Effectiveness of analytical thinking–based module to improve students’ learning outcomes using concept map

Puput Putri Kus Sundari¹, Sri Widoretno¹, and Ashadi²

¹Science Education Departement, Universitas Sebelas Maret. Jalan Ir. Sutami No. 36A, Surakarta, Jawa Tengah 57126
²Chemistry Education Departement, Universitas Sebelas Maret. Jalan Ir. Sutami No. 36A, Surakarta, Jawa Tengah 57126

¹Email: puputputrikussundari@yahoo.com

Abstract. The effectiveness of 21st century learning emphasizes higher order thinking skills, one of which is analytical thinking. The analytical thinking–based module used includes indicators based on the integration of analytical-thinking aspects and Concept Map components. This study aimed to measure improvement in student learning outcomes using Concept Map through an analytical thinking-based module. The research method used was quasi-experimental with a field test design in the form of a pretest-posttest non-equivalent control group design. Participants were 66 students divided into control class using conventional modules and experimental class using analytical thinking–based modules. The calculation of students' Concept Map scores is based on the Concept Map experts. The data were analyzed using the Ancova test. The effectiveness results showed: 1) the average score of the Concept Map of the experimental class (81.39%) was higher than the control class (47.89%), 2) the average score of the Concept Map component in the experimental class was higher than the control class, but the cross-link score obtained the lowest score. Concept Map is a powerful tool for educating new knowledge and supporting learning outcomes because has a positive effect on improving students’ learning outcomes and assessment of long-life learning in the teaching and learning process.

1. Introduction
The challenges of 21st century education are the quality of education [1,2] and the effectiveness of learning [3,4]. The effectiveness of learning is emphasized in higher order thinking skills that support 21st century education [5–7], one of which is analytical thinking [8,9]. Analytical thinking is a higher order thinking skill needed in the 21st century [10,11]. Analytical thinking has an important strategic value because it builds the ability to evaluate, plan and decide on the best choices and directions for the future [12–14].

Analytical thinking consists of three aspects, namely differentiating, organizing, and attributing [15,16]. Analytical thinking shows the level of thinking of sequential events for solving problems that are presented with reasons, principles, functions, linking issues, and answering problems by looking back at previous ones [17,18]. Analytical thinking helps student performance in improving learning outcomes that are supported by teaching methods [19] and the use of textbooks or modules [20].

Modules are materials that make students work independently [21]. The use of modules plays an important role in the learning process [22] by increasing the efficiency and effectiveness of learning in schools. The development of learning modules undergoes revolution and innovation [25], one of
which is by accommodating thinking skills. Modules that accommodate thinking skills [26] help students learn independently by stimulating scientific activities, facilitating students to understand concepts, and reinforcing them directly in the form of feedback for each activity [23,27].

The analytical thinking–based module contains indicators of analytical thinking in the objectives, materials, activities, and questions [28]. Analytical thinking–based modules contain daily phenomena and cases, so students are actively involved in learning. Improving learning in modules or teaching materials based on phenomena or cases [29] can combine symptoms that occur in the environment with learning contents [30] and encourage students to explore biological concepts [31,32], especially in learning biology [33].

Learning biology in the material of the human reproductive system is part of a science curriculum that has many concepts [34–36], so conceptual understanding is essential as the basis for higher order thinking processes such as formulating principles and generalizations [37]. Students’ analytical thinking processes to understand concepts depend on the complexity of the concepts and their cognitive development [38], so they must have knowledge about various concepts of the human reproductive system. The students' low mastery of understanding is influenced by difficulties, especially in understanding and mastering biological concepts [2,39,40] in the material of the human reproductive system. Conceptual understanding and analyzing various learning concepts require a tool [41], one of which is the Concept Map.

Concept Map is a graphical representation of topics, ideas, and relationships between concepts [42]. The Concept Map components consist of valid relationships, hierarchy levels, branching, patterns, cross-links, and specific examples [43]. The whole Concept Map components help illustrate analytical-thinking skills [44]. Concept Map as an instructional [45,46] and assessment technique that becomes the final product of learning [47,48], thus Concept Map as an instructional and assessment technique has a strategic value in science learning [49,50]. Concept Map is designed for effective teaching and learning activities, especially assessing conceptual understanding and change (conceptual understanding from time to time) [43,51]. Concept Map helps visualize the relationship between prior knowledge and newly introduced concepts and encourage meaningful learning [52]. It becomes a powerful tool for educating new knowledge and supporting learning outcomes [53,54], so it is necessary to measure the improvement in learning outcomes using the Concept Map through analytical thinking–based modules.

