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A Comparative Study of Chemistry for Sustainability Education in the Secondary School Curriculum in Selected Countries

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ABSTRACT

The purpose of this research is to compare the curriculum of chemistry education for sustainability in higher secondary schools of USA, Finland, Hong Kong, Nigeria, and Iran. This is a qualitative, experimental, applied, and comparative research in terms of nature, variable, purpose, and method respectively. By using the four-step approach of Bereday, the similarities and differences of the main curriculum components of chemistry education for sustainability such as logic, objectives, content, teaching-learning methods, and evaluation methods were determined in the selected countries. Also, the strategy of country selection was "different social systems, different educational outputs" using purposeful sampling technique. The findings reveal that the similarities among countries are mostly related to the logic, and objectives of chemistry education for sustainability and the differences are mainly related to the content and teaching-learning methods. The common similarity of the five countries in the dimensions of educational logic, and objectives is to determine, and explain the relationship of chemistry to moral and social issues and to prevent air and water pollution. The main difference among these countries is the freedom of teachers in choosing the content, and teaching method, which is much greater in Finland than in other countries. According to the findings, the attention of Iran's curriculum and educational planners should be directed to designing curricula related to chemistry education for sustainable development based on the needs of society, industry, environmental protection and coordinated with today's technologies.

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1. Introduction

Some of the main challenges of life in the current century that many countries - including Iran - are facing are completely related to chemistry, such as the supply of safe drinking water, the production and optimal consumption of energy, etc. Therefore, we need new ideas about Education for Sustainable Development (ESD) and the role of chemistry in its creation. In fact, to solve many global challenges - social, scientific and economic - citizens of the future will need to have a relatively good knowledge of chemistry. Therefore, "Chemistry Education" has become one of the important goals of modern educational systems. Educational and curriculum planners try to increase the knowledge of children, teenagers and young people about chemistry through formal and non-formal programs and especially the content of school textbooks.

The review, and analysis of the content of Iran chemistry school textbooks show that the scientific goals of chemistry education are emphasized more than the attitudinal and skill Objectives (Badrian, Honarparvar, & Naseri Azar, 2010). To face future challenges and solve recent problems, UNESCO introduced sustainable development as the most effective way of life (UNESCO, 2014). In this regard, one of the most complete definitions of sustainable development was provided by the Brantland Commission: "Sustainable development means meeting the needs of the present generation without compromising the ability of future generations" (Eilks & Hofstein, (2014; Garner, Siol, & Eilks, 2015). The adoption of the Education for Sustainable Development guidelines in 2015 by UNESCO, which includes 17 major Objectives, refers to a combination of the Sustainable Development Goals, and the Millennium Development Goals (UNESCO, 2017).

First of all, understanding the term sustainable development is an important starting point for understanding the concept of education for sustainable development. As a result, in most countries of the world, Education for Sustainable Development (ESD) has become a main goal for educational systems (Juntunen, 2015). Education for Sustainable Development represents a catalytic process for social change that strives to cultivate public awareness, values and lifestyles needed for a sustainable future in students through education. ESD includes teaching skills and how to make decisions in the long-term future (United Nations, 2010). It is also important to pay attention to the fact that since the introduction of the concept of sustainable development, the concept of sustainability has been used as its equivalent. But, the difference between the meaning of the term sustainable development and sustainability is this: those who prioritize economic development often use the term sustainable development and those who prioritize human development use the term sustainability. Also, the concept of sustainability often refers to a long-term goal that through the education of citizens, the new generation is prepared for long-term learning (Schreiber, & Hannes, 2016).

