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THE VISUAL LITERACY OF GRADE 10 LIFE SCIENCES LEARNERS IN CYTOLOGY

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Abstract

In Life Sciences Education, the use of educational external representations (ERs) such as diagrams, models and animations is increasingly appearing in learning and teaching resources. However, their effectiveness is limited if learners experience learning difficulties due to lack of visual literacy and spatial ability skills to work with ERs. This quantitative study explored the level of visual literacy of 225 Grade 10 Life Sciences learners in cytology across six high schools in Pretoria, South Africa. Through quantitative research method a Life Sciences visual literacy questionnaire and a spatial ability test were used to collect data. Collected data was analysed descriptively and inferentially through SPSS Version 23. The results showed that most Grade 10 Life Sciences learners lack average visual literacy skills. Furthermore, the results showed that gender doesn't play a role on the learners' performance in visual literacy skills as both genders performed approximately equally in both tests. Teachers need to incorporate different ERs that would stimulate different senses, and which will also enhance learners' visual literacy and spatial ability skills in their lessons. It is recommended that the use of ERs should be reinforced by providing the ERs to both teachers and learners and helping the teachers with necessary workshops to equip them with skills needed to explicitly teach learners using ERs that will stimulate different senses.

Keywords: Biology, cytology, external representations, Life Sciences, spatial ability skills, visual literacy skills.

1. INTRODUCTION

In the past years, learners were taught using textbooks and they were dependent on the teacher to bring abstract biological concepts into concrete ones. However, in the 21st century, learners are exposed to different technological devices such as computers with computerised software games and videos, digital devices such as camcorders and smart phones. All these devices are creating more room for visual literacy to be an area of critical importance in education. Therefore, at a scholarly level an effective learner, to fully function in this technology-driven world, must be able to efficiently communicate verbally, visually, digitally and through multimodal forms of communication (Liu & Xu, 2025; Boateng et al., 2024). Learners of today are more acquainted with rapid technological developments; however, many still lack visual literacy competencies. Visual literacy refers to the ability to interpret, analyse, construct and communicate meaning from visual information (Woods & Matuk, 2024). The increasing exposure of learners to technology offers teachers opportunities to use educational technologies to create positive learning environments and enhance classroom learning. Research has shown that external representations (ERs), including videos, animations and interactive multimedia, support teaching and learning more effectively than text-only instruction (Navarrete et al., 2023). Literature reveals that visualisation is not a simple process of observing an object, but a process involving active construction of meaning. Scholars in visual literacy argue that interpreting visual information requires learners to apply critical observation, reasoning and spatial skills (Woods & Matuk, 2024).

In Biology (Life Sciences) curricula, many concepts are abstract and cannot be observed directly with the naked eye. Such concepts become difficult for learners to understand if they are not taught using ERs. Teachers may also struggle to transform abstract concepts into concrete understanding if they are not adequately trained in the use of educational technologies and visual pedagogies (Educational Transformation Through Emerging Technologies, 2025). The increased use of web-based learning materials, multimedia and digital simulations is an attempt to address these challenges. Learners experience learning difficulties when learning scientific phenomena through ERs (Digital Learning in Sciences Education, 2023). Learners often struggle to recognise that ERs are representations rather than reality itself; they also experience difficulties linking two-dimensional diagrams to three-dimensional structures and relating unfamiliar ERs in assessment tasks to those encountered in textbooks. Furthermore, curricula often do not explicitly develop learners' visual literacy and spatial reasoning skills (Friedrich et al., 2024). Research has also explored whether gender influences visual literacy and spatial abilities in science education. Recent studies suggest that differences are increasingly minimal and are influenced more by exposure, digital learning opportunities and instructional support than by gender alone (Liu & Xu, 2025; Friedrich et al., 2024).

2. METHODOLOGY

To attempt to address the research questions the study followed a quantitative research approach where an exploratory survey was used. In the study the population consisted of Grade 10 learners taking Life Sciences as a subject in Pretoria, Gauteng province, South Africa. A sample of 225 Grade 10 learners enrolled for Life Sciences as an elective subject was conveniently selected. Two instruments were subsequently administered to empirically collect data. The Life Sciences visual literacy test (LSVLT) which was constructed and piloted by the researcher and a spatial ability test (SAT) adopted from Newton and Bristol (2009) based on visual recognition which measured the spatial abilities of learners were applied during the collection. The analysing of the empirical data was statistically done using Statistical Package for Social Sciences (SPSS) Version 23 through descriptive statistics, Levenes' test to test for homogeneity of variance, ANOVA (to test differences between groups) and correlations.