2. Research Method

The research method used was quasi-experimental with a field test design in the form of a pretest-posttest non-equivalent control group design [55] using two classes, namely the control class and the experimental class as shown in Table 1. The analytical thinking–based module used includes indicators based on the integration of analytical-thinking aspects and Concept Map components that are tailored to the material of the human reproductive system. This research was conducted in MA Negeri 1 Karanganyar class XI Science consisting 238 students divided into seven classes. The sample was selected using cluster random sampling technique consisting of 33 students of each class. Class XI Science 5 was the control class (using conventional modules) and Class XI Science 4 the experimental class (using analytical thinking–based modules).

| Class          | Pretest | Treatment | Posttest |
|---------------|---------|-----------|----------|
| Control       | O₁      | X₁        | O₂       |
| Experimental  | O₂      | X₂        | O₄       |

X₁: control class treatment using conventional modules
X₂: experimental class treatment using analytical thinking-based modules
O₁: initial tests Concept Map which is given to the control class
O₂: tests of Concept Map which is given to the control class
O₄: tests of Concept Map which is given to experimental class
The research data are the Concept Map scores of the students at the beginning (pretest) and end of learning (posttest). The analysis of the Concept Map score calculation is adjusted to the expert’s concept map using the CmapTools version 6.01.01 application, which consists of six components, namely valid relationship, hierarchy level, branching, pattern, cross-link, and specific examples [43] as exemplified in Figure 1. Figure 1 shows that the Concept Map consists of 12 valid relationships, 3 hierarchy levels, 3 branching, perfect patterns, 1 cross-link, and 2 specific examples. The Concept Map expert’s evaluation rubric used for the analysis of the research data is shown in Table 2. The Concept Map scores obtained by the students are expressed in percentages. The data were analyzed using the Ancova test which was preceded by parametric prerequisite tests including homogeneity, normality and verification tests including correlation and interaction tests using the SPSS version 22 application with a significance level (α) of 0.05.

![Figure 1. Concept Map [43]](image)

**Table 2. Expert concept map score according to Novak & Gowin (1984)**

| No | Komponen            | Skor   |
|----|---------------------|--------|
| 1. | Valid relationships | 78 x 1 point | 78 point |
| 2. | Hierarchy level     | 13 x 5 point | 65 point |
|    | Branching           |         |         |
|    | 1st level           | 1 point | 1 point |
|    | 2nd level           | 3 point | 3 point |
|    | 3rd level           | 3 point | 3 point |
|    | 4th level           | 3 point | 3 point |
|    | 5th level           | 3 point | 3 point |
|    | 6th level           | 3 point | 3 point |
|    | 7th level           | 3 point | 3 point |
|    | 8th level           | 3 point | 3 point |
|    | 9th level           | 3 point | 3 point |
|    | 10th level          | 3 point | 3 point |
|    | 11th level          | 3 point | 3 point |
|    | 12th level          | 3 point | 3 point |
|    | 13th level          | 3 point | 3 point |
| 3. | Pattern             | 5 point | 5 point |
| 4. | Cross-link          | 8 x 10 point | 80 point |
| 5. | Specific example    | 12 x 1 point | 12 point |
|    | Total Score         |         | 277 point |
3. Result and Discussion

3.1. Result

The effectiveness of the analytical thinking–based module to increase the students’ learning outcomes is measured using the results of the Concept Map component scores added with the total score in the pretest and posttest of the control class and experimental class based on Concept Map scoring techniques according to [43] analyzed with Ancova. The Ancova test is preceded by the parametric prerequisite tests. Parametric prerequisite tests include normality test (using Kolmogorov-Smirnov) and homogeneity test (using Levene's test) which show that the pretest and posttest data in the control class and the experimental class are normally and homogeneously distributed due to the value of sig. is > 0.05, so the verification test is performed, which includes correlation and interaction tests. The correlation test is used to find out whether there is a relationship between the Concept Map scores of the pretest and posttest results. The interaction test is used to find out the interaction between the scores of the pretest and Concept Map. The correlation test shows that Concept Map pretest scores are proven to have a correlation with Concept Map posttest scores with sig. value of 0.01 (< 0.05), so the pretest acts as a covariant and the pretest scores are strongly correlated with the posttest scores in terms of the sig. value of Pearson correlation of 0.531. The Concept Map pretest scores are proven to have no interaction with the control class or the experimental class variables as indicated by the sig. value of 0.357 (> 0.05). The results of the correlation and interaction tests meet the requirements to proceed to the Ancova test stage.

