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Critical Thinking in Biology Pre-AP Curricula

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Abstract: This study aims at investigating the extent to which critical thinking is utilized in the pre-AP (Advanced Placement) biology curriculum, identifying any gaps present, in additionto improving existing curriculum documents based on these gaps.Two questions drive this research study:"To what extent is critical thinking utilized in the pre-AP biology curriculum?" and "What perceptions do biology teachers have regarding planning for critical thinking?"Qualitative data analysis using the Critical Thinking Attribute Survey was used to analyze the curriculum documents and example lesson plans. Additional data was collected through semi-structured interviews. This study confirms that biology curriculum documents include attributes of critical thinking in all standards. In addition, it presents various effective teaching strategies that would promote students' critical thinking. Moreover, this study confirms the importance of teachers' professional development, especially for interpreting curriculum documents and identifying attributes of critical thinking. This will enable them to translate learning outcomes and implement effective strategies to develop students' critical thinking skills.

Keywords:critical thinking, biology curriculum, teacher training

1. Introduction

The 21st century civilization is full of upcoming challenges; new generations must be equipped with essential success skills that enable them to withstand a competitive future. Youth need to develop innovative ways of thinking to solve evolving global problems. On that note, education is the first effective facilitator that is acknowledged to shape young minds and provide them with opportunities to master critical thinking skills. This is achieved when students are able to use existing information, and interpret andevaluate data to construct knowledge, thus gaining the ability tomake informed decisions (Greene & Yu, 2016).Developing students' critical thinking skills must be done through effective communication and discussion,being either face-to-face or through social media(Pattanapichet&Wichadee, 2015).

1.1 Statement of the problem

Developing critical thinking skills is crucial in order to qualify students as problem solvers. However, although teaching critical thinking is possible, itis considered to bea challenging process, considering that it requires appropriate preparation and skilled teachers (Sinatra, Kienhues, & Hofer, 2014). Since school curricula provide teachers with the main guidelines to facilitate students' learning of knowledge, skills and competences,establishing critical thinking skills within curricula is an effective method of promoting critical thinking in education (Ornstein and Hunkins, 2008). This will ensure that students are exposed to situations that require them to use higher-order thinking skills,accordinglypreparing them to face future career challenges.

This study targetsa specific elite programin a series of high schools in Abu Dhabi. The programprovides students with a rigorous academic foundation and prepares them to sit for the Advanced Placement (AP) examinations,thuswaiving college-level courses. Students are enrolled in this program as early as in Grade 8.After completing foundation courses, they begin takingAP courses in Grades 11 and 12. This study focuses on the pre-AP biology curriculum offered to students in Grades 9 and 10. The aim of this study is to investigate the extent to which critical thinking is utilized in the pre-AP biology curriculum, identifying any gaps present, and improving existing curriculum documents based on these gaps.

Two questions drive this research study:

- To what extent is critical thinking utilized in the pre-AP biology curriculum?
- What perceptions do biology teachers have regarding planning for critical thinking?

1.2 Rationale and significance

In the United Arab Emirates, especially after the 2016 Program for International Student Assessment (PISA) results, it was clarified that students in the UAE need to develop reasoning and problem-solving skills. Therefore, science education reform should be centered around students' acquisition of critical thinking skills (Pennington, 2017). On the other hand, it is to be noted that students in UAE in general lack reasoning and

critical thinking skills (Scott, 2008; Forawi& Mitchell, 2012). In addition, literature identified developing critical thinking ashavingone of the challenges in the process of knowing called "epistemic cognition"(Sinatra, Kienhues, & Hofer, 2014; Greene & Yu, 2016).When observing best educational practices in other countries that have initiated science curriculum reform, it is noted that their curricula involved more experimentation and problem-solving skills and less memorization of facts (OECD, 2010).Therefore, the curriculum is to be considered as the main guidance for staff to develop behavioral objectives for the subject taught (Ornstein and Hunkins, 2008). This study is expected to facilitate teaching critical thinking skills by including them in specific learning outcomes, as well as outliningstudents' performance criteriain the curriculum documents.

1.3 Structure of the research study

This study comprises five main parts: the introduction in the current section, followed by the literature review,which includes the theoretical framework,identified as the base of critical thinking and curriculum review,in addition to discussing previous empirical studies related to examining critical thinking in the curriculum. The third part explains the methodology, including the study design, instrument and context. The fourth part presents the results. Finally, the fifth part analyzesand then discusses the results, concludes the study,and provides recommendations to close the identified gaps in the curriculum.

