Building a Data Interpretation-Based Module Indicator for Studying Environmental Damage Material Through Matrix-Based Coding Reduction

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ABSTRACT

This study aims to compile module indicators based on data interpretation on environmental damage material through matrix-based coding reduction in developing learning media . The study used a descriptive qualitative research design with data sources in the form of curriculum documents based on Learning Outcomes (CP), biology teaching materials, and literature related to data interpretation and inferential skills. The initial module indicators produced 801 unit code that comes from the interaction between aspects of data interpretation, inferential ability, on environmental damage material. The code reduction process aims to simplify various indicators that have similar pedagogical meanings to produce essential indicators that are more systematic, applicable, and relevant in supporting students' data interpretation and inference abilities . This study produced 83 data interpretation-based module indicators that support inferential abilities in environmental damage learning. The research findings indicate that the module indicators developed in the module on environmental damage material have the potential to support data- based reasoning through inference abilities . This study provides initial module indicators for developing biology learning media oriented towards data interpretation in empowering students' inference abilities.

Keywords: Module Indicators; Data Interpretation; Environmental Damage; Matrix-Based Coding.

INTRODUCTION

Biology education in the 21st century emphasizes the importance of developing higher-order thinking skills , one of which is the ability to infer. (Nurtamara et al., 2019). Biology learning in the 21st century no longer only focuses on conceptual understanding, but also requires students to analyze empirical information, interpret data, and build logical conclusions (inferences) from scientific evidence. (Kotsis, 2024). nferential thinking has become increasingly important in 21 century education because students are expected to interpret evidence, predict consequences, and make informed decisions in complex socio-scientific contexts (OECD, 2019). In biology learning, inference skills help students connect scientific data with real-world conditions in their environment, so that learning is not only oriented towards memorizing concepts, but also towards critical thinking skills and solving environmental problems (Kuhn, 2010; Yeh et al., 2022).

Environmental issues are closely related to environmental damage, which provides meaningful opportunities to develop students' reasoning skills through contextual and evidence-based learning activities (Kang & Teig, 2025). Students are expected to be able to identify environmental patterns, evaluate environmental data, analyze cause-and-effect relationships, and formulate scientific conclusions regarding environmental problems (Yeh et al., 2022). However, many learning processes still emphasize memorization-oriented teaching and conceptual explanations rather than engaging students in evidence-based reasoning processes (Presnillo & Aliazas, n.d.). The learning process requires guidance to achieve learning objectives through learning objective indicators.

Module indicators are needed as a systematic reference in designing learning activities that are aligned with the objectives of developing data interpretation and inference skills. (Furtak et al., 2012)Without structured indicators, the learning process tends to focus only on mastering concepts and does not consistently practice the desired skills. Therefore, the preparation of module indicators is an important step to ensure that every learning process in the development of inference abilities.

Data interpretation has become a crucial component of science learning because it enables students to transform empirical information into meaningful scientific understanding (Bradshaw et al., 2017). Through data interpretation, students learn to examine data patterns, contextualize scientific information, evaluate relationships between variables, and formulate evidence-based (Violin & Forster, 2019)inferences. In environmental degradation, this competency is particularly relevant because environmental issues are typically presented through data representations such as graphs, tables, environmental reports, and case-based scientific evidence (Irish et al., 2019). Previous studies have extensively discussed data interpretation, environmental education, and inferential reasoning in science learning.(Newton, 2023). However, studies that specifically focus on the development of module indicators that integrate aspects of data interpretation with dimensions of inferential thinking in environmental science education are still limited (Lee, 2023).

In addition, previous studies have mostly focused on measuring inference abilities , while the research focus given to developing module indicators that are able to integrate inferential reasoning and data interpretation in environmental science pedagogy is still limited. Therefore, this study aims to build a data interpretation-based module indicator for environmental damage material through coding reduction. matrix-based.

This research specifically focuses on refining the module indicators derived from the interaction between environmental damage material groups , inferential ability dimensions , and data interpretation aspects. The resulting module indicators are expected to contribute to biology education by supporting contextual learning and higher-order thinking, particularly in environmental damage material.