Ancova test was conducted to determine the difference in Concept Map posttest scores of the control and experimental classes which had previously met the parametric prerequisite tests and verification test. The summary of the Ancova test can be seen in Table 3.

| Class          | Pretest | Posttest | Sig. | F       | Partial Eta Squared | Estimation Parameter |
|----------------|---------|----------|------|---------|---------------------|----------------------|
| Control        | 19.97   | 47.89    | 0.00 | 1209.46 | 0.95                | -32.66               |
| Experimental   | 19.88   | 47.89    | 0.00 | 1209.46 | 0.95                | -32.66               |

Table 3 shows that the total posttest score of the Concept Map of students who use the analytical thinking–based module is 81.39% > 47.89%, which is higher than the score of those using the conventional one. Significant differences in posttest results between the control class and the experimental class are indicated by sig. value of 0.00 (< 0.05). The estimation parameter obtains -32.66, which means that the class that uses conventional modules gets a lower score of 32.66 compared to the one using the analytical thinking–based module. The analytical-thinking skill-based module has the effective contribution to the increase in the results of the Concept Map posttest score of 95%, which is seen based on the value in the Partial Eta Squared column.

The difference in the results of the Concept Map total scores between the control class and the experimental class represents the scores of the components of valid relationship, hierarchy level, branching, pattern, cross-link, and specific examples is shown in Table 4.

| Variable        | Control Class | Experimental Class |
|-----------------|---------------|---------------------|
|                 | Pretest | Posttest | Pretest | Posttest |
| Valid relationship | 10.38  | 46.50    | 10.81   | 83.92    |
| Hierarchy level  | 37.50   | 65.50    | 37.50   | 92.78    |
| Branching       | 31.82   | 63.64    | 31.82   | 92.14    |
| Pattern         | 40.00   | 85.45    | 40.00   | 100      |
| Cross-link      | 0.00    | 6.06     | 0.00    | 49.62    |
| Specific example| 0.00    | 19.44    | 0.00    | 73.17    |
Table 4 shows that the Concept Map components which include valid relationship (83.92%), hierarchy level (92.78%), branching (92.14%), pattern (100%), cross-link (49.62%), and specific examples (73.17%) of the experimental class increase higher than those of the control class, namely valid relationship (46.50%), hierarchy level (65.50%), branching (63.64%), pattern (85.45%), cross-link (6.06%), and specific examples (19.44%). The average percentage acquisition of all Concept Map component scores has increased, but the lowest cross-link scores in the pretest and posttest of the control class and the experimental class are 6.06% and 49.62%, respectively.

3.2. Discussion

The use of Concept Map has a positive effect and facilitates the assessment of students’ learning outcomes [56] through learning modules. Students’ learning outcomes with the Concept Map as an assessment through learning using analytical thinking–based modules obtain higher results than using conventional modules because the students can find concepts, patterns and relationships between concepts more easily and in a more directed way. The analytical thinking–based module that is applied to the experimental class contains the material content that is presented in the form of cases in the material of the human reproductive system, so it makes the students more enthusiastic and easy to analyze the concept of learning materials. The activities in the analytical-thinking module direct students to determine relevant and irrelevant pieces of information, construct information systematically and coherently, and determine the purpose of information. Indicators in the analytical-thinking module that are integrated with the analytical-thinking aspects (differentiating, organizing and attributing) and Concept Map components (valid relationships, hierarchy levels, branching, patterns, cross-links, and specific examples) make it easier for students to achieve learning objectives to obtain maximum learning outcomes. Students’ ability to obtain high learning outcomes is supported by high analytical thinking [57].

Another finding of this research is the gradual improvement in students’ learning outcomes as shown in the Concept Map construction because the students make the Concept Map at the end of each learning activity using the module. It was found that there is an increase in the complexity of the concept, the number of concepts extracted, understanding of a more accurate relationship between concepts and the use of knowledge [58,59] to obtain a maximum score for each component of the Concept Map. However, the obstacle to this research is the difficulty in conveying to students to participate in constructing the Concept Map, especially in the first sessions. This is because the students rely on traditional teaching/evaluation methods which make it difficult to engage in new learning strategies, especially Concept Maps. On the other hand, due to the anxiety problem, the students require a lot of time to produce a Concept Map, so good time management is needed [60,61]. However, with respect to the main benefits of the Concept Map in improving teamwork, analytical skills and deepening of learning, it is important to train and encourage students adequately in constructing Concept Maps, thus improving their learning outcomes. They need to receive adequate training on making Concept Maps, naming concepts and connecting concepts appropriately [58].