2. Literature review

2.1 Theoretical framework

2.1.1 Critical Thinking (CT) definition

Dewey (1910) established the first definition of critical thinking whenhe defined reflective thoughts as an "Active, persistent andcareful considerationof any belief or supposed form of knowledge in the light of the grounds that support it, and thefurther conclusions to which it tends". In this definition, Dewey clarified that thinking is an active process that is initiated due to a suspicion or uncertainty about an issue, requiring further investigation to reacha conclusion and make a decision. Fisher (2011) listed other definitions for critical thinking; all were extending from Dewey's initial definition. The widely used definition, "Critical thinking is reasonable, reflective thinking that is focused on deciding what to believe or do" is fromNorris and Ennis(1989).A later CT definition by Paul and Elder (2006) is, "Critical thinking is the art of analyzing and evaluating thinking with a view to improving it". Examining both definitions entails that CT is a process that requires people to think, evaluate and reflect upon their thinking to gain a deeper trust of what they think or do. An additional point can be understood from Paul and Elder's definition of CT, which mentions that CT requires people to improve and develop their beliefs and actions. The way CT is addressed in this study is in line with these definitions. This implies that CT entails thinking about the method followed to make a decision: deciding whether the way of thinking was sufficient to give the correct decision. Accordingly, the utilization of CT using this definition allowsfor the development of metacognitive skills (Fisher,2011;Forawi& Mitchell, 2012).

2.1.2 CT in Education

Dewey (1910) clarified that people can be trained to think and reflect upon their thoughts, as this is a skill that can be developed through practice. Forawi (2016) presented the historical development of critical thinking in education in three stages: before 1980, when education focused on CT as outcomes that students should gain through the learning process in the classroom.Between 1980 and 1990, when teaching CT developed as the pedagogies improved, the target was the requisition of creative thinking to solve problems, research, and make decisions in a cooperative learning context. The last stage post-1990 highlighted the importance of utilizing gained CT skills in all situations, inside and outside the classroom, resulting in the development of metacognitive skills.In education, the development of metacognitive skills is essential in order for students to gain the skill of thinking of their learning processes, reflect upon their understanding, and enabling them to select the appropriate strategy of learning (Long et al, 2011).

Critical thinking as per Paul and Elder (2006) is the thinking that is directed, monitored and corrected by a personindependently. Individuals learn to develop intellectual traits based on applying the standards onto the elements of learning, as illustrated in Figure 1, which was adopted from Paul and Elder's model (2006).Developing intellectual traits and gaining critical thinking dispositions is a long-term procedure that can be achieved through education (Forawi, 2016).

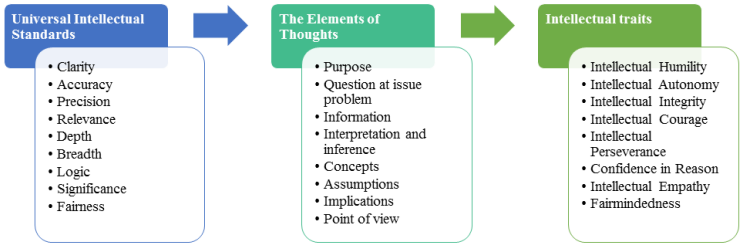

Figure 1:. Application of Universal standards on elements of learning to develop Intellectual traits (Paul& Elder, 2006)

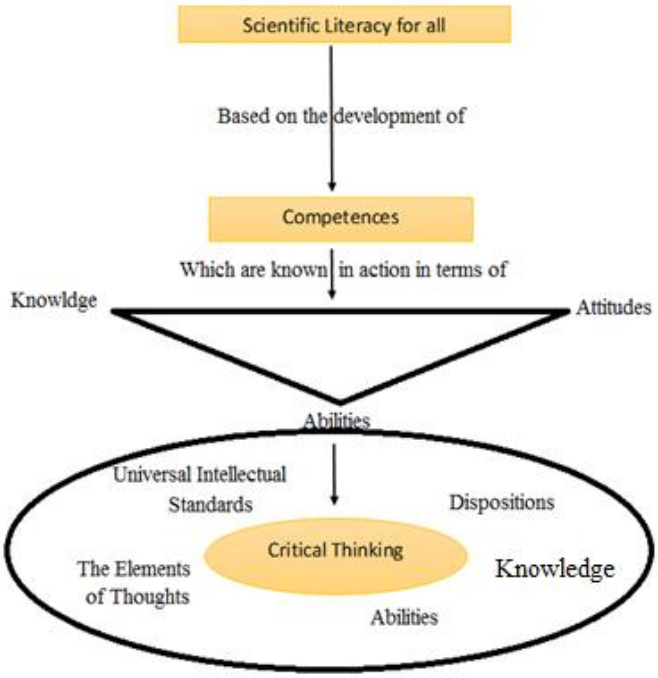

Figure 2. Framework of the relation between scientific literacy, competencies and critical thinking (Vieira, Tenreiro-Vieira & Martins, 2011)