One of the most important and practical sciences is chemistry, which has played a fundamental role in the development of human civilization and its place in economy, politics, and life has become more prominent day by day. During its advanced process, although chemistry has always benefited the society, it has also caused significant damage to human health, and the environment (Kirchhoff, 2005). In order to achieve sustainability, UNESCO introduced chemistry as a main goal (Vilches, & Gil-Perez, 2013). Teaching chemistry for sustainability helps students gain a deeper understanding of the relationship between science, society, and the environment (Hill, Kumar, & Verma, 2013). Bedgood (2008) first raised the question: "Why we are still teaching chemistry in the traditional way like in the 1980s”. Science programs for large numbers of students from different cultures, while we need new teaching methods. Read (2015) acknowledges that "in order to achieve maximum efficiency in science education, we must be able to match education with the issues and conditions of the daily life". It is clear that teaching chemistry for sustainability is a science that can be related to economic, sociology, culture, health, food, and agricultural issues, while there is no such relationship in traditional education of chemistry (Hill, Kumar, & Verma, 2013). In fact, Chemistry Education for Sustainability (CES) seeks to create a balance between social, cultural, and economic aspects of life with the science of chemistry with an emphasis on sustainable development (Eilks, Sjöström, & Hofstein, 2014). Thus, CES is one of the most innovative topics in the field of curriculum that covers a wide range of topics that the educational system of any country can face according to its challenges (Wang, Ya Li, & Liang, 2018). Studies show that the key goals of sustainable development are rarely present in chemistry curricula, meaning that education for sustainable development in the public education system still lacks deep roots (Kanapathy, et al, 2018).

After the establishment of sustainable development goals by the United Nations in 2015, Iran, as one of the members, committed to cooperate with these goals but its educational system has not made a significant move to design curricula based on ESD. Teachers have not been trained and it seems that Iran's educational system lags behind other countries and does not pursue ESD like the enthusiasm of other countries. In most of the researches that have been conducted in the field of curriculum studies, the four basic elements of goal, content, teaching and evaluation methods have been considered(Rezaei, 2016)..This research aims to study five elements of CES curriculum (logic, objectives, content, teaching-learning, and evaluation methods) among selected countries.

Therefore, the comparative study of CES in secondary school curriculum is the most important goal of present research. Based on this, the sub-goals of the research are:

- Description and identification of the current status of CES in selected countries
- Identifying and comparing the similarities of selected countries in CES
- Identifying and comparing the differences of selected countries in CES

2. Research Background

Zuin and Eilks (2021) in an article entitled "Education of Green Chemistry and Sustainable Chemistry: Perspectives of Sustainability" pointed out the need of the education system for widespread implementation of CES in curricula and the integration of three environmental issues, Green energy and chemistry are emphasized in the content of chemistry curricula of different educational levels (from high school to university). Mahaffy, Matlin, Whalen, & Holme (2019) in a research entitled "Incorporation of sustainable molecular foundations in chemistry through systematic thought" investigated chemical reactions with the help of the concept of sustainability. He suggested chemistry teachers the use of "systematic thought" to teach concept of sustainability to pupils. Miller (2018) in the article "Sustainable education and the use of problem-based learning" presented a conceptual framework for implementation in the UK curriculum and pointed out the need for more research in the future to use the principles of sustainability in education. De Goes, Chen, Nogueira, Fernandez, & Eilks (2018) investigated the teaching of sustainable development in Brazilian chemistry textbooks. Their findings revealed that this concept has not been sufficiently taught in chemistry school textbooks. In an article entitled "Reimagining Chemistry Education", Mahaffy, Brush, Haack, & Holl (2018) reviewed the articles of famous chemistry education journals and challenged the lack of teaching thinking skills through sustainable chemistry education in school textbooks. Ming Ho, Kamaruddin, & Ismail (2016) investigated the factors affecting the integration of sustainable education in the curriculum of Malaysian schools. They identified that there are many gaps for ESD in the current Malaysian curriculum. Juntunen (2015) in her PhD disertation "Pedagogy-based overview for sustainable development in chemistry" describes the teaching of chemistry for sustainability by 20 chemistry teachers in 9 classes of Finnish schools. The findings show an increase in students' learning. Burmeister, Schmidt, & Eilks, (2013) in the research "Perception of sustainability and education for sustainable development among German student teachers of chemistry" reveal that the knowledge of teachers in the field of ESD is limited. In his doctoral thesis, Rasmussen (2011) also examines the implementation of the comprehensive plan for ESD at the University of California. In his PhD dissertation, Eroll (2011) examines a fossil fuel energy alternative program in Arizona high school curriculum. Rezaei (2016) in her doctoral dissertation entitled “Designing and validating a suitable curriculum model for "Education for Sustainable Development" in the elementary school of Iran” concluded that the current state of curriculum is not very suitable in terms of the amount of attention paid to this concept. Egdami (2016) examines the components of ESD in the experimental science textbooks of Grade 1 of high school in Iran. The findings indicated that some components of ESD such as gender education and equality - have received little attention but more attention has been paid to the components of the environmental dimension.

