli et al., 2009). Identifying one's preferred learning style can lead to better learning results and increased student satisfaction with the educational process (Peacock, 2001; Divaris et al., 2008).

5.5 Discussion on the findings of Objective 5

Objective 5: ***To investigate whether Metacognitive awareness and Perceptual learning style preferences would be significant predictors of Academic achievement in left brained and right brained students.***

The results of Objective 5 indicated that both metacognitive awareness and perceptual learning styles have a significant impact on the academic performance of Biology students for both left brained and right brained students. Hierarchical regression analysis was conducted using different models. Model 1 included only Metacognitive knowledge. Model 2 included both Metacognitive knowledge and Metacognitive regulation, which together are components of Metacognitive awareness. Model 3 included Metacognitive knowledge, Metacognitive regulation, and Visual learning. Model 4 included Metacognitive knowledge, Metacognitive regulation, Visual learning, and Auditory learning. Model 5 included Metacognitive knowledge, Metacognitive regulation, Visual learning, Auditory learning, and Kinesthetic learning. The data indicated that Metacognitive awareness is a strong predictor of academic achievement in both groups of students. Furthermore, the inclusion of perceptual learning styles in the hierarchical model amplifies their influence. It is observed that their effect on academic achievement is most pronounced when students possess awareness of both their cognitive knowledge and regulation, as well as their learning styles.

Hierarchical regression analysis entails the selection of the most optimal set of predictors, with the order of variable entry predetermined by the researcher prior to conducting the analysis. Here, the researcher takes charge of making decisions about the hierarchical input of variables instead of relying on the software to make them randomly or automatically (Henderson & Vellman, 1981). Flavell (1979), often referred to as the 'Father of metacognition,' states that metacognitive regulation requires the presence of metacognitive knowledge. In other words, individuals can only manage their learning process once they have acquired knowledge about their own cognition. Metacognitive knowledge initially emerges according to Alexander et al. (1995), followed by the development of metacognitive regulation as indicated by Veenman et al (2004; 2006). Furthermore, students' understanding of their learning styles only emerges once they become conscious of their cognition. Students gain insight into their effective learning strategies only when they possess self-awareness as learners (Prins et al., 2006). This is due to the belief that metacognitive awareness contributes to self-regulation and exerting control over the learning process (Hartman, 2001). Learning styles, thus, follow metacognitive awareness in the hierarchical model. Also, previous studies indicate that the eyes can be considered as a means to understand someone's inner thoughts and emotions (Adams et al., 2010). Consequently, they play a significant role in perceiving and interpreting information (Baron-Cohen et al., 2001). The eyes have a greater influence than other senses in perceiving and understanding information that originates from within oneself (intrapersonal) and from others (interpersonal) (Vinette et al., 2004). Therefore, visual learning has been placed before auditory and kinesthetic learning among the three perceptual learning styles. Kinesthetic learning involves acquiring knowledge through physical engagement, following the initial exposure to visual and auditory stimuli. Therefore, the present investigation reveals that the model accurately predicts 62.6% and 64.6% of the variation in academic achievement scores among left-brained and right-brained individuals, respectively.

Other studies that have found significant relationships between metacognition and academic achievement are those conducted by Devaki and Marylilypushpam (2010); Ozsoy (2011), Nett et al. (2012), Narang & Saini (2013); Sawhney and Bansal (2015); Owo and Ikwut (2015); Callan et al. (2016); Akpur (2017); Nongtodu and Bhutia (2017); Sonowal and Kalita (2017); Miller and William (2019); Abdelrehman (2020); Pradhan and Das (2021); Ashfaq et al. (2022); Celik (2022). Regarding the relationship between metacognition and academic achievement, Pradhan and Das (2021) discovered that metacognition accounted for 43% of the variation in the academic achievement scores of undergraduate students. Specifically, 34 to 36% of students with above-average metacognition demonstrated higher academic achievement, while 64% of students with below-average metacognition had lower academic achievement. Ghaleb et al.'s (2015) research indicated that mastery goals and metacognition were able to significantly predict 36% of the academic motivation observed in university students. Akpur (2017) determined that 58% of the variation in academic achievement may be accounted for by the factors of need for cognition and metacognition. Adigüzel and Orhan (2017) found that self-regulation and metacognitive skills account for approximately 18% of the overall variation in academic performance in the English class. Oyelekan et al. (2019) discovered that self-efficacy and metacognition accounted for 69.1% of the variation in academic achievement test results among Chemistry students. Perceptual learning styles were found to be a strong predictor of academic achievement in language (Soodmand Afsar & Bayat 2018), science learning (Wang & Tseng 2015), and education (Akbulut & Cardak 2012). In the study conducted by Ortega-Torres (2021), it was shown that kinesthetic learning had significant impact on academic performance in the field of Science, although auditory and visual learning did not demonstrate the same predictive power. Ikechukwu's (2017) study found that perceptual learning styles had a strong but weak impact, explaining only 9% of academic achievement. In contrast, Semiyari and Jahani (2020) reported that learning styles did not have a significant impact on academic achievement.

Consequently, it is evident that individuals who possess both left-brain and right-brain characteristics perform effectively when they have developed metacognitive awareness and are also cognizant of their perceptual learning styles. The understanding of one's learning style and the use of learning styles as a method of absorbing knowledge have an impact on student learning outcomes (Behar-Horenstein & Dix, 2009; Behar-Horenstein et al., 2011). Hence, it is imperative for teachers, parents, school authorities, and students to cultivate a deeper understanding of the importance of metacognitive awareness and learning styles as influential factors in students' academic performance. Understanding the cognitive processes and learning strategies of learners is essential for developing and managing educational systems, since it can greatly influence the desired outcomes in the majority of instances. The topic of individual differences and their various learning styles have been extensively discussed by cognitive psychologists, as stated by Liu and Reed (1994). Enhancing our understanding of these differences enables us to more effectively analyse the process of acquiring knowledge.