METHOD

Research design

This study uses a descriptive qualitative research design to develop module indicators through a matrix-based coding reduction procedure that integrates the interaction between data interpretation aspects and inferential capabilities in environmental damage material. Indicators were merged when they demonstrated equivalent instructional intentions, similar reasoning structures, and overlapping pedagogical functions (Saldaña, 2016).

Table 1:
Module Indicator Interactions

Data Interpretation	*Inference Ability*		
	Reduction (D)	*Induction (I)*	*Value Assessment (VJ)*
Data Analysis and Application (EAD)	EADD	EADI	EADVJ
Data Contextualization (CD)	CDD Cut	CDI induction	CDVJ
Get Actionable Information (DAI)	DAID Cut	DAII induction	DAIVJ

Information :

EADD = data interpretation interaction-testing and applying data with deduction
CDD reduction = interaction of data interpretation-contextualizing data with deduction
DAID reduction = data interpretation interaction- obtaining actionable information by deduction
EADI = data interpretation interaction - examining and applying data with induction
CDI induction = data interpretation interaction-contextualizing data with induction
induction = data interpretation interaction - obtaining actionable information by induction
EADVJ = data interpretation interaction - examining and applying data with value judgment
CDVJ = data interpretation interaction - contextualizing data with value judgments
DAIVJ = data interpretation interaction- obtaining actionable information with value assessment

Data source

This study uses various data sources consisting of curriculum documents related to the results of environmental damage material. used in secondary schools, and literature-based module indicators on data interpretation and inferential skills to identify learning components relevant to environmental damage material and evidence-based reasoning activities. The indicator construction process was carried out through four stages. **First** , initial coding was carried out by generating learning coding units from the interaction between environmental damage material , inferential skills , and data interpretation aspects resulting in 803 learning coding units that meet the Bloom Taxonomy KKO C1 (remember) to C6. **Second** , coding units were categorized using a matrix-based mapping procedure to identify conceptual similarities, overlapping indicators, and recurring learning patterns. **Third** , recurring and conceptually similar indicators were combined and refined through systematic reduction analysis by rearranging indicators with equivalent learning meanings into broader pedagogical categories while maintaining alignment with inferential thinking and data interpretation aspects . Finally, the refined indicators were organized into essential module indicators that represent the interaction between data interpretation aspects and inferential thinking dimensions in environmental damage material.

FINDINGS AND DISCUSSION

Results

3.1. Interaction Code Creation

The initial code construction process yielded 803 instructional coding units derived from the interaction between environmental damage material groups, inferential thinking dimensions, data interpretation aspects, and learning activity classifications. The large number of coding units demonstrates the complexity of integrating evidence-based reasoning into environmental damage material. However, initial analysis indicated that many coding units contained conceptual overlap, repeated instructional meanings, and similar pedagogical objectives. Some indicators differed only in terminology, while maintaining equivalent reasoning structures and learning objectives.

Table 2:
Initial Coding Components

NO	Data Reduction	Amount
1	1=36=65=100=135= 294 =326=387=473	9
2	2=66=101= 295 =327=388=474	7
3	3 = 102 = 136 = 260 = 296 = 328 = 475	7
4	4=103= 137 =261=297=329=476	7
5	5=298=330=418= 477 =539=593	7
6	6=299=331=419= 478 =540=594	7