3. Research Method

The purpose of this research is to compare the curriculum of chemistry education for sustainability in higher secondary schools of USA, Finland, Hong Kong, Nigeria and Iran. This is a qualitative, experimental, applied and comparative research in terms of nature, variable, objectives, and method respectively. By using the four-step approach of Bereday, the similarities and differences of the main curriculum components of chemistry education for sustainability such as logic, objectives, content, teaching-learning methods and evaluation methods were determined in the selected countries (Madandar Arani & Kakia, 2015). Also, the strategy of country selection was "different social systems, different educational outputs" using purposeful sampling technique. To collect data, journal articles, documents and reports of UNESCO and international organizations, as well as all chemistry school textbooks of upper secondary schools of Iran and selected countries were reviewed.

4. Findings

This section contains the findings related to the objectives, content, teaching /learning methods and evaluation method in the chemistry curriculum for sustainability of selected countries, which is presented according to the four stages of Bereday's approach.

A) Description

Finland

According to the Finnish constitution, every person is responsible for preserving the environment and cultural heritage. Finland is one of the richest countries in the world. After the Second World War, high consumption had become part of the Finnish lifestyle (Ojala, Eloranta &

Jalava, 2006). In 1998, the Finnish State Council officially announced its decision to raise the level of sustainability. According to this council, if we want a greener planet for the future, we need to change our education system. The educational system should be designed in such a way that ESD - with special emphasis on inquiry-based lifelong learning, student-centeredness, community collaboration, use of modern technology, and information sharing - should be at the forefront of curricula. Since chemistry plays an important role in creating a sustainable future and solving global problems, curriculum logic, national and international educational strategies, and chemical industries should be based on sustainable development (Tani, et al 2007; Tilbury & Cooke, 2005). In Finland, ESD supports students' interest and active role in learning chemistry (Lester, Okhee & Lambert, 2006; Vilches, & Gil-Perez, 2013). Based on this, chemistry education is not only considered as a subject, and the philosophical and sociological perspectives of teaching this science are also considered. Finland's national program obliges school management to teach ESD, and to acquaint learners with extensive knowledge of chemistry (The Finnish National Board of Education, 2015). The integration of the concept of sustainable development in academic courses and the application of chemistry education is considered an important step for the development of the country, and therefore schools should align themselves with chemistry education programs for sustainability (Juntunen, 2015).

Table 1. The main curriculum components of chemistry education for sustainability in Finland

Elements	Descriptive
Logic	Acting to the Finnish Constitution - Adopting the Sustainable Development Plan on the Federal Government- Sustainable Development as a Reason for the Finnish National Program Reform - Chemistry Related to Many Ethical and Social Issues - Growth of the Chemical Industry - Environmental Degradation - Promoting health - Exorbitant costs - Technology innovations - Development of scientific literacy - Development of lifelong learning skills - Abandonment of traditional methods of education and improving education - Understanding the relationship between science, technology, society, and the environment.
Objectives	Making informed decisions about social issues - Applied knowledge of chemistry in everyday life, industry, and medicine - Relationship between chemistry with society and ethics - Increasing safety and health in the laboratory- Development of sustainable chemical processes - Important role of chemistry in development, and energy resources - Chemical research in technology and economic development - Understanding how chemicals affect the environment - Increasing students' skills in using technology, and computers -Providing Equal educational opportunities - Developing professional skills.
Content	Principles of green chemistry as part of the work of the science laboratory - Adding sustainability strategies in chemistry - Chemistry in society - Using controversial social topics - Chemical models and theories - Relationship between chemistry and other sciences - Chemistry research - Chemistry as a Technology.
Teaching-	Student-centered approach - Teaching scientific knowledge in a social context -