A Concept Map is an assessment that produces learning products in the form of Concept Map components that are calculated with scoring techniques [62]. The average score of the Concept Map components which include valid relationship, hierarchy level, branching, pattern, cross-link, and specific examples in this research is high in the experimental class that uses analytical thinking–based modules compared to that of the control class that uses conventional ones. The component of the Concept Map in the two classes of research that obtains the lowest score is cross-link because the construction of cross-links requires higher order thinking skills [63,64], explanation of the relationship between concepts on complex materials that make the students fail [65], involves higher order cognitive performance [66] and requires considerable time. Cross-links illustrate the ability of students to relate concepts to different levels of hierarchy [64]. Cross-links show a strong conceptual understanding [67] that can be seen from the ability to connect concepts to one another [52]. Cross-link scores with the right hierarchical structure show the level of ability to synthesize [47,68] concepts and creative thinking and students’ analyses [67].
The Concept Map component that obtains the highest score is pattern. The class that uses the analytical thinking–based module obtains a perfect score in the pattern component. It shows that the analytical-thinking skills direct students to analyze between concepts into deeper and more meaningful knowledge structures. Pattern is a representation of the overall understanding of the concept [69] that shows the structure of knowledge of the students [65]. Patterns automatically form a hierarchical structure of knowledge [70] that is depicted with the most general concepts that decline to become more specialized [65]. Pattern, hierarchy, and branching scores are interrelated in showing the students’ conceptual knowledge structure [71] and understanding [72]. Hierarchy and branching scores are closely related, so they represent the level of ability to find more visualized concepts [73] in describing superordinate and subordinate branches at different hierarchy levels to reach a specific example [74]. Specific examples, cross-links, hierarchy, branching, and patterns are interrelated with valid relationships because Concept Maps without valid relationships are not effective in facilitating meaningful learning [66]. The Concept Map as an assessment of learning outcomes with a highly integrated structure shows a deep understanding of students’ conceptual knowledge.

4. Conclusion
Learning using analytical thinking–based modules using Concept Map as an effective learning assessment in improving students’ learning outcomes. The Concept Map components which include valid relationships, hierarchy levels, branching, patterns, cross-links, and specific examples are a structural unit that can facilitate and build students’ levels of conceptual understanding. Concept Map has a positive effect on improving students’ learning outcomes and assessment of long-life learning in the teaching and learning process. Further research use of concept maps can be integrated with other higher order thinking skill. The concept map can also be used to measure the results of learning other than the material of the human reproductive system.