Developing CT skills is an essential target in all disciplines in education(Fisher, 2011; Forawi, 2016; Mok& Yuen, 2016). Particularly inscience, students are always required to develop conceptual changeswhen learning new concepts about different phenomena (Abell & Lederman, 2010). Science education entails many processes that can help students develop critical thinking skills, including inquiry-based learning, research, experimentation through discussion, and cooperative learning (Forawi, 2016). When students develop CT skills, they gain self-regulatory learning skills, enabling them to judge their own performance, reflect upon their thinking, identify their learning gaps and plan how to close them, accordingly becoming independent learners (Mok& Yuen, 2016; Dwyer et al, 2014).
Vieira, Tenreiro-Vieira,and Martins (2011) suggested a framework, illustrated in Figure 2, which guides science teachers to utilize critical thinking in order to develop students' scientific literacy.

2.1.3 Curriculum change towards Critical Thinking

To enforce an educational change that develops students' CT skills, it is essential to consider a holistic view of change that includes curriculum, teacher preparation programs, instructional strategies and the involvement of society (Vieira, Tenreiro-Vieira,& Martins, 2011; Abell and Lederman, 2010). Changing attributes related to students' learning is a complex process that involves different variables;Anderson (1992)proposed a diagram illustrated in Figure 3 to demonstrate the level of complexity required to administer any educational change.

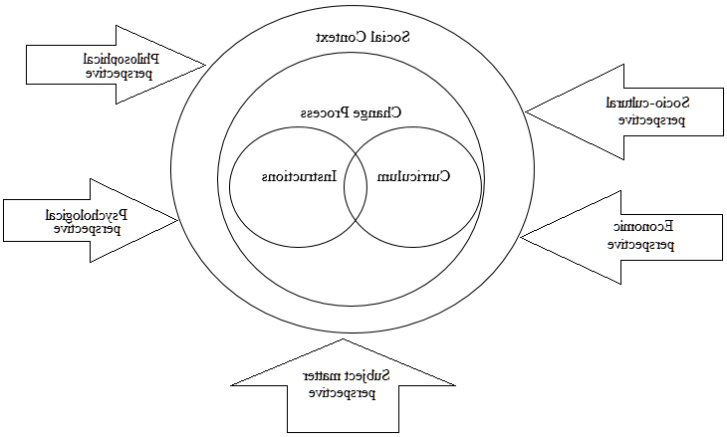

Figure 3.A Model of Complexity (Anderson, 1992, cited in Abell & Lederman, 2010)

As demonstrated in the diagram, an educational change would require a consistent and systematic change in the curriculum and instructions inside the classroom, taking into consideration other factors such as subject matter, society, philosophical and psychological perspectives of education, that help achieve a successful change. This study focuses on the curriculum and how it is understood by teachers, which is the core of any educational change.

The curriculum review process, as per Ornstein and Hunkins(2008), must follow a sequential reasoning based on evidence. They developed a model that expands Pellegrino, Chudowsky, and Glaser's assessment triangle, in which the process of reasoning from evidence is tracked in a way that relates cognitive theories regarding students' learning with observations of their behavior in that respect, then interpreting data to make a decision regarding students' performance (Chudowsky, Glaser & Pellegrino, 2004). The current study follows the same model to identify the gaps in CT implementation in the biology curriculum, and make the necessary improvements accordingly.

2.2 Previous empirical studies

2.2.1 Teachers' perceptions of CT inclusion in the curriculum

Integrating critical thinking into science curricula, and training teachers to interpret the curriculum and translate performance expectations to actual learning practices in the classroom,are important steps to support teachers in order to help develop students' CT skills (Forawi& Mitchell, 2012; Vieira, Tenreiro-Vieira & Martins, 2011). Different countries aimed to develop their students' critical thinking skills through curriculum development, and the integration of CT requirements in the learning objectives. However, Vieira, Tenreiro-Vieira, and Martins (2011) reported that efforts should focus on teachers' preparation programs, enabling them to identify CT in the curriculum.

A study carried outin China by Mok and Yuen (2016) evaluated teachers' understanding of CT, in order to examine their ability to nurture students as critical thinkers.The results revealed that most of the teachers thought that CT is a generic reasoning process that can be developed. They identified critical thinkers as students who are able to give independent opinions and respect others. Teachers' understanding of CT was limited due to the lack of considerationtowardsthe socioeconomic context. Insufficient understanding of CT will lead to poor implementation and incorporation of CT requirements into educational processes.