Elements	Descriptive
learning	Students interacting in groups with each other - Exploration - Arguing social issues - Encouraging students to discuss with each other, and justify their claims - Projects - Teaching thinking skills -Collaborative learning - Holding video conferences - teacher freedom in how to teach ,and select content.
Evaluation	Emphasis on self-Evaluation in the curriculum - Final test in the solved education process - Laboratory activities - Article writing - Social activities - Class projects - Ability to discuss, and work in a group.

Hong Kong (China)

Throughout its history, China has played a significant role in innovations related to chemical science. Although this science has helped improve the lives of hundreds of millions of Chinese, but like many developing countries, the government's attention and focus to increase industrial growth has caused significant damage on environment. In the report of the 17th National Congress of China, the issue of sustainable development through chemistry was brought to the attention of politicians for the first time. Integrating sustainable development into China's development plans was one of the most innovative and challenging tasks in developing the chemistry curriculum. “Hope Project " was very important for China in the late 1970s. This project emphasized on reforming the education system and that chemistry education should be placed in the context of sustainable development. Also, the goal of this project was to provide opportunities for development of scientific literacy and create basic scientific skills for lifelong learning in science and technology (Wang, Ya Li, & Nian, 2018). In Table 3, the chemistry curriculum for sustainable development in Hong Kong (an autonomous region of the Republic of China) is presented.

Table 2. The main curriculum components of chemistry education for sustainability in Hong Kong

Elements	Descriptive
Logic	Curriculum reform towards sustainability, Project Hope, and report of the 17th National Congress - Growth of chemical industry - Environmental degradation - Exorbitant costs - Meeting economic challenges - Technology innovations - Replacing traditional methods with new methods - Development of scientific literacy - Development of lifelong learning skills - Active participation of students in society.
Objectives	Increasing safety and health in laboratories - Appreciating positive values and attitudes - Respecting Chinese culture and pluralism in society - Appreciating the knowledge of chemistry in the production of important technologies in industry, and society - Understanding the relationship between chemistry and other disciplines - Ability of scientific, critical, and creative thinking in solving problems related to chemistry - Assessing social consequences, Ethical, economic, environmental with chemistry- Understanding the role of green chemistry to manage and control the impact of industrial processes on the environment - Understanding the importance of recycling processes and limitations of natural resources.
Content	Earth - Microscopic world - Metals – Acids and bases - Fossil fuels - Cell redox

	reaction - Chemical reactions and energy - Reaction rate - Organic chemistry - Patterns in the world Chemistry - Industrial chemistry - Materials chemistry, and decomposition chemistry.
Teaching-learning	Video shows- IT and multimedia packages- Problem solving- Group discussion- Debates- Project work.
Evaluation	Written tests-oral questions - individual Evaluations - project evaluation / portfolio - Research report.

Iran

The structure of the educational system in the Islamic Republic of Iran is determined based on the approvals of the responsible authorities and upstream documents. According to one of the upstream documents, namely "National Curriculum", there is an expectation that schools can raise a capable generation through the teaching of school materials, content and subjects. The characteristics of this generation should be as below:

- Discovering, understanding and interpreting natural phenomena and events as divine revelations;
- Preservation of natural resources as a divine trust and honoring and enriching them;
- Acquiring useful scientific teachings for personal and social life in order to have a healthy and cheerful life;
- Responsibility, philanthropy, collectivism and global thought.