Reference
[1] Glaze A L 2018 Teaching and Learning Science In The 21st Century: Challenging Critical Assumptions in Post-Secondary Science Educ. Sci. 8 1–8
[2] Vebrianto R, Rery R U and Osman K 2016 BIOMIND Portal for Developing 21st Century Skills and Overcoming Students’ Misconception in Biology Subject Int. J. Distance Educ. Technol. 14 55–67
[3] Hiong L C and Osman K 2013 A Conceptual Framework for The Integration of 21st Century Skills in Biology Education Res. J. Appl. Sci. Eng. Technol. 6 2976–83
[4] Ghavifekr S and Rosdy W A W 2015 Teaching and Learning with Technology: Effectiveness of ICT Integration in Schools Int. J. Res. Educ. Sci. 1 175
[5] Arsad N M, Osman K and Soh T M T 2011 Instrument Development for 21st Century Skills in Biology Procedia - Soc. Behav. Sci. 15 1470–4
[6] Duran E, Yaussy D and Yaussy L 2011 Race to the Future: Integrating 21st Century Skills into Science Instruction Sci. Act. Classrr. Proj. Curric. Ideas 48 98–106
[7] Geisinger K F 2016 21st Century Skills: What are They and How Do We Assess Them? Appl. Meas. Educ. 29 245–9
[8] Davies M 2011 Concept Mapping, Mind Mapping and Argument Mapping: What are The Differences and Do They Matter? High. Educ. 62 279–301
[9] Areesophonpichet S 2013 A Development of Analytical Thinking Skills of Graduate Students by Using Concept Mapping The Asian Conference on Education (Osaka, Japan: Official Conference Proceedings) pp 1–16
[10] Art-in S 2015 Current Situation and Need in Learning Management for Developing the Analytical Thinking of Teachers in Basic Education of Thailand Procedia - Soc. Behav. Sci. 197 1494–500
[11] Thaneerananon T, Triampo W and Nokkaew A 2016 Development of a Test to Evaluate Students’ Analytical Thinking Based on Fact versus Opinion Differentiation Int. J. Instr. 9
[12] Saengprom N, Erawan W, Damrongpanit S and Sakulku J 2015 Exploring The Different Trajectories of Analytical Thinking Ability Factors: An Application of The Second-Order Growth Curve Factor Model Acad. Journals 10 994–1002
[13] Sánchez A V and Ruiz M P 2014 Competence-based learning. (A. V. Sánchez, M. P. Ruiz, & Authors, Eds.) (Spanyol: University of Deusto)
[14] Montaku S, Kaititkomol P and Tiranathanakul P 2012 The Mdel of Analytical Thinking Skill Training Process Res. J. Appl. Sci. 7 17–20
[15] Krathwohl D R 2002 A Revision of Bloom ’ s Taxonomy : Theory Pract. 41 37–41
[16] Anderson L W (Ed. .), Krathwohl D R (Ed. .), Airasian P W, Cruikshank K A, Mayer R E, Pintrich P R, Raths J and Wittrock M C 2001 A taxonomy for learning, teaching, and assessing: A revision of Bloom’s Taxonomy of Educational Objectives (Complete edition) (New York: Longman)
[17] Robbins J K 2011 Problem Solving, Reasoning, and Analytical Thinking in a Classroom Environment Behavior Anal. Today 12
[18] Irwanto, Rohaeti E, Widjajanti E and Suyanta 2017 Students’ Science Process Skill and Analytical Thinking Ability in Chemistry Learning AIP Conf. Proc. 1868
[19] Owusu K A, Monney K A, Appiah J Y and Wilmot E M 2010 Effects of Computer Assisted Instruction on Performance of Senior High School Biology Students in Ghana J. Comput. Educ. 55
[20] MeenuDev 2016 Factors Affecting the Academic Achievement: A Study of Elementary School students of NCR Delhi, India J. Educ. Pract. 7
[21] Rufii 2015 Constructivist Learning Module on Developing Strategies to Promote Students ’ Independent and Performance Int. J. Educ. 7 1948–5476
[22] Nurhayati B and Bahri A 2018 Effectiveness of the Use of Integrated Character Biology Modules in Improving Student Affective Learning Outcomes Prosiding Seminar Nasional Biologi dan Pembelajaran pp 227–32
[23] Hadianto H, Mudakir I and Asyiah I N 2018 Effectiveness of the Module with Scientific Approach to the Study of Biology in Senior High School Int. J. Adv. Eng. Res. Sci. 5 126–9
[24] Nagpal K, Priyamakhija B J and Gyanprakash 2013 Independent Learning and Student Development Int. J. Soc. Sci. Res. Interdiscip. 2 27–35
[25] Mulyasa E, Iskandar D and Aryani W D 2017 Revolusi Pembelajaran Sesuai Standar Proses (Bandung: PT. Remaja Rosda Karya)
[26] Khasanah A N, Sajidan S and Widoretno S 2017 Effectiveness of Critical Thinking Indicator-Based Module in Empowering Student’s Learning Outcome in Respiratory System Study Material J. Pendidik. IPA Indonesia. 6 187–95
[27] Ali R, Ghazi S R, Khan M S and Faitma Z T 2010 Effectiveness of Modular Teaching in Biology at Secondary Level Asian Soc. Sci. 6
[28] Sundari P P K, Widoretno S and Ashadi 2019 Profile Content and Context of Biology Modules Based Analytical Thinking Skill on The Material of The Human Reproductive System J. Phys. Conf. Ser. 1241 1–7
[29] Nuangchalerm P and Kwuanthong B 2017 Teaching “Global Warming” Through Socioscientific Issues-Based Instruction Asian Soc. Sci. 6 42–7
[30] Presley M L, Sickel A J, Muslu N, Merle- D, Witzig S B, Izci K and Sadler T D 2013 A Framework for Socio-Scientific Issues Based Education Sci. Educ. 22 26–32
[31] Permata T I, Suwono H and Listyorini D 2016 Pengaruh Pembelajaran Berbasis Masalah Penyakit Tropis terhadap Kecakapan Hidup Siswa SMA J. Pendidik. Teor. Penelitian, Dan Pengemb. 1
[32] Kamaludin S, Surtikanti H K and Surakusumah W 2018 Developing Issue-Based Teaching Materials to Improve Student Learning Outcomes in Freshwater Biology Course J. Pendidik. Biol. Indonesia. 4 161–70
[33] Soyibo K 2015 Using Concept Maps To Analyze Textbook of Respiration Presentations Am.
[34] Çimer A 2012 What Makes Biology Learning Difficult and Effective: Students’ Views Educ. Res. Rev. 7 61–71

