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Analysis of Students' Understanding of the Carbon Cycle through the GCCDI Approach in Environmental Chemistry Education

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ABSTRACT

This study aims to analyze the understanding of first and second-year Chemistry Education students about the global carbon cycle. The design of this research is descriptive research, using the Global Carbon Cycle Diagnostic Instrument (GCCDI) instrument with 11 questions. The subjects of this study were first- and second-year undergraduate students of Chemistry Education at Bengkulu University, with a total of 15 students in each group. The students' understanding was analyzed qualitatively through the survey method. The data were analyzed and categorized into four groups: understand, misconception, doubt, and do not understand for the GCCDI. The students' understanding was categorized into simple, medium, and complex schemes for the survey method. The results indicated that, for first- and second-year students, respectively, the category of understanding comprised 53.31% and 58% of responses, the misconception category accounted for 22.38% and 27.24%, the doubtful category represented 4.8% and 6.65%, and the category of "does not understand" comprised 19% and 7.85%. The survey method was employed to analyze the responses of first- and second-year students on three schemes: simple (40% and 20%), medium (26.6% and 33.3%), and complex (33.3% and 46.6%). The low level of understanding of the carbon cycle indicates the need for more effective learning approaches, such as in-depth curriculum development, the use of interactive learning methods, and the integration of technology to improve students' understanding of the carbon cycle concept in the broader context of science.

INTRODUCTION

The global carbon cycle represents a fundamental natural process that plays a pivotal role in maintaining Earth's ecological equilibrium. The carbon cycle is defined as the exchange of carbon between different reservoirs, including the atmosphere, terrestrial biosphere, oceans, and sediments (Bao, 2023). In the field of environmental chemistry, the global carbon cycle is intimately connected due to the involvement of various chemical reactions that occur within it. Environmental chemistry is a multidisciplinary field of study that examines the sources, reactions, transport, effects, and fate of chemical species in the environment. In the context of environmental chemistry, the carbon cycle represents the movement of elemental carbon through its various reservoirs or storage sites in the biosphere, lithosphere, hydrosphere, and atmosphere (Ivlev, 2023).

The carbon cycle is a natural process that has evolved to provide a renewable source of biomass synthesis. Nevertheless, anthropogenic activities have disrupted natural geochemical processes, including the carbon cycle (Peccerillo, 2021). Human activities, including the combustion of fossil fuels, deforestation, and land use change, have significantly disrupted the natural carbon cycle (Reichle, 2020). These activities have resulted in the transfer of carbon from the lithosphere to the atmosphere, leading to elevated CO_2 levels and the disruption of Earth's climate, water chemistry, and marine biota (Mondav et al., 2022). The binding of carbon in compounds such as methane (CH_4) or other gaseous forms has a significant impact on global warming.

A comprehensive understanding of this concept is essential in the context of global warming and ongoing climate change. It is of great importance that students gain an understanding of the carbon cycle, as this is a fundamental concept in both environmental and natural sciences. Students must comprehend the global carbon cycle and its impact on global warming, as this directly affects their lives and the future of the planet. Students must comprehend the global carbon cycle and its influence on global warming, as this directly affects their lives and the future of the planet. By grasping the intricacies of the carbon cycle, students can proactively address global environmental shifts and contribute to climate change mitigation (Park et al., 2020). It is of paramount importance for students to possess an integrated comprehension of the carbon cycle to facilitate their educational pursuits and to dispel any erroneous notions they may hold.

It is common for students to hold misconceptions about the global carbon cycle. These misconceptions encompass a range of topics, including the sources of carbon, the processes involved in the cycle, and its impact on the environment (Natalia et al., 2023). One of the most prevalent misconceptions about carbon is the belief that it is solely associated with CO_2 emissions from the combustion of fossil fuels. This narrow perspective fails to acknowledge the diverse forms of carbon present in living organisms, soils, and oceans. Another prevalent misconception is that the carbon cycle is solely comprised of photosynthesis and respiration, with the role of decomposition, the formation of carbonate rocks, and the intricate interactions between the oceans, atmosphere, and biosphere being overlooked (Bubnova, 2023). In addition, some students underestimate the impact of human activities on the global carbon cycle. They fail to recognize the effects of deforestation, fossil fuel burning, and consumption patterns on environmental change. It is, therefore, of the utmost importance to address these misconceptions to gain a more comprehensive understanding of the role of carbon in the environment and its implications for global climate change (Sharma, 2022).

Assessing students' comprehension of the global carbon cycle is essential for evaluating the efficacy of science education curricula (You et al., 2021). It is of paramount importance to ensure that students can comprehend the concept of climate change in its entirety, as this will facilitate their understanding of the underlying mechanisms and enable them to make informed decisions that will contribute to the protection of the environment. Correct measurement can assist in the assessment of students' comprehension of this concept. Furthermore, their capacity to apply this understanding in real-world contexts and their proficiency in disseminating this knowledge to others is indicative of students' satisfactory comprehension of the carbon cycle (Muroi & Bertone, 2019).