Another example that reflected teachers' poor CT skills was presented in a study by Akgun and Duruk (2016),which investigated pre-service teachers'critical thinking disposition.The study revealed that pre-service science teachers' CT disposition was low;after comparing results from student teachers in different years at the university, it was found that they did not even improve their CT disposition over time. These results are alarming and indicate that teacher preparation programs should be revamped to include CT in the curriculum, in order to provide opportunities for pre-service teachers to improve their CT dispositions. Consequently, they will then be able to utilize CT when they teach science curricula.

Forawi (2016) identified how pre-service teachers interpret National Science standards and CT attributes when planning science lessons. Findings indicated that process skills' standards had more CT attributes than knowledge-based standards. The study recommended further research using the Critical Thinking Attribute Survey (CTAS) developed by Forawi (2012) to identify how other curricula implement critical thinking in other countries. Therefore, the main reason behind the current study is aligned with this action, which is to review the curriculum and explore CT attributes from teachers' perspectives. This is to further develop the curriculum and ensure the clarity of CT components.

2.2.2 Critical thinking implementation in the classroom

One example of empirical studies focusing on including CT in the curriculum is by Bati and Kaptan (2015), who examined the effect of a modeling-based science program on Grade 7 students' development of critical thinking. The modeling-based design consisted of an objective, a process describing scientific phenomena, and a series of inquiry stages that led the students to either accept the phenomena, or to refuse it and dofurther research. Their results revealed that the students in the experimental group that utilized model-based science education showed a significant difference in the development of critical thinking skills; more than the control group that studied the same concept in the traditional method.

Similarly, Gunn and Pomahac (2008) examined CT in the middle school science classroom. The results presented a significant difference between the experimental and the control group, as students who were taught through CT instructions and were exposed to critical class discussionsreflected higher cognitive skills when they were assessed for the CT development. An additional study by Chowning et al (2012) was related to a high school curriculum and investigated the effect of including structured reasoning in the biology curriculum on the development of high school students' CT skills. They implemented the Collaboration of Understanding Research and Ethics (CURE) program within biology lessons. Their results confirmed that teaching structured reasoning through CURE in the classroom is effective and promoted students' CT skills, as students were able to analyze complex case studies, make decisions and defend their opinions. The researchers recommended further studies on the curriculum content, to examine the extent to which it could develop students' reasoning skills, without the need for teachers' professional development. Therefore, the aim of the current study is to examine a biology curriculum and identify CT components from the teachers' perspectives, to identify the gaps and close them in future developments.

3. Methodology

The main method driving this research study is qualitative, as the intention is to analyze curriculum documents and teachers' lesson plans (Fraenkel & Wallen, 2006). The main aim of the data analysis isto identify the attributes of critical thinking, utilizing the Critical Thinking Attribute Survey (CTAS) developed by Forawi (2012).Two types of document analysis are performed: the first one is for the biology curriculum documents written by teachers, and the second one is for the lesson plans designed by the researcher.Document analysis is then followed by a semi-structured interview over the phone to discuss teachers' perceptions and suggestions.Merriem (2009) clarified that interviews are used to collect more information about the feelings and ideas of participants about the research question.

3.1 Design

The study focused on the pre-AP biology curriculum offered to elite students in the advanced science program in the school. The students in this program are expected to complete Advanced Placement (AP) courses and take AP exams by the end of Grade 12. It is essential to ensure that the curriculum provides suitable opportunities to build students' CT skills.

The main procedure followed in this study is data mining from documents (Merriem, 2009). The curriculum documents used for this research were developed for the first time in 2014 by the biology curriculum specialist in UAE and a team of expert teachers. They were then reviewed annually, based on teachers' feedback and updated requirements from the system. Curriculum documents are open to all the school staff to use, as guidance to the learning outcomes required to promote students to the next grade level.

The study design included:

- A training session that was offered to volunteeringteachers on identifying CT in the curriculum and using the CTAS instruments
- Data collection for this study that occurredin threestages:
  - ✓ Teachers worked individually to analyze the curriculum documents and provided their feedback regarding the inclusion of CT in the curriculum documents
  - ✓ Teachers provided samples of the lesson plans they implemented during the academic year,wherethey included CT attributes.The researcher analyzed these lesson plans using the same instrument
  - ✓ An interview to confirm the results and assure triangulation of data collectionwas conducted(Cohen, Manion and Morrison, 2007).