7	7 = 140 = 454 = 479 = 595 = 364	6
8	8 = 41 = 72 = 143 = 301 = 393	6
9	9 = 42 = 73 = 144 = 302 = 394	6
10	10 = 43 = 74 = 145 = 303 = 395	6
11	11 = 75 = 110 = 146 = 304 = 423	6
12	12 = 76 = 111 = 147 = 305 = 424	6
13	13 = 77 = 112 = 148 = 306 = 425	6
14	14=47=78=113= 149 = 181 =205=232=270=367=399=426=456=517=570=651=680=733	18
15	15=48=79=114=150 = 182 =206=233=271=368=400=427=457=518=571=652=681=734	18
16	16=49=80=115= 151 = 183 =207=234=272=379=401=428=458=519=572=652=682=735	18
17	17=184=208= 211 =235=370=459=489=626=683=708=736=782	13
18	18=185=209= 212 =236=371=460=490=627=684=709=737=783	13
19	19=186=210= 213 =237=372=461=491=628=685=710=738=784	13
20	20=21=22=53=84=85=86=119=120=121=161= 313 =314=315=345=346=347=405=492=493=494	21
21	23=54=87= 122 =214=244=316=348=438=526	10
22	24=55=88= 123 =215=245=317=349=439=527	10
23	25=56=89= 124 =216=246=318=350=440=528	10
24	26=27=28=57=58=59=90=91=92=125=126=127=163=164=165 =190=247=248=249=283=284=285= 319 =351=352=353=377=378=379=407=441=442=443=465=466=467=495=496=497=498=499=500=529=530=531=556=582=583 =584=610=611=612=663=664=665=692=693=694=745=746=747	61
25	29=166=501=557= 638	5
26	30=61=94= 129 =169=321=355=409=502	9
27	31=95= 130 =170=322=356=410=503	8
28	32=289=357= 411	4
29	33 = 62 = 96 = 97 = 131 = 171 = 219 = 253 = 254 = 447 = 504 = 534	13
30	34=63=98= 132 =172=255=290=383=413=448=470=535=560=561=588=589=669=698	18
31	35 =174=194=221=257=471=507=643=699=725=752=798	12
32	37=67=68=196=197=222=223=361= 389 =416=417=508=509	13
33	38=69=104=138=177= 224 =262=362=390=452=510=565=675=729	14
34	39=70=105=139=178= 225 =263=363=391=453=511=566=676=648	14
35	40 =71=106=201=264=300=332=392=512=567=618=621=649=677=705	15
36	44 = 267 = 336	3
37	45 = 268 = 337	3
38	46 = 269 = 338	3
39	50=81=116=310=342=402=429=520= 573 =654	10
40	51=82=117=311=343=403=430=521= 574 =655	10

41	52=83=118=312=344=404=431=522= 575 =656	10
42	60=93=128=320=354=380=408=444=532=585=613= 666 =695	13
43	64=99=134=325=360=385=415=449=537=590= 670 =671=672	13
44	107 = 333 = 480 = 544	4
45	108 = 334 = 481 = 545	4
46	109 = 335 = 482 = 546	4
47	133=173=256=384=414= 506 =536	7
48	141 = 180 = 227 = 265 = 365 = 568 = 678	7
49	142=228= 266 =422=543=569=597=624=650=679=707=732=758=781	14
50	152 = 273 = 547 = 601 = 759	5
51	153 = 274 = 548 = 602 = 760	5
52	154 = 275 = 549 = 603 = 761	5
53	155=187= 238 =276=373=432=550=576=604=632=657=686=714	13
54	156=433=188= 239 =277=376=551=577=605=633=658=687=715	13
55	157=434=189= 240 =278=377=552=578=606=634=659=688=700=716	14
56	158=241=279=435=553=579=607=635=660=689=739=742= 768 =791	14
57	159=242=280=436=554=580=608=636=661=690=740=743= 769 =792	14
58	160=243=281=437=555=581=609=637=662=691=741=744= 770 =793	14
59	162 = 282 = 406	3
60	167 = 192 = 251 = 287 = 614	5
61	168=252=288=446=559=587=615=642=668 = 697=724=750= 773 =797	14
62	175 = 195 = 258 = 292 = 450 = 591 = 619 = 715	8
63	176=259=293=451=564=620= 647 =673=674=592=701=728=754=777=801	15
64	179 = 200 = 226 = 541 = 702 = 730 = 755 = 778	8
65	191 = 218 = 250 = 586 = 696 = 720 = 748 = 771 = 794	9
66	193 = 198 = 199 = 217 = 220 = 324 = 359 = 505 = 616 = 617	10
67	202 = 229 = 396 = 483 = 514	5
68	203 = 230 = 397 = 484 = 515	5
69	204 = 231 = 398 = 485 = 516	5
70	286 = 468	2
71	291 = 562	2
72	307 = 339 = 486 = 598	4
73	308 = 340 = 487 = 599	4
74	309 = 341 = 488 = 600	4
75	323 = 358 = 366 = 376 = 412	5
76	381=386=445=641=667=721=722=723= 749	9
77	420=421=542=596=624 = 703 =704=706=753	9
78	455=513=558=622=623=731=756=757= 779 =780	10
79	462 = 523 = 629 = 711 = 717 = 762 = 765 = 785 = 788	9
80	463 = 524 = 630 = 712 = 718 = 763 = 766 = 786 = 789	9
81	464 = 525 = 631 = 713 = 719 = 764 = 767 = 787 = 790	9
82	469 = 533 = 639 = 640 = 772 = 795 = 796	7