The use of appropriate evaluation instruments can facilitate the identification and correction of student misconceptions. Several studies have demonstrated the efficacy of different evaluation instruments in identifying and addressing students' misconceptions. For instance, a study conducted by Kai Niebert (2011) employed qualitative analysis as an evaluation method. In his study, Kai Niebert (2011) successfully enhanced students' comprehension of the carbon cycle by employing a container scheme to illustrate the flow of carbon. Furthermore, other methodologies employed to identify misconceptions include the use of open-ended questions, multiple choice, multi-level diagnostic questions, surveys, and interviews (Majer et al., 2019). The research conducted by Majer (2019) demonstrated the efficacy of measuring and comprehending the misconceptions that students hold about a given subject matter. Research conducted by Waluyo et al. (2021) indicates a correlation between students' year level and their comprehension scores. The findings indicated that students' comprehension scores exhibited variability based on their year level.

It is of great importance to be able to measure the understanding of misconceptions between two levels of students to be able to compare their level of understanding. The first step in designing a more effective learning approach is to understand the misconceptions that often occur (Laksono, 2020). Improving students' understanding of the global carbon cycle in environmental chemistry is not merely about imparting facts; it is also about fostering awareness of the pivotal role of carbon in the Earth's ecosystem and its impact on climate change. The objective of this study was to analyze the comprehension of first- and second-year students enrolled in chemistry education programs regarding the global carbon cycle. This research is crucial for gauging students' comprehension and identifying any misconceptions they may have about the global carbon cycle, with a particular focus on comparing their understanding with that of scientists.

METHODS

Research Design

This research was conducted on November 15, 2023. The research employed a descriptive analysis approach, integrating quantitative and qualitative methodologies. The objective was to identify students' understanding and misconceptions regarding the Global Carbon Cycle Diagnostic Instrument (GCCDI) instrument and to ascertain their perceptions through qualitative survey methods.

Research Target

The subjects of this study were first-year and second-year undergraduate students of the Chemistry Education study program at Bengkulu University. The total sample size was 30 students. The subjects were selected using a random sampling technique. This technique involves selecting samples without regard to the specific characteristics of the population (Soegiyono, 2017). The proportion of the research sample is 1:1, with 15 students from the first year and 15 students from the second year.

Research Data

The data collected in this study are the results of quantitative and qualitative tests conducted by first-year and second-year students of the Chemistry Education study program. Data collection was carried out through the administration of a three-level test and the assignment of carbon flow scheme drawings from the carbon cycle narrative to students. This data collection method is designed to yield comprehensive and in-depth information about students' understanding of the carbon cycle in environmental chemistry

Research Instruments

The instrument utilized in this research is the Global Carbon Cycle Diagnostic Instrument (GCCDI), which is employed to assess student comprehension. GCCDI is a multi-level instrument comprising three levels of 11 questions. The first level requires a fact-based response (multiple choice answer level). The second level is the rationale for the response (multiple-choice rationale level). The third level is a confidence scale (six-point confidence scale level) to indicate the respondent's level of confidence in the truth (Majer et al., 2019). The question grids can be seen in Table 1.

Table 1. GCCDI Instrument Grid

Number	Material	Question indicator	Question items
1	Carbon exchange in the atmosphere,	Given pictures and stories related to the carbon cycle, students can determine the components of the carbon cycle.	1
		Given several carbon reservoirs, students can determine the main reservoir.	2

Number	Material	Question indicator	Question items
	vegetation, oceans, and fossil carbon.	Given several alternative answers, students can choose the relationship between components in the carbon cycle and the reasons.	3
		Given a question about the beginning and end of the carbon cycle. Students can choose the answer and the reason.	4,5
2	Carbon cycle process	Presented with several alternative answers. Students can determine what makes carbon move in the carbon cycle.	6
		Students can determine what process makes carbon return to plants.	7
3	Climate change and the carbon cycle	Presented with two alternative answers. Students can determine if there is a relationship between the carbon cycle and climate change based on the story given.	8
		Presented with two alternative answers. Students can determine whether climate change is due to the imbalance of the carbon cycle.	11
4	Influence of human activities	Students can explain the influence of humans on the carbon cycle.	9
		Given some alternative answers. Students can determine the cause of the unbalanced carbon cycle.	10

The GCCDI instrument has been subjected to a validity and reliability assessment using SPSS 29 software. The validity test is designed to ascertain the suitability of the measuring instrument with the outcomes to be measured (Reza et al., 2021). The results of the validity measurement can be found in Table 2, while the results of the reliability analysis can be seen in Table 3.

Table 2. Validity Test Result

Items	1	2	3	4	5	6	7	8	9	10	11
Pearson Correlation	.903**	.669**	.803**	.580**	.780**	.470**	.455*	.537**	.726**	.726**	.903**
Sig. (2-tailed)	<,001	<,001	<,001	<,001	<,001	.009	.011	.002	<,001	<,001	<,001
N	30	30	30	30	30	30	30	30	30	30	30

Table 3. Reliability Test Result

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.883	.889	11

The results of the validity test indicate that each item is valid with a two-way test, with a significance value of more than 0.05 (Sofia et al., 2020). In the context of statistical testing, the use of symbols such as * or ** indicates the level of significance of the statistical test results, particularly in the Pearson section. These symbols are commonly used to indicate the level of statistical significance. The symbol * is typically used to represent a p-value below 0.05, while the symbol ** is used to indicate a p-value below 0.01. This indicates that the tested item is considered valid based on the statistical analysis performed (Ongiem, 2018).