[35] Ogunkola B and Samuel D 2011 Science Teachers’ and Students’ Perceived Difficult Topics in the Integrated Science Curriculum of Lower Secondary Schools in Barbados World J. Educ. 1 17–29

[36] Etobro A B and Fabiniu O E 2017 Students’ Perceptions of Difficult Concepts in Biology in Senior Secondary Schools in Lagos State Glob. J. Educ. Res. 16 139–147

[37] Chin C and Chia L G 2004 Implementing Project Work in Biology Through Problem-Based Learning J. Biol. Educ. 38 69–75

[38] Mohd Ali S, Kamisah O and Lilia H 2007 Content Scaffolding or Cognitive Scaffolding? Which Scaffolding Technique Encourage Students to Think Actively While Doing Problem Based Learning? Int. Probl. Learn. Symp. 3 150–73

[39] Yustina P and Kamisah OMeerah T S . 2011 Developing Positive Towards Environmental Management: Constructivist Approach Procedia Soc. Behav. Sci. 15 346–350

[40] Vebrianto R and Kamisah O 2014 BIOMIND: Strategic Approach Science Learning Indonesians Towards Preparing 21st Century Tech. Technol. Educ. Manag. 9 361–8

[41] Liu S and Lee G 2013 Computers & Education Using A Concept Map Knowledge Management System to Enhance The Learning Of Biology Comput. Educ. 68 105–16

[42] Katagall R, Dadde R, Goudar R H and Rao S 2015 Concept Mapping in Education and Semantic Knowledge Representation: an Illustrative Survey Procedia - Procedia Comput. Sci. 48 638–43

[43] Novak J D and Gowin D B 1984 Learning How to Learn (Cambridge: Cambridge)

[44] Assaraf O B-Z, Dodick J and Tripto J 2013 High School Students’ Understanding of the Human Body System Res. Sci. Educ. 43 33–56

[45] Miller K J, Koury K A, Fitzgerald G E, Hollingsead C, Mitchem K J, Tsai H and Park M K 2009 Teacher Education and Special Education: The Journal of the Teacher Education Division of the Council for Exceptional Teach. Educ. Spec. Educ. 32 365–78

[46] Adlaon R B 2012 Assessing Effectiveness of Concept Map As Instructional Tool in High School Biology (Louisiana State University)

[47] Turan N and Ekmekci G 2011 Preservice Chemistry Teachers’ Opinions about Drawing Concept Map Procedia Soc. Behav. Sci. 15 681–684

[48] Watson M K, Pelkey J, Noyes C R and Rodgers M O 2016 Assessing Conceptual Knowledge Using Three Concept Map Scoring Methods J. Educ. Educ. Technol. 105 118–146

[49] Reiska P, Soika K, Möllits A, Rannikmäe M and Soobard R 2015 Using Concept Mapping Method for Assessing Students’ Scientific Literacy Proc. Soc. Behav. Sci. 177 352–357

[50] Jack G U 2013 Concept Mapping and Guided Inquiry as Effective Techniques for Teaching Difficult Concepts in Chemistry: Effect on Students’ Academic Achievement J. Educ. Pract. 4 9–16

[51] Zvacek S M and Chozual M F 2013 Concept Mapping for Higher Order Thinking iJEP 3 6–10

[52] Chiou C, Lee L and Wang Y 2017 Analyzing the Effects of various Concept Mapping Techniques on Learning Achievement under different Learning Styles EURASIA J. Math. Sci. Technol. Educ. 8223 3687–708

[53] Moattari M, Soleimani S, Moghaddam N . and Mehbofi F 2014 Clinical Concept Mapping: Does it Improve Discipline-Based Critical Thinking of Nursing Students Iran. J. Nurs. Midwifery Res. 19 (1), 70–76 Iran. J. Nurs. Midwifery Res. 19 70–6