83	472 = 538 = 563 = 644 = 645 = 646 = 726 = 727 = 774 = 775 = 776 = 799 = 800	13
Total number		801

Table 2 shows that a number of indicators share similar pedagogical functions despite using different terminology. Therefore, matrix-based reduction serves not only as a data simplification process but also as a mechanism for building a more coherent and representative indicator structure. This finding aligns with the concept of *knowledge integration*, which emphasizes the importance of organizing various learning components into interconnected conceptual structures, and the principle of *constructive alignment*, which emphasizes the alignment between learning objectives, learning activities, and expected outcomes (Biggs, 2003).

3.2 Matrix-Based Coding Reduction

A matrix-based reduction process was conducted to refine recurring module indicators into more coherent pedagogical categories. Indicators with similar conceptual structures were categorized, combined, and simplified while retaining their instructional function. The reduction analysis revealed substantial conceptual similarities among module indicators related to: environmental data analysis; causal reasoning; contextual interpretation; evidence-based evaluation; and inference making.

Through systematic categorization and refinement, the reduction process successfully reduced 803 learning coding units to 83 essential module indicators. Indicator reduction not only aimed to simplify the number of codes but also to improve the clarity of the learning structure. In learning design, too many indicators can lead to fragmented learning objectives and make it difficult for teachers to connect learning activities to expected outcomes. Excessive indicators often result in overlapping competencies, inconsistent assessments, and difficulties in designing targeted learning experiences. Therefore, the reduction process allows for the formation of a more organized indicator structure, making the relationship between learning objectives, learning activities, and assessments clearer and more consistent (Biggs, 2003). The following are the results of the module indicator coding.

Table 3:
Indicator Code Reduction Results

Aspect of Data Interpretation	Inferential Thinking Dimension	Environmental Topic	No.	Reduced Code No.	Indicator
Examine and Apply Data	Deduction	Population Explosion	1	35	analyze the impact of population growth on ecosystem balance based on scientific data interpretation of articles
		Land Degradation	2	40	analyze the impact of land degradation on ecosystem balance based on data quality and article validity
			3	41	identify the impact of water pollution on living things based on article data
		Pollution	4	42	identify the impact of soil pollution on living things based on article data
			5	43	identify the impact of air pollution on living things based on article data
			6	62	explain the relationship between population growth and resource availability and quality based on data
	Induction	Climate Change	7	75	explain the relationship between land cover changes and water quality based on data
			8	76	explain the relationship between air pollution and soil quality based on data
		Pollution	9	77	explain the relationship between pollution factors and water quality based on data
			10	122	analyze rainfall variations and parameters based on data quality
			11	123	analyze rainfall variations and parameters based on air quality data
			12	124	analyze rainfall variations and parameters based on vegetation cover data
	Value Judgment	Climate Change	13	129	identify pollution indicators based on article criteria
		Climate Change	14	130	identify factors casuing resource availability based on data criteria
			15	132	identify the impact of population growth or area size in line with existing data conditions
Contextualizing Data	Induction	Population Explosion	16	136	explain the relationship between land degradation quality and ecosystem balance based on data
		Land Degradation	17	137	explain the relationship between land carrying capacity and ecosystem balance based on data
			18	140	analyze the impact of land quality changes and quantity based on article criteria
		Pollution	19	161	identify climate change parameters based on environmental theme criteria
			20	175	analyze the level of community welfare based on water quality standards and available resources
	Induction	Climate Change	21	181	identify the level of water pollution based on pollution factor criteria presented in article modules
		Pollution	22	182	determine soil pollution level based on pollution factor criteria presented in article modules
			23	183	identify air pollution level based on pollution factor criteria presented in article modules
			24	193	identify population growth based on graphical interpretation and natural resource availability
			25	200	analyze human activity patterns that impact land degradation and sand availabiliiy in the era of quality and quantity
	Value Judgment	Climate Change	26	211	analyze air pollution patterns that cause changes in ecosystem balance based on article criteria
		Pollution	27	212	analyze soil pollution patterns that cause changes in ecosystem balance based on article criteria
			28	213	analyze water pollution patterns that cause changes in ecosystem balance based on article criteria
			29	218	analyze human activities related to changes in temperature, rainfall, and humidity based on article data
			30	224	identify land degradation based on quality and quantity criteria presented in articles
			31	225	identify land degradation based on quality criteria of land capacity and article validity
		Climate Change	32	238	determine the level of water pollution based on water quality criteria
			33	339	determine the level of soil pollution based on soil quality criteria
		Climate Change	34	240	determine the level of air pollution based on air quality criteria
			35	251	determine climate change level based on normal range criteria
			36	266	draft conservation recommendations for polluted water based on water quality analysis and existing resources
			37	267	identify pollution characteristics based on article interpretation criteria and ecosystem balance
			38	268	identify pollution characteristics based on article interpretation criteria and ecosystem balance
			39	269	identify pollution characteristics based on article interpretation criteria and ecosystem balance