Furthermore, the reliability testing yielded reliable results for the question items with a Cronbach's alpha value of 0.883 and Cronbach's Alpha Based on Standardized Items of 0.889, which exceeded the r table 5% threshold of 0.6. The data is deemed reliable if the r count is greater than the r table 5% (Lela et al., 2023). The GCCDI instrument, which has been validated and deemed reliable, can be employed to assess student comprehension.

Additionally, qualitative identification of student understanding can be achieved through survey methods. One illustrative example of this approach is the use of a narrative instrument about the global carbon cycle. In a study conducted by Kai Niebert (2011), students were tasked with describing the global carbon cycle using a container scheme as part of the research instrument. The data obtained in this study are the responses to the questions posed by the GCCDI instrument and the images of a carbon cycle description provided to the students.

Data Analysis

The data on students' responses collected through the GCCDI instrument will be examined using a rubric to categorize the level of student conception. In this analysis, the responses and reasoning presented by both groups will be identified and evaluated to ascertain their level of understanding of the global carbon cycle concept. Table 4 presents the eight possible combinations of student answers and the guidelines for categorizing answers on the three-level concept mastery question.

Table 4. Three-Level Test Diagnostic Rubric

First Tier	Second Tier	Third Tier	Category
Correct	Correct	Confident	Understand/Master the concept
Correct	Wrong	Confident	Misconception
Wrong	Correct	Confident	Misconception
Wrong	Wrong	Confident	Misconception
Correct	Correct	Not Confident	Guess the concept
Correct	Wrong	Not Confident	Do not understand the concept
Wrong	Correct	Not Confident	Do not understand the concept
Wrong	Wrong	Not Confident	Do not understand the concept

(Pramesti et al., 2021).

Qualitative data in the form of carbon flow schematic images will be analyzed using qualitative survey methodology. Qualitative survey methodology is a research approach that involves the analysis of qualitative data, enabling researchers to analyze and interpret textual data systematically, thereby providing a deeper understanding of the phenomena under investigation (Drisko & Maschi, 2015).

RESULTS AND DISCUSSION

Measuring Student Understanding with GCCDI

The initial analysis employed the GCCDI. Following the analysis of the responses of first-year (FY) and second-year (SY) students to the GCCDI, the percentage of correct answers for each item was calculated. This is presented in Table 5.

Table 5. Percentage of First and Second-Year Students' Understanding Category

No	Fill in the test items	Understand		Misconceptions		Doubtful		Do not understand	
		FY	SY	FY	SY	FY	SY	FY	SY
1	Components of the carbon cycle	93,3%	80%	6,6%	13,3%	0	0	0	6,6%
2	Major reservoirs	0	6,6%	73,3%	66,6%	6,6%	0	20%	26,6%
3	Relationship between components	26,6%	73,3%	46,6%	6,6%	6,6%	20%	20%	0
4	Cycle start point	60%	100%	20%	0	6,6%	0	13,3%	0
5	Cycle endpoint	60%	86,6%	6,6%	6,6%	6,6%	6,6%	26,6%	0
6	Carbon drivers in the cycle	20%	80%	53,3%	13,3%	6,6%	0	20%	6,6%
7	Carbon and plants	60%	46,6%	26,6%	53,3%	0	0	13,3%	0
8	Climate change	93,3%	86,6%	0	0	0	0	6,6%	13,3%
9	Human activity in the carbon cycle	66,6%	33,3%	0	53,3%	6,6%	0	26,6%	13,3%
10	Carbon cycle imbalance	66,6%	13,3%	6,6%	53,3%	0	20%	26,6%	13,3%

11	Climate change and carbon cycle imbalance	40%	33,3%	6,6%	33,3%	13,3%	26,6%	40%	6,6%

Based on the percentage per question item discussed above, it can be seen that the greatest understanding is in question items number 1 and 3 for first-year students. Second-year students showed a high understanding of item number 4. Meanwhile, for misconceptions, the largest percentage was in item number 2 for first-year and second-year students. This similarity in terms of misconceptions shows that students do not correctly understand the main reservoir in the carbon cycle. According to (Dusing et al., 2019), several studies have shown students' and prospective teachers' misunderstanding of the main reservoirs of the carbon cycle. They tend to have an incomplete understanding of key concepts in the carbon cycle.

Few students experienced hesitation in answering, as seen from the small percentage of both first-year and second-year students. This shows that they have high confidence in the questions they answer correctly. According to Omer (2023), first-year or second-year students generally have high confidence in the questions they answer. The percentage of first-year students' incomprehension was greatest in test item number 11, which was about climate change and carbon cycle imbalance. Several studies have shown that students often have incomplete or incorrect knowledge about climate change and related concepts (Chang & Pascua, 2016). The findings suggest that students have difficulty in understanding the relationship between climate change and carbon cycle imbalance.

The percentage of the overall level of understanding of the 11 questions presented for first and second-year students can be seen in Table 6.