Table 3. The main curriculum components of chemistry education for sustainability in Iran

Elements	Descriptive
Logic	Environmental pollution - depletion of natural resources -shifting education from content-oriented to skills-oriented.
Objectives	Attention to the relationship between technology, science, environment, and society - economic prosperity - awareness of the adverse effects of some chemicals on humans and environment - observing safety tips.
Content	radiopharmaceuticals- Gases - Properties of metal oxides - Greenhouse effect - Green chemistry - Ammonia production - Water - Earth gifts - Oil - Hydrocarbons - Healthy food - Molecules in the service of health - Comfort and well-being in the shadow of chemistry - Chemistry manifestation in art.
Teaching-learning	Direct instruction- Inquiry-Problem solving-Practical work.
Evaluation	Centralized and national Evaluation - group activities - observation -checklist - written exams.

(Ministry of Education, 2019)

Nigeria

In Nigeria, science education as an educational priority to achieve sustainable development and improve the economic situation, environment and society is considered by educational policy makers. At present, climate change is one of the most important challenges of the Africa. In recent years, the destruction of the ecosystem - increased due to destructive human activities- has caused many concerns among African leaders; for example, incidents such as the discovery of 3888 tons of radioactive waste in Koko port, Nigeria. These events led to increased attention to science curricula for teaching sustainable development in schools, although the state of science education in schools is still not very favorable. The content, and topics of chemistry are not noticeable in school textbooks, and students often cannot make connections between chemistry and the issues of their living environment (Mwendwa, 2017). Therefore, there is hope that students will find sufficient motivation to learn through familiarity with chemistry education for sustainability (Alake, 2013). Of course, the success of any training depends a lot on the budget and financial resources. Inadequate budget in this country is one of the factors influencing the lack of quality of education (Jimoh, 2005).

Table 4. The main curriculum components of chemistry education for sustainability in Nigeria

Elements	Descriptive
Logic	Concern of the African leaders about climate change and increasing ecosystem degradation - Improving the quality of education - Lack of skilled labor - Development of science and technology - Cultivating responsible citizens for others- Improving the economic, environmental, and social situation.
Objectives	Understanding the limitations of natural resources - Developing ethical, social, and legal issues with chemistry - Preventing air, and water pollution - Understanding different values and perspectives - Using new technologies in chemistry - Identifying Cost-effective products and safe processes - reduce the consumption of materials, energy, and waste when producing products needed by humans without harming the environment.
Content	Chemistry and Industry - World of Chemistry - Chemistry and Environment - Chemistry of Life - Sustainable Experiments.
Teaching-learning	Lecture - Direct discussion - Using guest speakers - Group conversations - Problem-solving.
Evaluation	Centralized and national Evaluation - group activities - observation checklist - student work samples - written exams.

(Alake, 2013; Nigerian educational research and development council (NERDC), 2020; Moyinoluwa, 2013; Kimiti, 2013)

United States of America

The people of the United States of America consume more material resources compare to most countries in the world, and as a result put more waste into the environment. Therefore, the promotion of ESD is considered a vital issue for the progress and future health of this country. Also, the education system on a global scale does not pursue sustainable education with the same speed and enthusiasm of other countries. So; ESD in USA schools should be considered as a new educational paradigm. Although the USA education system is largely decentralized, each state is required to include the same headings or standards in their school textbooks approved by the Department of Education. In addition, in USA, national councils such as the National Council for Science & Mathematics- prepare headings or standards for different school subjects, which are made available to everyone after the approval of the Ministry of Education. Nowadays, many researches, academic and planning centers are working and studying in the field of chemistry curricula. It can be said that this country more than most countries is heavily involved in research, discovery and use of new technologies in chemistry (Watson, 2017). In terms of attention to chemistry education, USA is a pioneer compared to other countries. In this research, among the different USA states, only the chemistry curriculum in upper secondary schools of Washington State has been studied.