3. RESULTS

The Visual Literacy of Learners in Cytology

In Life Sciences there are a lot of concepts that are abstract and not possible to perceive with the unaided (naked) eye. Such concepts become very intricate for learners to understand if they are taught without the use ERs. The results revealed that most learners indicated that they understand Life Sciences better when presented in three different modes. Most of the learners understand it better if its text coupled with diagrams, drawing or real life examples (Table 1).

Table 1: Learners preference to different ER modes to understand Life Sciences better

Three ERs to present Life Sciences phenomena	Learners' frequency	Percentage
Text, diagrams and drawings	10	14
Text, diagram and physical models	2	3
Text, diagram and real-life examples	4	5
Text, diagram and videos	2	3
Text, photos and real-life examples	3	4
Text, drawing and photos	1	1
Text, drawing and real-life example	1	1
Diagrams, drawing and real-life examples	13	18

Teachers use ERs to enhance learners' visual literacy skills and to convey abstract concepts into concrete examples. The findings also depicted that teachers always use chalkboards, textbooks and exercise books to teach Life Sciences than any other ERs (Figure 1). In addition, the ERs learners use to study and ERs they prefer to use to study Life Sciences are somehow influenced by their teachers' choices of ERs to teach Life Sciences.

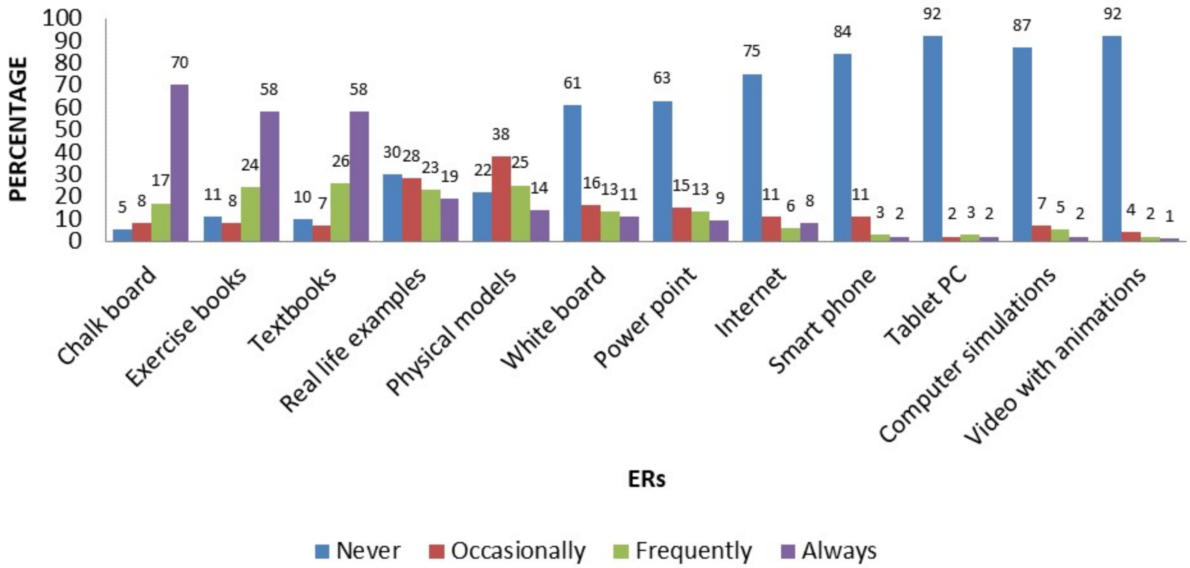

Figure 1. Frequency of opinions of learners regarding teachers' use of ERs to teach Life Sciences

The ability to translate text into a drawing is one of the skills required in visual literacy known as translation. Therefore, learners were asked to draw a mitochondrion, they drew an oval structure. The oval structure was mostly incorrectly drawn and labelled with chloroplast labels (Figure 2). Only a few attempted to draw 3D drawings (Figure 3). The incorrectly labelled structures may result in confusion between a mitochondrion and a chloroplast, failing to grasp content knowledge depicted by the ERs used to teach about cells or difficulties with applying skills learned in one situation to a new situation.