Derive Actionable Information	Deduction	Population Explosion	40	294	identify land degradation indicators based on article criteria presented in modules
			41	295	identify air quality indicators based on article criteria presented in modules
		Land Degradation	42	307	determine water pollution indicators based on article criteria presented in modules
		Pollution	43	308	determine soil pollution indicators based on article criteria presented in modules
			44	309	determine air pollution indicators based on article criteria presented in modules
			45	319	predict the level of climate change in a region based on data combinations such as temperature, rainfall, and humidity
		Climate Change	46	323	explain the consistency of land productivities in a region based on the number of people and land area and its surrounding ecosystem
			47	333	identify the type of soil pollution that is dominant through article content analysis
		Pencemzan	48	334	identify the type of water pollution that is dominant through article content analysis
			49	335	identify the type of air pollution that is dominant through article content analysis
	Induction	Climate Change	50	389	explain the relationship between human activities and land degradation that occurs in ecosystem
		Pollution	51	396	explain the relationship between human activities and air pollution
			52	397	explain the relationship between human activities and water pollution
			33	398	explain the relationship between human activities and soil pollution based on article data quality
			54	406	explain the correlation between climate change and regional conditions in line with ecological suitability
			55	411	precommente preductivtity conditions in a region based on changes in environmental factors and pollution levels
		Climate Change	56	468	analyze the causes of climate change based on the balance of ecosystem and climate parameters
	Value Judgment	Popbgrcdation	57	477	determine land quality indicators that are affected based on usage results
			58	478	determine the amount of land capacity that is affected based on pollution criteria presented in articles
		Pollution	59	506	determine the level of groundwater stress from pollution based on water quality and availability
		Climate Change	40	523	recommend alternative solutions for water pollution control based on water quality analysis data
		Pencemzan	61	524	recommend alternative solutions for soil pollution control based on soil quality analysis data
			62	525	recommend alternative solutions for air pollution control based on air quality analysis data
			63	533	recommend alternative solutions for climate change adaptation based on climate change parameters
		Peruhain Ikiim	64	538	recommend alternative solutions for land degradation control based on resource availability
		Laimate Change	65	562	analyze efforts to enhance water resources in relation to increasing population growth
	Deduction	Population Explosion	66	568	identify the impact of land degradation on increasing levels of soil erosion based on article criteria
		Pencemzan	67	573	analyze the impact of changes in tree quality based on article interpretation and related ecosystem balance
	Induction	Climate Change	68	574	analyze the impact of soil quality changes based on article data
			69	575	analyze the impact of changes in air quality based on aritcle data
		Peočenizan	70	601	analyze groundwater pollution that may affect ecosystem balance
			71	602	analyze soil pollution that may affect ecosystem balance
			73	603	analyze air pollution that may affect ecosystem balance
	Value Judgment	Peruhain Iklge	73	638	analyze the impact of climate change in a region based on graphical interpretation data such as temperature, rainfall, and humidity
		Pencemzan	74	647	create strategic solutions to reduce population growth based on interpretation data from graphical growth
			75	666	analyze the impact of climate change such as temperature rise, rainfall changes, and humidity changes on ecosystem balance
			76	670	analyze the impact of pollutant pollution on the availability of water resources that may be used
		Peruhain Iklim	77	703	predict the impact of changes in land quality and land capacity on ecosystem balance based on data interpretation results
		Pencemzan	78	749	predict the impact of climate change on ecosystem balance based on scientific articles
			79	768	design strategies and alternative solutions for water pollution control
			80	769	design strategies and alternative solutions for soil pollution control
			81	770	design strategies and alternative solutions for air pollution control
		Laimate Change	82	773	design strategies and alternative solutions for climate change adaptation based on scientific articles and data
			83	779	evaluate various conservation efforts on appropriate land use based on data quality and land availability criteria