3.2 Instrument

3.2.1 Critical Thinking Attribute Survey (CTAS)

Creswell (2014) recommended that documents must be organized and prepared for data analysis. In this study, the researcher prepared instruments for Grade 9 and Grade 10 documents based on the CTAS adopted from Forawi (2016). CTAS included ten attributes to measure CT, listed in Figure 4.

Critical Thinking Attributes
CTA1 – Think Independently and develop intellectual courage
CTA2 – Explore how egocentricity and sociocentricity affect feeling, thought and behavior
CTA3 – Suspend judgment or prior conceptions
CTA4 – Utilize various processes to resolve, re-address, and re-analyze complex situations to gain new insight
CTA5 – Develop and use valid criteria for evaluation
CTA6 – Raise and pursue significant questions
CTA7 – Analyze arguments, interpretations, beliefs, or theories and their implications.
CTA8 – Generate and assess solutions
CTA9 – Make arguments, interpretations, beliefs, or theories and their implications
CTA10 – Think precisely about thinking- using critical thinking vocabulary

Figure 4. Critical Thinking Attributes adopted from Forawi (2016)

The instruments prepared considered the main biology standards to be discussed in each Grade level. The instruments are enclosed in Appendix 1.The same criteria were used in a tool to analyze teachers' lesson plans.

3.2.2 Interview questions

The semi-structured interview is used to get specific data from all participants (Merriem, 2009). The questions focused on identifying the standards and outcomes that required more CT utilization, and the pedagogical approaches used by teachers to deliver these outcomes.Open-ended questions were developed to gain an in-depth understanding of the teachers'responses and their experiences after using the CTAS. The responses were recorded and then transcribed (Creswell, 2014).
The main questions planned for the interview are as follows:

- Based on the analysis you did, where do you think teachers were required to use CT teaching strategies more? Justify by example.
- How did you teach these topics?
- What were students' reflections about the procedure used?
- Do you think that your students developed CT skills when this strategy was used? How can you decide?

3.3 Setting and participants

The study took placein a series of high schools in the UAE. Biology teachers across the schools were invited to participate, and fiveteachers from three different schools accepted to participate and received the required training.Sampling was purposeful, as it targeted biology teachers only. The sampling procedure followed the volunteeringsampling; participating teachers were only the ones who were interested in performing the analysis(Muijs, 2011). The documents used were for Grades 9 and 10 advanced science program classes. Teachers provided sample lesson plans for the same grade levels, and responded to open-ended questions regarding their input into the document analysis, their lesson plans, and their suggestions and individual plans forintegrating CT attributes in the future.

3.4 Limitation

Teachers' ability to identify CT in the curriculum was not assessed. They were trained to use the CTAS instrument and reflected a good understanding of the application of each CT attribute mentioned. One of the participants withdrew their contribution after receiving the training session, which led to having input from only four teachers instead of five.

Like other research studies that use document analysis, one limitation would be judging the value of the resource (Merriem 2009), therefore interviews were used as another source of data, to strengthen the results.

3.5 Ethical consideration

Official permission was obtained from the school system management, individual teacherswere contacted, and the research requirements were explained. An email was sent to participants to inform them that the information and the data collected from them would be used for academic research purposes only and would remain anonymous (see Appendix 2).

4. Results and Data analysis

Data was collected to answer the research questions through three different procedures: the document analysis performed by four teachers on two different campuses, four samples of lesson plans, and data collected through audio recordings of four interviews.

4.1 Document analysis from teachers' perspectives

To answer the first question, "To what extent is critical thinking is utilized in the pre-AP biology curriculum?"the input from four teachers was compared and compiled, then the average number of attempts given to each attribute for the standards in Grade 9 and Grade 10 was calculated. Tables 1 and 2 present the results compiled from the four teachers.

The critical thinking criteria that was repeated the most in bothGrade 9 and Grade 10 documents is the first one, which was "think independently and develop intellectual courage," followed by the sixth, "Raise and pursue significant questions." The critical thinking attribute repeated the least was the second, "Explore how egocentricity and sociocentricity affect feeling, thought and behavior." Other CTAs were repeated an average of 10-20 times in the documents.

4.2 Lesson plans

To answer the second question, "What perceptions do biology teachers have regarding planning for critical thinking?"five sample lesson plans were received as examples of implementing critical thinking in the classroom. Data analysis is presented in Table 3.