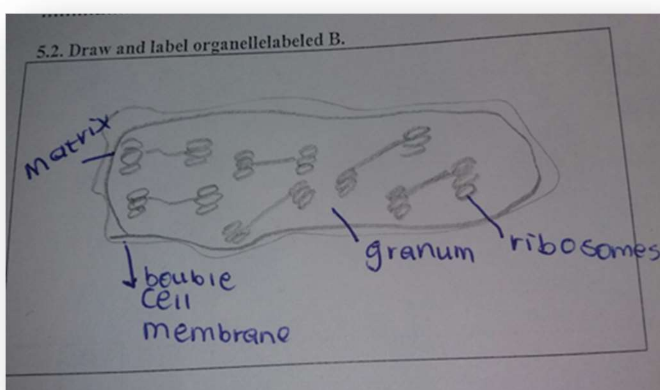

Figure 2. A learner drawing of a mitochondrion

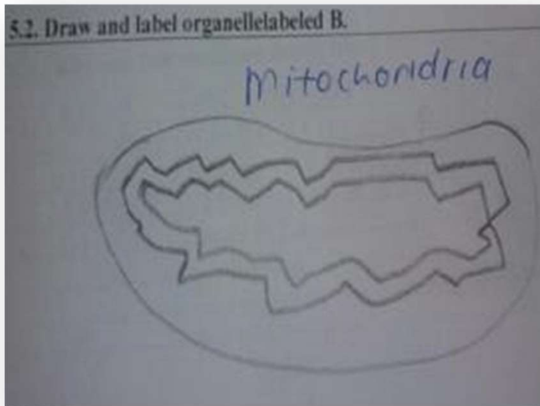

Figure 3. A learner drawing of a 3D mitochondrion

Learners' Performance in a Life Sciences Visual Literacy Test

Learners scored highly in questions that ordered lower visuo-spatial skills like *arrange, order,* and *compare* in the Life Sciences visual literacy test (Table 2).

Table 2: Highly scored questions in the Life Sciences visual literacy test

Question no	Skills Required	Percentage Correct	Incorrect
1	Identify/perceive colors	48	51
3i	Complete, Imagine	78	16
3ii	Recall/ retrieve	77	17

Moreover; learners scored lower in the questions that ordered high cognitive skills like mental rotation, analyse, complete (cognitively), imagine, relate, infer and predict (Table 3).

Table 3: Most difficult questions in the Life Sciences visual literacy test

Question no	Skills Required	Percentage Correct	Incorrect
5.1	Outline and Recall/Retrieve	21	57
6.1a	Arrange/order/organize/classify	20	66
6.1b	Recall/retrieve	22	64
6.1c	Analyse	12	75

Question no	Skills Required	Percentage	
		Correct	Incorrect
6.1d	Relate	64	62
6.2a	Arrange/order/organize/classify/ Recall/retrieve/Manipulate/ mental rotation; recognize orientation; recognition	36	38
6.2b		21	54
6.2c		15	60
6.2d		37	38

Learners' Performance in the Spatial Ability Test

In the spatial ability test, the results portrayed that questions that required mental rotation more, comparison, pattern detection, discrimination, and analysis skills were questions where learners scored above a percentage of eighty (Table 4).

Table 4: Highly scored questions in the spatial ability test

Question no	Skills Required	Percentage	
		Correct	Incorrect
1	Mental rotation, compare, pattern detection, discriminate, analyse and find	96	4
2		80	20
4		90	10
6		90	10
8		85	15
9		91	9
10		90	10
12		83	17
13		95	5
14		81	19
15		85	15
19		87	13
23		87	13

Furthermore, the questions that involved complex mental folding, visualization and perception or learners having to perform certain skills cognitively are questions where learners performed poorly (Table 5).

Table 5: Low scored questions in the spatial ability test

Question no:	Skills Required	Percentage	
		Correct	Incorrect
26	Mental rotation, compare, pattern detection, discriminate, analyse, find	33	67
29		34	66
33	Mental rotation, analyse, complete (cognitively), imagine, relate, infer, predict, arrange	35	65
34		21	79
35		31	69
36	Mental rotation, perception, analyse, complete (cognitively), imagine, relate, infer, predict, arrange, depth	28	72
38		30	70
40	Analyse, predict, complete, mental rotation Analyse, complete, predict	29	71
41		15	85
42		20	80
43		32	68
44		28	72
45		26	74

Influence of Gender on the Visual Literacy and Spatial Ability Skills of Learners

Addressing the question whether gender has an influence on the level of visual literacy of learners a t-test was run. Since the p-value was greater than 0.01 ($t= -1.029$, $p = 0.305$), the null hypothesis was not rejected and there is no statistically significance difference in the performance of Life Sciences visual literacy scores between genders.