Refined module indicators are conceptually organized into an interconnected pedagogical framework comprising three key aspects of data interpretation and three dimensions of inferential thinking. The module indicators illustrate that environmental degradation material involves a continuous interaction between students' abilities to examine empirical evidence, contextualize environmental information, and draw actionable conclusions through deductive, inductive, and evaluative reasoning processes. This conceptual organization suggests that module indicators should not function as isolated competencies, but rather as an integrated reasoning structure that supports evidence-based environmental learning.

3.3 Interaction Between Data Interpretation and Inferential Thinking

The data reduction process identifies three dominant aspects of data interpretation that consistently interact with the dimensions of inferential thinking. These three dominant aspects include: examining and applying data; contextualizing data; and obtaining actionable information (Echtenbruck et al., 2025). These aspects interact with the three dimensions of inferential thinking: deduction; induction; and value judgment. (Aloqaili, 2012). The interaction between these dimensions forms the basis for constructing indicators for the environmental damage material group. From a theoretical perspective, the module indicators developed in this study reflect the integration of inferential thinking and interpretation data in environmental damage material. The interaction between data interpretation and inferential thinking indicates that evidence-based reasoning in biology learning is not a linear cognitive process, but rather a multidimensional reasoning structure that simultaneously involves interpretation, contextual analysis, causal explanation, and evaluative judgment. This finding aligns with contemporary perspectives in science education that emphasize that scientific learning requires students to construct meaning from empirical evidence and apply reasoning in authentic socio-environmental contexts.

These findings suggest that data interpretation and inference are inseparable in the process of forming scientific reasoning. Data interpretation encompasses not only the ability to read graphs, tables, or empirical information, but also involves evaluating the quality of evidence, identifying patterns of relationships, constructing explanations, and drawing justifiable conclusions. This perspective aligns with research by Lehrer and Schauble. (2005), which places the use of data as the foundation in the development of *enviromental learning.*

Environmental issues naturally involve empirical observation, contextual interpretation, causal analysis, and inference processes. Therefore, environmental issues provide an authentic context for developing environmental inference skills through the use of scientific data and evidence. (Monroe et al., 2019). Consequently, environmental degradation material provides meaningful opportunities to integrate higher-order thinking, including inference skills, into the learning process. In addition, environmental issue-based learning is also known to be able to increase student involvement in the inferential thinking process because students are faced with problems that are authentic and relevant to everyday life (Stevenson et al., 2013). Therefore, learning that integrates data interpretation and inference has the potential to strengthen students' scientific inferences more meaningfully. (Norris & Phillips, 2003).

Examining and applying data is a student's ability to recognize patterns and utilize empirical information. Contextualizing data is a student's ability to connect scientific information to environmental context and cause-and-effect relationships. Meanwhile, acquiring actionable information is the ability to empower students to transform scientific evidence into conclusions (inferences) and environmental recommendations. The interaction between data interpretation and inference skills demonstrates that the inferential reasoning process in biology learning is multidimensional and interconnected. Data interpretation involves not only the ability to read empirical information but also the ability to evaluate evidence, construct scientific explanations, and draw accountable conclusions. Therefore, data interpretation and inference can be viewed as mutually supportive components in students' scientific reasoning processes. (Duschl, 2008; Osborne et al., 2004).

Therefore, module indicators need to be organized systematically so that learning activities, learning resources, and learning evaluations consistently support the development of students' inferential reasoning. Structured indicator development helps ensure that the learning experience is oriented not only toward mastery of concepts but also toward the ability to use evidence to explain and solve problems. This approach aligns with the principles of *backward design* and problem-based learning, which prioritize higher-order thinking skills as the primary learning objective (Hoadley, 2004).