Table 6. Percentage of Student Understanding on All Questions

Category	First-year	Second-year
Understand	53.31%	58%
Misconceptions	22.38%	27.24%
Doubtful	4.8%	6.65%
Do not understand	19%	7.85%

Based on Table 3 above, the bar graph can be seen in Figure 1.

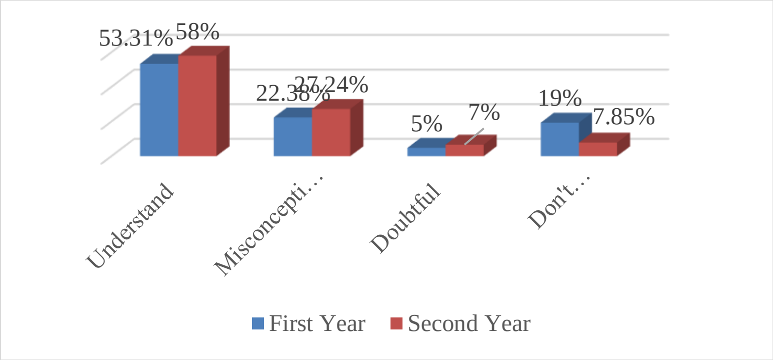


Figure 1. Graph of Student Understanding Level on All Questions

Table 3 and the graph in Figure 1 provide an overview of the level of understanding of first and second-year students on the 11 questions presented. From the table, it can be seen that in the second year, the percentage of students who understood the material as a whole (understand) was 58%, while in the first year, the percentage was 53.3%. This shows that the understanding of the second-year students is better than the first year.

In addition, the percentage of misconceptions in the second year (27.24%) was higher than in the first year (22.38%). This suggests that while there was an improvement in overall understanding, there was also an increase in misinterpretations or misconceptions in the second year. This high comprehension and high misconception for the second year shows a correlation.

According to Kulgemeyer and Wittwer (2022), the illusion of understanding created by misconceptions can lead to the belief that a topic is understood, even though learners develop more misconceptions and fewer scientifically correct conceptions. Therefore, misconceptions are closely related to the understanding that students already have. Students often develop misconceptions about science based on their prior knowledge and experiences (Faizah, 2016).

The existence of the "doubt" category indicates that a small proportion of students in both years felt unsure regarding the material presented. Although the increase was not significant, this could indicate that the complexity of the material in the second year caused more confusion or uncertainty in some students. However, the percentage is very low, indicating that the majority of students have strong confidence in their understanding. The "do not understand" category showed a drastic difference between the first year of 19% and the second year of 7.85%. This shows that the lack of understanding of the material in the second year is much less compared to the first year.

In this analysis, it can be seen that second-year students overall have a better level of understanding compared to first-year students. Their overall understanding of the carbon cycle is still lacking, as the percentage of understanding hovers around 50. This shows that the overall understanding of the carbon cycle is still low, and there is a need for educators to address misconceptions about the global carbon cycle (Ali, 2021).

Analysis of Student Understanding with Survey Method

Bringing students' understanding to the level of scientists is an important goal in education (Astuti & Marzuki, 2017). More than just mastering facts, it also involves being introduced to the critical, logical, and analytical thinking that characterizes scientists. It is important to investigate student understanding and evaluate how it relates to the teaching methods applied (Srivishagan et al., 2021). In this qualitative survey research, students' responses were compared with scientists' viewpoints to assess the extent to which students' understanding had developed.

Based on the prompts given, first- and second-year students depicted the carbon cycle in several carbon reservoirs. The depiction was done using a container scheme. The container scheme was chosen in this study based on research from Niebert & Gropengiesser (2013), which showed that students and scientists have different conceptions of the global carbon cycle, but both use the same scheme. The container, path-source-destination, and circle schemes are combined into a more complex container flow scheme when thinking about the carbon cycle.