Table 1: Data analysis for lesson plan samples

Critical Thinking Attributes		*LP 1 G 9*	*LP 2 G 9*	*LP 3 G 9*	*LP 1 G 10*	*LP 2 G10*
		Photo-synthesis	*DNA, the Genetic Material*	*Photo-synthesis*	*Limits to Growth*	*Blood and the Lymphatic System*
CT A1	Think independently and develop intellectual courage	×		×	×	×
CT A2	Explore how egocentricity and sociocentricity affect feeling, thought and behavior				×	
CT A3	Suspend judgment or prior conceptions				×	
CT A4	Utilize various processes to resolve, re-address, and re-analyze complex situations to gain new insight	×	×			×
CT A5	Develop and use valid criteria for evaluation	×	×	×		×
CT	Raise and pursue	×		×	×	

A6	significant questions					
CT A7	Analyze arguments, interpretations, beliefs, or theories, and their implications		×			
CT A8	Generate and assess solutions		×		×	
CT A9	Make arguments, interpretations, beliefs, or theories, and their implications			×		
CT A10	Think precisely about thinking, using critical thinking vocabulary					×

The most repeated CT criteria in the concepts discussed and the activities planned were the first, "Think independently and develop intellectual courage,"and the fifth, "Develop and use valid criteria for evaluation."The critical thinking criterionleast utilized was the tenth, "Think precisely about thinking, using critical thinking vocabulary." Two samples of the submitted lesson plans are attached, in Appendix 3.

4.3 Interviews

Data collected from the interviews explored information regarding the second question, "What perceptions do biology teachers have regarding planning forcritical thinking?"From the four participating teachers, three volunteered to be interviewed, all female, two of them having about seven years of experience(mentioned as T1 and T2) and one with more than 15 yearsof teaching biology (T3). Interview questions were developed to follow up on the feedback received regarding curriculum document analysis; four main points presented below were discussed.

4.3.1 Main concepts that required CT

Teachers' responses mentioned a variety of topics that included the attributes of CT.Two teachers (T1 and T2) referred to the standard about living systems and mechanisms to maintain homeostasis. T1 stated, "*Cells are the fundamental structure and function of life, it discusses homeostasis and how different systems work together to maintain homeostasis; students are required to link different topics."* This concept would require students to use CTA 7. T2 gave another example from the same standard about human genetic disorders: "*Analyzing arguments that I found, two in living systems, one about the human genome project and how people are looking at disorders and how society looks at testing for disorder*,[itcontains a] *large variety of CT in many ways."* The example given by T3 mentioned environmental concepts, and the discussions related to Earth's resources; she mentioned, "*In Grade 10 ecology, a lesson about resources and how humans impact the environment."*In her opinion, this concept requires students to think about real problems and present applicable solutions.

4.3.2 Teaching strategies used

The teachers mentioned different instructional methodologies that were used to implement the example lessons they provided. T1 emphasized the importance of case studies as a method of teaching human body systems and homeostasis; she said, "*Students are given case studies showing the symptoms and the students have to conclude what is the disease based on the symptoms."* In addition, she agreed withT2 on the importance of experiments and practical work to provide opportunities for students to analyze results and relate them to a specific scientific phenomenon.

T1 mentioned an example from photosynthesis experiments:"*Photosynthesis experiment that ended with a further extension using what they did in the lab, if they flip the result what they mustchange in the experiment. Not all students answered it correctly, but they give their own explanations."*T2 added another strategy that she used to explain the human genetic project and genetic disorders. She said, "*We had a nice debateabout if we could have any genetic testing, and finding out the genome of humans. What they are testing for? Debate about beliefs and if it is allowed in religion."*T3 gave an additional example of a group activitywhich she used to teach a topic related to the structure of the cell. She stated, "*It was a group activity in which each of the students had a specific role, to complete an analogy through comparing the work of cell organelles with the job of an actual team in the school such as a maintenance team."*In an additional example about her strategies, T3 mentioned a group task given to Grade 10 students, where they were required to relate

the topic to society problems related to pollution, and sustainable resources. She stated, "*Students were required to research human impact on Earth's resources and present their work with applicable daily life examples."*

4.3.3 Students' development of CT

The teachers expressed that students enjoyed the lessons in which CT was utilized. T1 mentioned in her comments that "*students enjoy the hands on and like when they are challenged."* However, students were not asked to reflect about these activities. T2 stated that she inferred that students enjoyed the lesson due to their engagement in the debate, as she stated: "*It was* [a]*heated debate that students enjoyed; we didn't make any reflection about thinking".* T3 thinks that her students experienced CT this year. Yet, they could practice it in a better way. She said, "*They did*[the] *most part of it but they could do better, now I understand critical thinking more."*