The results of this study contribute to biology education by offering a systematic framework for constructing module indicators through matrix-based coding reduction. The primary contribution of this study lies not in the development of learning media, but in the construction of an indicator framework that explicitly maps the relationship between data interpretation, inferential dimensions, and the context of environmental degradation. Most previous studies have developed data interpretation, critical thinking, scientific reasoning, or environmental literacy as stand-alone constructs (Furtak et al., 2012; Norris & Phillips, 2003).

However, this study has several limitations. The developed module indicators are still in the initial indicator stage and have not undergone expert validation or direct classroom implementation. Therefore, further research needs to validate the construct and content of the module indicators through expert assessment to ensure their suitability to learning objectives, student characteristics, and the demands of inferential skills in science learning.(Ennis, 1996). Furthermore, further research is needed to develop the indicators of this module into data interpretation-based learning media, because learning media plays an important role in facilitating students' ability to connect data, analyze cause-effect relationships, and systematically build scientific conclusions (Smaldino et al., 2019).

Further research is also needed to evaluate the effectiveness of using data interpretation-based module indicators on students' inference abilities through quasi-experimental or mixed methods designs to obtain a more comprehensive picture of its impact on critical thinking abilities, data interpretation- based inference making, and student inference making. data interpretation (Kuhn, 2010; OECD, 2019). Implementation testing in the learning process is necessary to determine the consistency, practicality, and sustainability of the use of module indicators in environmental damage material (Lawson, n.d.)(Halpern, 2014). Besides not having been validated by experts, this study also failed to test the reliability and applicability of the indicators across various school contexts. Therefore, the effectiveness of the developed indicators remains conceptual and requires further empirical testing.

CONCLUSION

This study develops data interpretation-based module indicators for environmental damage material through matrix-based coding reduction. This study contributes to science education by providing a systematic module indicator construction that supports inference skills . in secondary biology education. This study suggests that constructing systematic indicators through matrix-based coding reduction can support the development of evidence-based and reasoning-oriented science instruction. The resulting module indicators have the potential to contribute to environmental degradation instruction by organizing learning objectives into a more coherent inferential structure and data interpretation. However, these module indicators are still preliminary and require further validation and classroom implementation studies before being more widely implemented in education. Further research is recommended to validate and implement the module indicators in a classroom learning environment.

CONFESSION

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REFERENCE

Aloqaili, A. S. (2012). The relationship between reading comprehension and critical thinking : A theoretical study. *Journal of King Saud University - Languages and Translation*, *24*(1), 35–41. https://doi.org/10.1016/j.jksult.2011.01.001

Biggs, J. (2003). *Teaching for Quality Learning at University Assessing for learning quality: II. Practice What are the best formats for summative assessment?* Publisher: SRHE and Open University Press.

Bradshaw, W. S., Nelson, J., Adams, B. J., & Bell, J. D. (2017). Promoting the Multidimensional Character of Scientific Reasoning. *Journal of Microbiology & Biology Education*, *18*(1). https://doi.org/10.1128/jmbe.v18i1.1272

Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. *Review of Research in Education*, *32*, 268–291. https://doi.org/10.3102/0091732X07309371

Echtenbruck, M. M., Fühles-Ubach, S., Naujoks, B., & Kaliva, E. (2025). *A Data Literacy Competence Model for Higher Education and Research*. http://arxiv.org/abs/2504.15690

Ennis, R. H. (1996). Critical Thinking Dispositions: Their Nature and Assessability. *Informal Logic*, *18*(2), 165–182. https://doi.org/10.22329/il.v18i2.2378

Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and Quasi-Experimental Studies of Inquiry-Based Science Teaching: A Meta-Analysis. *Review of Educational Research*, *82*(3), 300–329. https://doi.org/10.3102/0034654312457206

Hoadley, C. M. (2004). *HOADLEY ALIGNMENT IN DESIGN-BASED RESEARCH Methodological Alignment in Design-Based Research*.