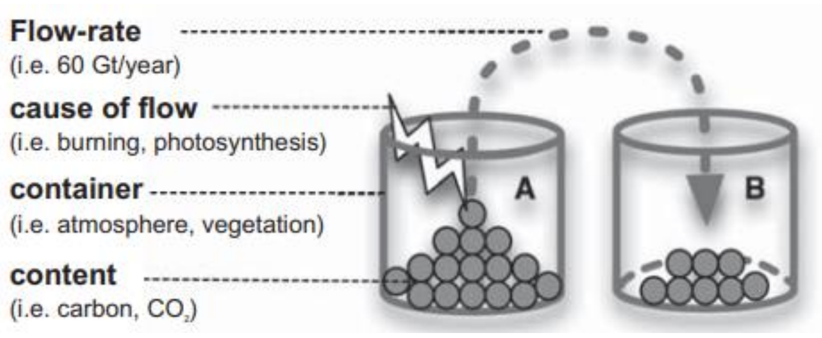
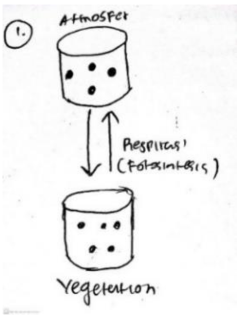
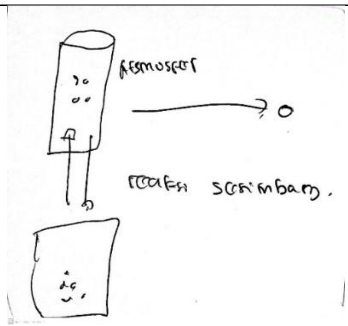
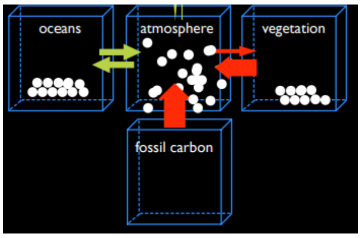
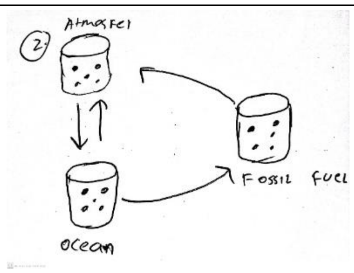
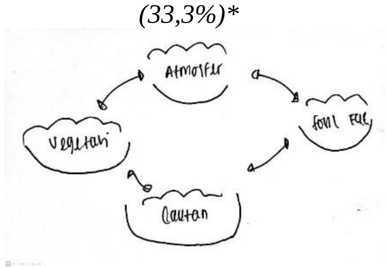
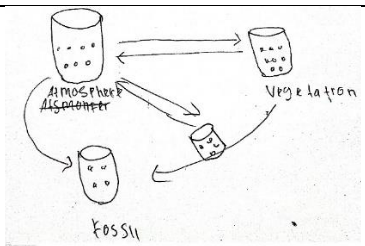
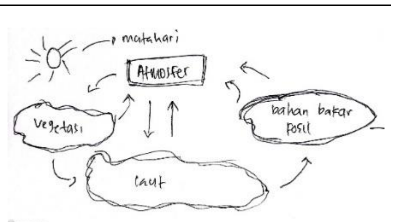


Figure 2. Carbon Cycle Container Scheme (Niebert & Gropengiesser, 2013).

Using this schema, the researcher categorized conceptions of the carbon cycle in terms of understanding the reservoir and flow of the carbon cycle. The selection of images was based on a few representative images. The ranking started from the simplest to the most complex answer according to the scientist's perspective. This ranking is classified into simple, medium, and complex categories. The thinking patterns of students and scientists regarding carbon cycle images can be seen in Table 7. (*percentage of some students who expressed parallel thinking patterns).

Table 7. Comparison of Student and Scientist Conception Images

	First-year Students	Second-year Students	Scientist
Understanding	Understand that the carbon cycle reservoirs are the atmosphere and vegetation. They do not yet understand that there are four main reservoirs.	Understand that the carbon cycle reservoirs are the atmosphere and vegetation. They do not yet understand that there are four main reservoirs.	
schema (simple)	 *(40%)**	 *(20%)**	
Understanding	Understand the three carbon cycle reservoirs and the flow of carbon between them. They do not understand the exact flow between ocean and fossil fuel.	Understand the four main reservoirs of the carbon cycle but do not have a good understanding of the proper flow of carbon between reservoirs.	There are four main reservoirs of the carbon cycle with balanced flows of carbon except for fossil carbon. Fossil burning only provides a one-way flow to the carbon cycle (Niebert et al., 2011). 
schema (medium)	 *(26,6%)**	*(33,3%)** 	
Understanding	Have a good understanding of the four main reservoirs and the proper flow of carbon in the carbon cycle (according to scientist's conception).	Has a good understanding of the four main reservoirs and the proper flow in the carbon cycle (according to the scientist's conception).	
schema (complex)	 *(33,3%)**	 *(46,6%)**	

A comparative analysis of first- and second-year students' understanding of the carbon cycle revealed a pattern of evolution in the understanding of both groups. The results indicated that while most first- and second-year students demonstrated a limited comprehension of the four major reservoirs in the carbon cycle, they exhibited an emerging understanding of carbon flows.

The results of the drawings for simple schemes indicated that 40% of first-year students drew such schemes, which was the largest percentage among the three categories (simple, medium, and complex). This suggests a high level of incomprehension for first-year students. In contrast, the second-year students were only at 20%, indicating a low level of incomprehension. This is because the simple scheme refers to the scheme for students with the lowest level of understanding. A significant proportion of students (26.6%) demonstrated an understanding of the carbon cycle, which comprises two reservoirs: the atmosphere and vegetation (Tsigaris & Wood, 2016).

The moderate drawing category demonstrated an improvement, although it remained below the level expected of scientists. First-year students depicted the scheme at 26.6%, which is lower than the percentage of simple schemes. This lower percentage indicates greater incomprehension (Screti, 2023). In contrast, second-year students demonstrated a higher level of comprehension, with a percentage of 33.3%. This indicates a more nuanced understanding of the global carbon cycle. According to Morales et al. (2023), an increase in the percentage of students' understanding from simple to medium (intermediate) categories in a learning context can indicate a significant increase in understanding. This increase also reflects students' ability to comprehend more complex relationships between carbon cycle components.