[54] Hsu L L, Pan H C and Hsieh S I 2016 Randomized Comparison Between Objective-Based Lectures and Outcome-Based Concept Mapping for Teaching Neurological Care to Nursing Students Nurse Educ. Today 37 83–90

[55] Sugiyono 2013 Metode Penelitian Pendidikan Pendidikan Kuantitatif, Kualitatif, dan R&D (Bandung: Alfabeta)
[56] Richmond S S, Defranco J F and Jablokow K 2014 A Set of Guidelines for The Consistent Assessment of Concept Maps Int. J. Eng. Educ. 30 1072–82
[57] Jamaris M 2019 Implementing Cognitive Strategy Instruction to Improve the Actual Intellectual Abilities of the Undergraduate Students with Cognitive Expression Difficulties Journal of ICSAR. 3
[58] Koc M 2012 Pedagogical Knowledge Representation Through Concept Mapping as A Study and Collaboration Tool in Teacher Education. Australas J. Educ. Technol. 28 656–670
[59] Jaaafarpour M, Aazami S and Mozafari M 2016 Does Concept Mapping Enhance Learning Outcome of Nursing Students? Nurse Educ. Today 36 129–32
[60] Buldu M and Buldu N 2010 Concept Mapping as A Formative Assessment in College Class-Rooms: Measuring Usefulness and Student Satisfaction Proc. Soc. Behav. 2 2099–2104
[61] Oliver K and Raubenheimer D 2006 Lessons Learned from Unstructured Concept Mapping Tasks Proc. Second Int. Conf. Concept Mapp. 3 351–8
[62] Chen W and Allen C 2017 Concept Mapping : Providing Assessment of , for , and as Learning Int. Assoc. Med. Sci. Educ. 16
[63] Cañas A J, Reiska P and Möllits A 2017 Developing Higher-Order Thinking Skills with Concept Mapping: A Case of Pedagogic Frailty Knowl. Manag. E-Learning 9 348–65
[64] Cañas A J and Novak J D 2008 Concept Mapping - Connecting Educators Proceedings of the 3rd International Conference on Concept Mapping 2
[65] Hung C H and Lin C Y 2015 Using Concept Mapping to Evaluate Knowledge Structure in Problem-Based Learning BMC Med. Educ. 15 1–9
[66] Atapattu T, Falkner K and Falkner N 2017 Computers & Education A Comprehensive Text Analysis of Lecture Slides to Generate Concept Maps Comput. Educ. 115 96–113
[67] Murdy R G C, Weber K P and Legge R L 2011 Exploring Concept Maps as Study Tools in A First Year Engineering Biology Course: A Case Study Int. J. Eng. Educ. 27 985–91
[68] Tuan L T and Thuan L T B 2011 The Linkages between Concept Maps and Language Learning Stud. Lit. Lang. 2 28–46
[69] Hidayati N and Widoretno S 2017 Penerapan Instruksi pada Tahap Orientasi Pembelajaran Guided Inquiry untuk Meningkatkan Kemampuan Menemukan dan Menghubungkan Konsep Implementation Instruction of Orientation Stage in Guided Inquiry Learning to Improve Ability for Discovering and Relating Proceeding Biol. Educ. Conf. 14 386–90
[70] Singh I Sen and Moono K 2015 The Effect of using Concept Maps on Student Achievement in Selected Topics in Chemistry at Tertiary Level J. Educ. Pract. 6
[71] Dewi A W K, Widoretno S, Dwiastuti S, Sajidan and Muzzazinah 2019 Instructional Techniques’ Teacher’s Questions in The Presenting Stage Of Project-Based Learning to Improve Students’ Concept Map Scores J. Phys. Conf. Ser. 1241 012016
[72] Kinchin I M 2012 Concept Mapping and The Fundamental Problem of Moving Between Knowledge Structures J. Educ. Teach. Trainers 4 96–106
[73] Nielsen A 2016 Concept-Based Learning in Clinical Experiences: Bringing Theory to Clinical Education for Deep Learning J. Nurs. Educ. 55 365–371
[74] Englebrecht A C, Mintzes J J, Brown L M and Kelso P R 2005 Probing Understanding in Physical Geology Using Concept Maps and Clinical Interviews J. Geosci. Educ. 53 263–270