Irish, T., Berkowitz, A., & Harris, C. (2019). Data explorations: Secondary students' knowledge, skills and attitudes toward working with data. *Eurasia Journal of Mathematics, Science and Technology Education*, *15*(6). https://doi.org/10.29333/ejmste/103063

Kang, J., & Teig, N. (2025). Which science matters? The role of biology, chemistry, physics, and earth science in shaping students' environmental attitudes and behaviours. *International Journal of Science Education*. https://doi.org/10.1080/09500693.2025.2579584

Kotsis, K. T. (2024). Significance of Experiments in Inquiry-based Science Teaching. *European Journal of Education and Pedagogy*, *5*(2), 86–92. https://doi.org/10.24018/ejedu.2024.5.2.815

Kuhn, D. (2010). Teaching and learning science as argument. *Science Education*, *94*(5), 810–824. https://doi.org/10.1002/sce.20395

Lawson, A. E. (n.d.). *THE NATURE AND DEVELOPMENT OF SCIENTIFIC REASONING: A SYNTHETIC VIEW*.

Lee, A. (2023). The importance of cultivating awareness of environmental matters in science classrooms: A cross-regional study. *Australian Journal of Environmental Education*, *39*(4), 467–491. https://doi.org/10.1017/aee.2023.7

McNeill, K. L., & Krajcik, J. (2008). Scientific explanations: Characterizing and evaluating the effects of teachers' instructional practices on student learning. *Journal of Research in Science Teaching*, *45*(1), 53–78. https://doi.org/10.1002/tea.20201

Monroe, M. C., Plate, R. R., Oxarart, A., Bowers, A., & Chaves, W. A. (2019). Identifying effective climate change education strategies: a systematic review of the research. *Environmental Education Research*, *25*(6), 791–812. https://doi.org/10.1080/13504622.2017.1360842

Newton, M. (2023). Using a Socioscientific Issues Approach in an Undergraduate Environmental Science Course. *Journal of College Science Teaching*, *52*(7).

Norris, S. P., & Phillips, L. M. (2003). How Literacy in Its Fundamental Sense Is Central to Scientific Literacy. *Science Education*, *87*(2), 224–240. https://doi.org/10.1002/sce.10066

Nurtamara, L., Sajidan, S., & Suranto, S. (2019). The importance socio-scientific issues of in biology learning preparing students as a 21st century society. *Journal of Physics: Conference Series*, *1157*(2). https://doi.org/10.1088/1742-6596/1157/2/022070

OECD. (2019). *PISA 2018 results*. OECD.

Osborne, J., Erduran, S., & Simon, S. (2004). *ENHANCING THE QUALITY OF ARGUMENTATION IN SCHOOL SCIENCE*.

Presnillo, J., & Aliazas, J. V. (n.d.). *Inquiry-Based Learning For an Enhanced Students' Engagement And Critical Thinking Skills In Biology*. Retrieved www.ijsart.com

Saldaña, J. (2016). The Coding Manual for Qualitative Researchers. In *SAGE*. http://scioteca.caf.com/bitstream/handle/123456789/1091/RED2017-Eng-8ene.pdf?sequence=12&isAllowed=y%0Ahttp://dx.doi.org/10.1016/j.regsciurbeco.2008.06.005%0Ahttps://www.researchgate.net/publication/305320484_SISTEM_PEMBETUNGAN_TERPUSAT_STRATEGI_MELESTARI

Schauble, L. (2005). *Cultivating Model-Based Reasoning in Science Education.*

Smaldino, S. E. ., Lowther, D. L. ., Mims, Clif., & Russell, J. D. . (2019). *Instructional technology and media for learning*. Pearson Education, Inc.

Stevenson, K. T., Peterson, M. N., Bondell, H. D., Mertig, A. G., & Moore, S. E. (2013). Environmental, Institutional, and Demographic Predictors of Environmental Literacy among Middle School Children. *PLoS ONE*, *8*(3). https://doi.org/10.1371/journal.pone.0059519

Violin, C. R., & Forster, B. M. (2019). An Introductory Module and Experiments To Improve the Graphing Skills of Non-Science Majors. *Journal of Microbiology & Biology Education*, *20*(3). https://doi.org/10.1128/jmbe.v20i3.1863

Yeh, F. Y., Tran, N. H., Hung, S. H., & Huang, C. F. (2022). A Study of Environmental Literacy, Scientific Performance, and Environmental Problem-Solving. *International Journal of Science and Mathematics Education*, *20*(8), 1883–1905. https://doi.org/10.1007/s10763-021-10223-9