The categorization of complex schemes illustrates a more in-depth understanding by the conception of scientists (Davidson, 2013). First-year students were 33.3%, and second-year students were 46.6%. The percentage for this complex category is a percentage that measures how many students have a good understanding of the global carbon cycle (Dusing et al., 2019). First-year students' understanding is classified as less well-understood because it is seen in a greater percentage of simple schematic images (Screti, 2023). The understanding of second-year students is seen from this large percentage of complex schematic images, which can be classified as understanding. However, this understanding is not 100%, and the incomprehension of first-year students is also not 100%. This shows that there are still misconceptions for students (Marifah et al., 2023). The percentage in the complex category shows the extent of students' understanding of the global carbon cycle, but there are still misconceptions that need to be addressed.

When it comes to understanding carbon flows, both first-year and second-year students do not seem to fully understand how carbon flows are supposed to take place in the cycle. Both groups of students showed similarities in their lack of in-depth understanding of carbon flows in the cycle. Therefore, to provide students with a better understanding of an easier depiction of the carbon cycle, a container scheme for scientists' conceptions was used. This depiction is a form of content-specific theory. Students and scientists use the same schema to understand the carbon cycle but conceptualize it differently (Niebert & Gropengiesser, 2013).

The research, which employed the GCCDI and qualitative analysis, demonstrated that second-year students exhibited a significantly enhanced comprehension of the global carbon cycle in comparison to their first-year counterparts. Additionally, the study indicated that the rate of academic development over time can profoundly influence the understanding of specific learning materials and concepts. According to Jean Piaget's theory of cognitive development, a higher stage of cognitive development in second-year students may explain their better understanding of the topic (Cheval et al., 2023). However, based on the research findings, students' understanding of the global carbon cycle still shows a relatively low level, with significant misconceptions and incomprehension. To overcome this, it is necessary to improve learning approaches that can assist students in comprehensively understanding the global carbon cycle by scientists' conceptions (Natalia et al., 2023).

A deep understanding of the carbon cycle is particularly relevant in the field of environmental chemistry, given its relationship with the problem of climate change and various other environmental impacts (Hans et al., 2023). Consequently, endeavors to enhance this comprehension represent a pivotal stride in confronting mounting complexities within the domain of environmental challenges.

This study has several strengths and weaknesses that must be acknowledged. One of its principal advantages is the use of two analytical methods, namely the GCCDI and qualitative analysis through surveys. These methods provide a comprehensive view of students' understanding of the global carbon cycle. This approach enabled the researcher to identify not only the level of understanding but also the misconceptions and misunderstandings that exist among students. The use of container schemas was also an innovative step to visualize complex concepts, facilitating comparative analysis between students and scientists.

Additionally, this study highlighted significant differences in understanding between first- and second-year university students, suggesting that academic development has a positive impact on the understanding of scientific concepts. These findings are in line with cognitive developmental theory, which suggests that students' understanding develops as their level of education increases. This provides a basis for more effective curriculum development in the future. However, it should be noted that this study also has some shortcomings. While the use of the GCCDI and the qualitative survey provided rich results, the study may not have delved deeply enough into the reasons behind students' misconceptions and incomprehension. In-depth interviews or focus group discussion approaches may be needed to gain more comprehensive insights.

CONCLUSION AND RECOMMENDATIONS

This study examined the understanding of first- and second-year students in the context of the global carbon cycle, an important aspect of environmental chemistry. The results of the GCCDI indicated that second-year students exhibited a superior comprehension of the global carbon cycle in comparison to first-year students. The application of qualitative analysis techniques in conjunction with surveys also demonstrated that second-year students exhibited a superior understanding of the global carbon cycle in comparison to first-year students. This understanding was classified into three categories. Although the understanding of second-year students is higher than that of first-year students, both groups are still classified as having a very low level of understanding.

The level of understanding of the carbon cycle remains relatively low, and misconceptions and misunderstandings are prevalent. Consequently, further research is required to provide a more comprehensive insight into students' understanding compared to scientists' perceptions. Although second-year students demonstrated some improvement in their understanding of the concept, there remained a notable deficiency in their comprehension of carbon flows between reservoirs. This analysis underscores the necessity of developing more engaging learning strategies, enhancing the identification of misconceptions, and conducting further research on the correlation between grade level and student comprehension. These endeavors are directed towards the enhancement of an adaptive and efficacious environmental chemistry curriculum to augment students' comprehension of the global carbon cycle.