Spatial ability is the over-arching concept that largely refers to skills representing, transforming, generating and recalling of symbolic non-linguistic information. Results revealed that both males and females performed at an average level of approximately 46% (Table 6). In the SPSS output 'Total_SAT' refers to the actual SAT score that was out of 45and 'Total_LSVLT' refers to the actual LSVLT score that was out of 24. Thus, the mean percentage for SAT for males equals 20.63/45100 = 45.8% and the mean percentage for LSVLT equals 7.70/24100 = 32.08% whereas, the mean percentage for SAT for females equals 20.71/45100 = 46.03% and the mean percentage for LSVLT equals 8.04/24100 = 33.50%. A t-test resulted in a p-value greater than 0.01 (t= -

0.0051, p-value = 0.794) therefore, the null hypothesis was not rejected and there was no statistically significance on how genders performed.

Table 6: Descriptive statistics for gender in Life Sciences visual literacy test and spatial ability test

	Gender	N	Minimum	Maximum	Mean	Std. deviation
Total: LSVLT	Male	121	0	67	31.47	13.703
	Female	99	4	67	33.50	15.510
Total SAT	Male	111	4	82	45.89	19.950
	Female	94	7	76	46.03	19.800

4. STATISTICAL CORRELATIONS

A correlation between the LSVLT and SAT scores was firstly considered. Since these are continuous correlations, a Pearson correlation coefficient was computed. The correlation between LSVLT and SAT equals to 0.226 with a significance level of 0.001. This positive correlation is statistically significant, since the p-value = 0.001 (< 0.01). this means that a learner who obtained high scores in LSVLT also obtained high scores in SAT and vice versa, a learner who performed poorly in one performed poorly in the other test.

Correlation Between the Mean (Life Sciences Visual Literacy Test) and Gender Variable

The correlation between gender and average performance in the Life Sciences was analysed using Point-biserial correlation. The correlation between Life Sciences visual literacy test and gender variable equals 0.070 with a significance level of 0.305 (refer to Table 7). Even though this is a weak positive correlation, the correlation is not statistically significant, since the p-value = 0.305 (> 0.01).

Table 7: Correlation between the mean LSVLT, mean SAT and gender variable

Variables Correlated	Statistics	Value
Gender and LSVLT_ percentage	Correlation	0.070
	Sig. (2-tailed)	0.305
	N	220
Gender and SAT_ percentage	Correlation	0.004
	Sig. (2-tailed)	0.959
	N	220

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Correlation Between the Mean (Spatial Ability Test) and Gender Variable

The correlation between spatial ability test and gender is equals to 0.004 with a significance level of 0.959 (see Table 7) which denotes a weak positive relationship however, the correlation is not statistically significant because the p-value is equal to 0.959 (> 0.01).

Correlation Between Opinions of Learners Regarding Teachers' Frequent use of ERs to Teach Life Sciences and the Total Score in the Life Sciences Visual Literacy Test

The teachers' use of different ERs in a classroom may create a positive learning atmosphere where learners may get a chance of interacting with a variety of text that will grant them a solid background on content. A Spearman correlation between the frequent use of ERs by teachers and the total score in the Life Sciences visual literacy was calculated. A Spearman correlation was used, since the LSVLT score is continuous and the frequent use of ERs are all Likert-type variables coded as follows: 1 = Never; 2 = Occasionally; 3 = Frequently; 4 = Always.

The results revealed that out of all the ERs teachers used (chalkboard, internet, textbooks, video with animations, computer simulations, physical models, exercise books, real life examples, power point presentations, smart phone, tablet PC and a white board) the only p-value that was less than 0.01 is the p-value associated with the use of video with animations. This correlation equals 0.179, thus, the more frequently the teacher uses video with animations in class, the better learners perform in the Life Sciences visual literacy test.

Correlation Between Learners' Preference of ERs to Study Life Sciences and Total Score in the Spatial Ability Test

When learners' preference of ERs was correlated with total score in the SAT the only p-value that was less than 0.01 is the p-value associated with the use of the whiteboard. This correlation equals -0.200, thus, the more frequently the teacher uses the whiteboard the worse learners perform in the spatial ability test (Table 8).