4.3.4 Teachers' suggestions and future plans

The three teachers that were interviewed agreed that the curriculum provided opportunities to implement CT. Yet, they were only able to identify these opportunities after the workshop they attended and the exercise they did in this document analysis. They confirmed that they would change the way they plan their lessons to include more CT in the required tasks. T1 explained her new understanding of the curriculum documents after this research study: "*Looking at the curriculum document from a different light as each objective is broken down into ten criteria, next year when I plan my lessons, I will include an item that requires students to practice and build these skills."*

T2 was enthusiastic regarding practical work and experimentation; she suggested that teachers should plan long-term experimental projects and run them early in the term to allow for follow-up and adjustment of the procedure, based on the results that students get. She mentioned, "*What would be really nice is having more labs, and the students' decide about their independent variables, they analyze their results and change their procedure.* [They would have]*more time to think about the results and adjust their procedure and find out the theory behind the practical work required."*

T3 emphasized that the plan next year is to change the approach of lesson planning to include CT items in every lesson. She said, "*Next year, my plan will be different; it will be critical thinking based. I will plan all lessons to give the opportunities to help students* [use]*CT."*

5. Discussion and conclusion

5.1 Discussion

The aim of this study was to investigate the extent to which CT is included in biology curriculum documents, in addition to exploring teachers' practices in planning and implementing CT. Results are discussed in this section to explain the answers to the research questions.

5.1.1 Critical Thinking in Biology Curriculum Documents

The results revealed that questioning and thinking independently are repeated more than 30 times in the curriculum. Assuming that the academic year consists of a minimum of 30 weeks, students are exposed to this CTA once every week. More attention is required to close the gaps that were identified in the implementation of CTA 2 and CTA 9, as they are not sufficiently repeated in the curriculum, which necessitates modifications in the curriculum to include clear outcomes that indicate their utilization. Sinatra, Kienhues, and Hofer, (2014) and Greene and Yu (2016) clarified thattraining students to use reasoning in thinking will develop their CT skills, enabling them to think of science-related problems that they encounter in their daily life, and allowing them to develop epistemic cognition. CTA 2, which was concerned withsociocentricity and the development of an individual's behavior, was also highlighted by Lim (2014), as this study recommended that teaching students CT must be related to their role in their society.

The results of this study confirmed that concepts related to mechanisms that living organisms performto store, retrieve, and transmit information, require students to think critically. The example mentioned in this study is related to the human genome project and new research studies regarding genetic testing, and using it as a topic for class debate emphasized the utilization of CTA 4 and CTA 7. Another study by Cargas (n.d.) and Mayfield (2017)also confirmed that utilizing arguments in issues related to new scientific developments such as genetic testing will help students develop CT.Cargas (n.d.) also supports the other example mentioned in this study regarding the use of casestudies to explain homeostasis in living organisms, as their study confirmed the importance of case studies to improve students' CT skills.

The utilization of CT in the biology curriculum is in line with the results of research bySimms (2016),whichrecommended the inclusion of CT that develops students' ability to analyze arguments and claims, interpret evidence, evaluate the credibility of evidence, and identify errors in reasoning.

5.1.2 Biology Teachers' Planning of Critical Thinking

The findings of this research study indicated that laboratory work and experimentation are excellent opportunities for teachers to utilize CT. All the CTAs mentioned in the study can be enforced through practical work, and promote the development of CT skills in students, especially when students are required to do long-term experiments that require them to design a procedure and then adjust it to get better results. This is in line with Duran and Dökme's (2016) findings that confirmed that using guided inquiry instructions, such as open labs, develops students' CT skills.This is also supported by Enger and Yager (2009),who related the creative domain attribute to the experience of implementing laboratory experiments.Moreover, teachers in this study clarified that critical thinking activities increased students' engagement in the lesson and encouraged them to participate. Attitude was defined by Enger and Yager (2009) as an important domainthat must be considered when planning any science lesson.

The analysis of lesson plans, in addition to the interviews,showed that professional development is an important requirement to ensure teachers' understanding of the concept of CT, and how it is implemented in the classroom. Similar results were described by Mok and Yuen (2016) and Akgun and Duruk (2016), who confirmed teachers' inadequate understanding of CT.

The teachers mentioned the environment and the effect of humans on natural resources as a topic that requires CT, andwas implemented in a group work activity that required students to reflect and link their knowledge to solve local society problems. This is supported by Bowman and Govett (2015), who confirmed that when teaching ecology in the Next Generation Science Standards, the ecology standard requiredstudents to practice critical thinkingto interpret how organisms interact in ecosystems. Additionally, using a student-centered teaching approach offers wide opportunities for students to think, reflect and receive feedback about their thinking (Slavin, 2014; Orlich, 2013; Chappuis, 2015).