REFERENCES

Ali, W. N. S. W. (2021). Climate Change: Climate Literacy and Response among USM Students. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, *12*(3), 2205-2210. https://doi.org/10.17762/turcomat.v12i3.1168

Astuti, R. T., & Marzuki, H. (2017). Analisis kesulitan pemahaman konsep pada materi titrasi asam basa siswa SMA. *Orbital: Jurnal Pendidikan Kimia*, *1*(1), 22-27.

https://doi.org/https://doi.org/10.19109/ojpk.v1i1.1862
Bao, Y. (2023). *Global Carbon Cycle of Earth System Model FIO-ESM with Surface Waves* (No. EGU23-4824). Copernicus Meetings. https://doi.org/10.5194/egusphere-egu23-4824
Chang, C. H., & Pascua, L. (2016). Singapore students' misconceptions of climate change. *International Research in Geographical and Environmental Education*, *25*(1), 84-96. https://doi.org/10.1080/10382046.2015.1106206
Cheval, B., Saoudi, I., Maltagliati, S., Fessler, L., Farajzadeh, A., Sieber, S., ... & Boisgontier, M. P. (2023). Initial status and change in cognitive function mediate the association between academic education and physical activity in adults over 50 years of age. *Psychology and Aging*. https://orcid.org/0000-0002-6236-4673
Davidson, D. (2013). On the very idea of a conceptual scheme. *The American Philosophical Association Centennial Series*, 209-222. https://doi.org/10.5840/apapa2013236
Drisko, J. W., & Maschi, T. (2015). *Qualitative content analysis. Dalam Content Analysis, Pocket Guides to Social Work Research Methods* (hal. 67–92). New York: Oxford Academic. https://doi.org/10.1093/acprof:oso/9780190215491.003.0004
Düsing, K., Asshoff, R., & Hammann, M. (2019). Students' conceptions of the carbon cycle: Identifying and interrelating components of the carbon cycle and tracing carbon atoms across the levels of biological organization. *Journal of Biological Education*, *53*(1), 110-125. https://doi.org/10.1080/00219266.2018.1447002
Faizah, K. (2016). Miskonsepsi dalam pembelajaran IPA. *Jurnal Darussalam: Jurnal Pendidikan, Komunikasi dan Pemikiran Hukum Islam*, *8*(1), 115-128. https://doi.org/10.30739/darussalam.v8i1.10
Hans, M., Hikmawati, E., & Surendro, K. (2023, February). Predictive Analytics Model for Optimizing Carbon Emission from Student Activity and Behavior with A Design Thinking Approach: Case Study: Bandung Institute of Technology. In *Proceedings of the 2023 12th International Conference on Software and Computer Applications* (pp. 77-82). https://doi.org/10.1145/3587828.3587841
Ivlev, A. A. (2023). A New View on the Global Redox-Cycle of Biosphere Carbon. *C*, *9*(2), 53., doi: https://doi.org/10.3390/c9020053
Jumadi, J., Sukarelawan, M. I., & Kuswanto, H. (2023). An investigation of item bias in the four-tier diagnostic test using the Rasch model. *International Journal of Evaluation and Research in Education (IJERE)*, *12*(2), 622-629. http://doi.org/10.11591/ijere.v12i2.22845
Kulgemeyer, C., & Wittwer, J. (2023). Misconceptions in physics explainer videos and the illusion of understanding: An experimental study. *International Journal of Science and Mathematics Education*, *21*(2), 417-437. https://doi.org/10.1007/s10763-022-10265-7
Laksono, P. J. (2020). Pengembangan three tier multiple choice test pada materi kesetimbangan kimia mata kuliah kimia dasar lanjut. *Orbital: Jurnal Pendidikan Kimia*, *4*(1), 44-63. https://doi.org/10.19109/ojpk.v4i1.5649
Lela, M., Amilda, A., & Jayanti, E. (2023). Efektivitas Penggunaan Modul Pembelajaran Kimia Berbasis POE Materi Larutan Elektrolit dan Non Elektrolit terhadap Hasil Belajar. *Orbital: Jurnal Pendidikan Kimia*, *7*(1), 11-24. https://doi.org/10.19109/ojpk.v7i1.17202
Majer, J., Slapničar, M., & Devetak, I. (2019). Assessment of the 14-and 15-Year-Old Students' Understanding of the Atmospheric Phenomena. *Acta Chimica Slovenica*, *66*(3). https://doi.org/10.17344/acsi.2019.5087
Marifa, H. A., Abukari, M. A., Samari, J. A., Dorsah, P., & Abudu, F. (2023). Students' Perceptions of the Pedagogical Content Knowledge of Chemistry Teachers on the Concept of Hybridization. *Science*, *11*(2), 61-76. https://doi.org/10.11648/j.sjedu.20231102.11
Mondav, R., Martin, G., Peura, S., & Garcia, S. L. (2022). Network analysis uncovers associations in the turnover of C1 molecules in a winter lake. *bioRxiv*, 2022-10.