Table 8: Spearman correlation coefficients between the frequent uses of ERs to teach Life Sciences and total score in the Life Sciences visual literacy test and the frequent use of ERs to study Life Sciences and the total score in the spatial ability test

Variables correlated	Statistics	Value
Frequency of LTSMs use: Video with animations (V36)	Correlation Coefficient	0.179
	Sig. (2-tailed)	0.010[a]
	N	216
Frequency of LTSMs use: Whiteboard (V43)	Correlation Coefficient	-0.200
	Sig. (2-tailed)	0.005
	N	192

[a] Although it seems that the p-value equals 0.01 and is significant, when running this analysis is SPSS and presenting the output to 10 decimals places, this p-value is, in fact, greater than 0.01 and, accordingly, the correlation is not significant.

5. DISCUSSION

Research shows that inadequate visual literacy skills, including interpretation, reasoning and communication using ERs, together with weak spatial ability skills, contribute to learning difficulties when learners engage with scientific representations. These challenges negatively affect conceptual understanding. Recent studies indicate that visual and spatial reasoning skills are essential for interpreting scientific representations effectively (Navarrete et al., 2023). The findings of this study indicated that most Grade 10 Life Sciences learners lack basic visual literacy and spatial ability skills. Teachers often rely on traditional instructional resources such as chalkboards and textbooks; however, learners' preferred modes of ERs are not always aligned with those used in classrooms. This mismatch may inhibit the development of visual literacy and spatial reasoning skills and may overload learners' cognitive resources (Educational Transformation Through Emerging Technologies, 2025). Combining text with visual and auditory ERs can enhance working memory and improve learning experiences (Teaching and Learning Innovations for Distance Learning in the Digital Era, 2023).

The results also showed confusion between a mitochondrion and a chloroplast among learners. This may suggest that the conceptual meaning represented by the ERs was not made sufficiently explicit. Recent research indicates that allowing learners to generate and manipulate their own diagrams and models can significantly improve scientific visual literacy and conceptual understanding (Navarrete et al., 2023).

Furthermore, learners struggled with higher-order thinking questions, suggesting limited visualisation skills due to insufficient exposure to diverse ERs. Studies indicate that learners with stronger visual literacy skills are more capable of engaging in higher-order reasoning and scientific communication (Friedrich et al., 2024). When learners are introduced to unfamiliar ERs that differ from those used by teachers or textbooks, they often struggle to interpret and relate them to prior learning experiences (Digital Learning in Sciences Education, 2023). Such difficulties may discourage learners from engaging with ERs holistically.

6. CONCLUSION AND IMPLICATIONS

The findings contributed to the literature on visual literacy in Life Sciences teaching and learning with ERs, since research in this area is relatively new and the related literature is still limited. The learners are still at early stage in high school where choosing of subjects for their career paths is very important, therefore, the findings should contribute to the understanding of the development visual literacy skills in Life Sciences curricula, the modes of ERs learners prefer and understand when learning, so they are able to understand phenomena better and successfully respond to assessment tasks. The study also contributed in indicating that learners in Grade 10 Life Sciences are on a low to average levels in visual literacy therefore, this indicates that explicit teaching of visual literacy is no longer optional but a necessity.

This study suggests some evidence for a call to integrate different strategies that will enhance visual literacy in the Life Sciences curricula. Therefore, teachers should explicitly address and develop visual literacy skills through designed instructional programmes that would promote diversity in the cognitive images formed using formalised ERs.

Formal training of teachers should be introduced at tertiary level on how to use different ERs to teach Life Sciences phenomena. For teachers who are already in the field, the Department of Basic Education should develop workshops where teachers are trained on how to implement effective teaching that will develop visual literacy of the learners and how to use ERs that will enable effective visual thinking, learning and communication by learners. Also, teachers have to be trained to design different ERs that will stimulate different senses in formal teacher training programmes. The study appears to support the argument that learners still encounter learning difficulties when learning with ERs. They fail to correctly visualise and interpret ERs in the way the ER and the lesson were intended to. The teaching tools which teachers use are not effectively developing visual literacy skills and visuospatial skills.

It is recommended that similar research should be replicated in other provinces to determine the level of visual literacy of the learners in Life Sciences, to investigate different ERs that could be used in Life Sciences to enhance better understanding of Life Sciences phenomena and at the same time improve visualisation skills of learners and to investigate the relationship between visual literacy, spatial abilities and Life Sciences content. Furthermore, more research should be done on the role and place of ERs in learning and the learning cycle.

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