5.2 Conclusion

This study answered the first question regarding CT in biology curriculum documents, as it confirms that biology curriculum documents include attributes of critical thinking in all standards. Yet, attention is required to include critical thinking when teaching some concepts. As for the second question regarding biology teachers' perceptions on planning for CT,the results of this study present various effective teaching strategies that aremeant to promote students' critical thinking. Moreover, this study confirms the importance of teachers' professional development for interpreting curriculum documents and identifying attributes of critical thinking. This will enable them to translate the learning outcomes and implement effective strategies to develop students' critical thinking skills.

5.3 Implications and limitation

The findings of this research study have implications in the educational field, as the results identified specific gaps in the curriculum where CT attributes must be clearly identified. In addition, one of the important recommendations of this study would be to arrange professional development workshops for all science teachers, to promote teachers' understanding of CT and enable them to identify the main critical thinking attributes in curriculum documents and translate these into actual teaching strategies in the classroom.

5.4 Recommendation for further studies

This study analyzed the Grades 9 and 10 biology curriculum.Further research could be carried out to include different subjects and different grade levels. The same study could be repeated with other teachers on a larger scale, and data could be collected through lesson observations. Studies could measure students' critical thinking abilities before and after conducting CT professional development for teachers.

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Appendix 1

Critical Thinking Attribute Survey (CTAS). Adopted from: Forawi, S. (2016). Standard-based science education and critical thinking. *Thinking Skills and Creativity*, 20, pp.52-62

Critical Thinking Attributes		**Grade 9 ASP Curriculum Document**		
		Cells are a fundamental structural and functional unit of life.	Biological systems utilize energy and molecular building blocks to carry out life's essential functions.	Living systems have multiple mechanisms that are used to store, retrieve and transmit information.
CTA1	Think independently and develop intellectual courage			
CTA2	Explore how egocentricity and sociocentricity affect feeling, thought and behavior			
CTA3	Suspend judgment or prior conceptions			
CTA4	Utilize various processes to resolve, re-address, and re-analyze complex situations to gain new insight			
CTA5	Develop and use valid criteria for evaluation			
CTA6	Raise and pursue significant questions			
CTA7	Analyze arguments, interpretations, beliefs, or theories, and their implications			
CTA8	Generate and assess solutions			
CTA9	Make arguments, interpretations, beliefs, or theories, and their implications			
CTA10	Think precisely about thinking, using critical thinking vocabulary			

Critical Thinking Attributes		Grade 10 ASP Curriculum Document			
		Cells are a fundamental structural and functional unit of life.	Interdependent relationships characterize biological ecosystems.	The diversity and unity of life can be explained by the process of evolution.	Living systems have multiple mechanisms that are used to store, retrieve and transmit information.
CTA1	Think independently and develop intellectual courage				
CTA2	Explore how egocentricity and sociocentricity affect feeling, thought and behavior				
CTA3	Suspend judgment or prior conceptions				
CTA4	Utilize various processes to resolve, re-address, and re-analyze complex situations to gain new insight				
CTA5	Develop and use valid criteria for evaluation				
CTA6	Raise and pursue significant questions				
CTA7	Analyze arguments, interpretations, beliefs, or theories, and their implications				
CTA8	Generate and assess solutions				
CTA9	Make arguments, interpretations, beliefs, or theories, and their implications				
CTA10	Think precisely about thinking, using critical thinking vocabulary				

Appendix 2

Dear LT's

I am intending to perform an educational research regarding the integration of critical thinking in Biology curriculum documents before the summer break. The main purpose of the research is to examine Grades 9 & 10 ASP Biology curriculum documents using the Critical Thinking Attribute Survey, from the teachers' perspective.

Please ask if any of the Biology teachers in your campus are interested to volunteer to participate in this study.

The participants will:

- contribute in an orientation workshop (location to be decided based on the number of volunteers and their locations)
- use a survey to analyze the curriculum documents and identify the level of critical thinking inclusion.
- provide examples for lesson plans in which critical thinking was utilized.

Please let me know if any of the teachers in your campus is interested.

Thank you,

Sura Moh'd Sabri

Appendix 3

Samples of lesson plans

Grade 9 Sample lesson plan 9ASP.docx

Grade 10 Sample 2 G10 Lesson Plan.docx

Author Profile

Sura Sabri holds a master's degree in science education from British university in Dubai 2015, and a BSc in Biology from Jordan University in 1994. She is currently a student pursuing a PHD in Science Education at BUID. She has been teaching middle school science and biology for 20 years. Currently working as a Supervisor instructional developer at the institute of applied technology in the United Arab Emirates.