https://doi.org/10.1101/2022.10.31.514531
Morales, U., Joanan, S., & Julia, H. (2023). Development of Arabic E-Book Media Based on Flip PDF Professional Application for Students. *JILTECH: Journal International of Lingua & Technology*, *2*(1). https://doi.org/10.55849/jiltech.v2i1.243
Muroi, S. K., & Bertone, E. (2019). From thoughts to actions: The importance of climate change education in enhancing students' self-efficacy. *Australian Journal of Environmental Education*, *35*(2), 123-144. https://doi.org/10.1017/aee.2019.12
Natalia, M., Ullah, W., Khan, A. R., Wahid, A., Mehmood, M. S., & Naz, M. (2023). Investigation among students' and teachers' perceptions of climate health awareness regarding low carbon eco-friendly practices. *Frontiers in Environmental Science*, *11*, 1177952. https://doi.org/10.3389/fenvs.2023.1177952
Niebert, K., & Gropengiesser, H. (2013). Understanding and communicating climate change in metaphors. *Environmental Education Research*, *19*(3), 282-302. https://doi.org/10.1080/13504622.2012.690855
Niebert, K., & Gropengießer, H. "It Is Not the Co2 Itself, It's The Imbalance!" Conceptual Reconstruction of The Carbon Cycle in Global Warming".
Nunes, L. J., Meireles, C. I., Pinto Gomes, C. J., & Almeida Ribeiro, N. M. (2019). Forest management and climate change mitigation: A review on carbon cycle flow models for the sustainability of resources. *Sustainability*, *11*(19), 5276. https://doi.org/10.3390/su11195276
Omer, S. (2023). Social Adjustment Challenges of First-Year Students: Peer Influence, Misuse of Freedom, Ignorance of Life Skills Management, Living in Anxiety and Guilt. In *Handbook of Research on Coping Mechanisms for First-Year Students Transitioning to Higher Education* (pp. 160-173). IGI Global. DOI: https://doi.org/10.4018/978-1-6684-6961-3.ch010
Ongiem, A. (2018). Validation of the Tests. *Thai Journal of Anesthesiology*, *44*(1), 36-42.
Park, B. Y., Jeon, J., Lee, H., & Lee, H. (2020). An Analysis of Research Trend for Integrated Understanding of Environmental Issues: Focusing on Science Education Research on Carbon Cycle. *Journal of The Korean Association for Science Education*, *40*(3), 237-251. https://doi.org/10.14697/jkase.2020.40.3.237
Peccerillo, A., & Peccerillo, A. (2021). The geochemical cycles and the environment—how man is changing the Earth. *Air, Water, Earth, Fire: How the System Earth Works*, 153-181. https://doi.org/10.1007/978-3-030-78013-5_8
Pramesti, Y. S., Mahmudi, H. A. R. I. S., & Setyowidodo, I. R. W. A. N. (2021, March). Using three-tier tests to diagnose students' level of understanding. In *Journal of Physics: Conference Series* (Vol. 1806, No. 1, p. 012013). IOP Publishing. https://doi.org/10.1088/1742-6596/1806/1/012013
R., S., Bubnova. (2023). *Carbon dioxide and the rocks of the Earth*. Pp.62-88 doi: https://doi.org/10.1093/oso/9780198869412.003.0004
Reichle, D. E. (2020). The global carbon cycle and the biosphere. *The Global Carbon Cycle and Climate Change (pp. 183-208). https://doi.org/10.1016/b978-0-12-820244-9.00010-x*
Reza, M., Hamama, R., Maulida, S., Nurdin, N., Mayasri, A., & Rizkia, N. (2021). Persepsi Mahasiswa terhadap Pembelajaran Daring Berbasis Video dengan Bantuan Pen Tablet Selama Pandemi Covid-19. *Orbital: Jurnal Pendidikan Kimia*, *5*(2), 124-136. https://doi.org/10.19109/ojpk.v5i2.9216
Screti, F. (2023). Using Google Docs for guided Academic Writing assessments: students' perspectives. *Language Learning in Higher Education*, *13*(1), 153-174. https://doi.org/10.1515/cercles-2023-2007
Sharma, B. (2022). Analysis of Global Carbon Cycle Extremes, Their Compound Climate Drivers, and Implications for Terrestrial Carbon Cycle (Doctoral dissertation, Northeastern

University). doi: https://doi.org/10.17760/D20474678

Soegiyono, P. D. (2017). Metode Penelitian Kualitatif, Kuantitatif dan R&D. *Bandung: Anggota Ikatan Penerbit Indonesia (IKAPI)*.

Sofia, S., Permanasari, A., Sholihin, H., & Supriyanti, F. M. (2020). Konten dan Konstruk Asesmen Keterampilan Berpikir Evaluatif pada Tema Karbohidrat dalam Kimia Pangan. *Orbital: Jurnal Pendidikan Kimia*, *4*(1), 88-98.

Srivishagan, V., Madhusankha, W. A. I., Munasinghe, J. C., Danthanarayana, C. P., & Samarasinghe, H. G. D. S. (2021). Students'understanding Level Of Online Teaching In The Technical And Vocational Education And Training (Tvet) Sector. *International Journal of Teaching And Learning*, *1*(1), 58-64. https://doi.org/10.17501/26827034.2021.1105

Tsigaris, P., & Wood, J. (2016). A simple climate-solow model for introducing the economics of climate change to undergraduate students. *International Review of Economics Education*, *23*, 65-81. https://doi.org/10.1016/j.iree.2016.06.002

Waluyo, M., & Vidákovich, T. (2021). Assessment of students' mathematical proof comprehension: Gender and year level background. *Journal of Physics: Conference Series*, 1776(1), 012017. https://doi.org/10.1088/1742-6596/1776/1/012017

You, H. S., Marshall, J. A., & Delgado, C. (2021). Toward interdisciplinary learning: Development and validation of an assessment for interdisciplinary understanding of global carbon cycling. *Research in Science Education*, 51, 1197-1221. https://doi.org/10.1007/s11165-019-9836-x