Table 5. The main curriculum components of chemistry education for sustainability in USA

Elements	Descriptive
Logic	Slowness and enthusiasm in sustainability education - The most consumed country - solving problems for humans, and the environment.
Objectives	Understanding the relationship between chemistry and other sciences - role of chemists in society - Understanding the dependence of chemistry on society - Development of scientific literacy - Application of new technologies Increasing safety in schools - A sense of responsibility towards the environment - Reducing consumption and waste - Using renewable resources.
Content	Climate Change - Green Chemistry - Life Cycle and Sustainable Development - Catalysts - Chemical Industry - Biopolymers - Cosmetics - Fuels - Green Fuels-Nuclear Chemistry – Nano chemistry - Biochemistry - Biotechnology - Energy-Electrochemistry - Medicinal chemistry.
Teaching-learning	Improving thinking skills in students - Performing social and environmental services - Exploration - Collaborative learning - Inquiry-based activities - Film screenings - Writing articles - Workshops - Presence of chemists in schools - Training using laboratory equipment.
Assessment	Attention to three areas: cognitive, emotional, and skill-based on national standards of laboratory activity - intangible observation - oral questions - written tests - self-assessment - project evaluation/portfolio - Research report.

(Erdogan, &Stuessy, 2015; Watson, 2017; Washington School Chemistry Curriculum Guide, 2016)

B) Interpretation

The summary of the results of the interpretation section is as follows:

- The research results show that chemistry education for sustainability in the United States of America is included in most of the chemistry topics of school textbooks accordance with the intellectual development of students. Chemistry education for sustainability is conducted through regular classrooms and laboratories simultaneously (Watson, 2017, Holm, 2019).

- Although efforts to improve the quality of education, economic problems, and lack of skilled professionals are important factors that have helped to promote the concepts of ESD and chemistry for sustainable development in Nigeria, but due to lack of funding, science teachers often fail to provide many opportunities to teach these concepts to pupils, and traditional teaching/learning and assessment methods are still prevalent (Kimiti, 2013. Read, 2015).
- Chemistry education for sustainability is considered as a national action in the Hong Kong education system due to the emergence of a competitive economy, scientific and technological innovations, and responds to new challenges. The main approach to providing content in chemistry education for sustainability is interdisciplinary approach (Wang, Ya Li., & Nian, 2018).
- In the Finnish curriculum, there are no speceific guidelines for teaching chemistry education for sustainability, and teachers use a variety of approaches. The purpose of evaluating students in chemistry education for sustainability is to institutionalize scientific thought in their personality (Juntunen, 2015).
- In the two dimensions of the logic and Objectives of the Iran's chemistry curriculum, chemistry education for sustainability is not directly mentioned, but the approach of the educational system in providing content related to this subject in chemistry books is based on "bio-technological approach" and context-oriented.

C) Juxtaposition

According to Tables 6,7,8,9 and 10 the similarities and differences of the main curriculum components of chemistry education for sustainability are as below:

Table 6. The main similarities and differences in the logic of chemistry education curriculum for sustainability

Logic	USA	Nigeria	Hong Kong	Finland	Iran
Climate change-Environmental degradation-Developing science and technology-Educating responsible citizens-Improving the economic, environmental, and social situation-Relating chemistry to ethical, and social issues-Exhaustion of natural resources and need for economy, Consumption-nurturing values in the next generation-solving life problems with chemistry-growth of chemical industries.	*	*	*	*	*

Acting to the UNESCO Declaration	*	*	*	*	=
National and governmental action	*	*	*	*	=
Training skills development	=	*	*	=	*
Lack of skilled specialists	=	*	=	=	*
Consumable country	*	=	=	*	=
Reports of the Environmental Protection Agency about schools	*	=	=	=	=
Students' reluctance to chemistry	*	*	=	=	=
Slow movement, and enthusiasm in sustainability education on a global scale	*	=	=	=	=
Raise teachers' understanding of ethics education in chemistry.	=	=	=	*	=

Table 7. The main similarities and differences in the objectives of the chemistry education curriculum for sustainability

objectives	USA	Nigeria	Hong Kong	Finland	Iran
Understanding the limitations of natural resources - Preventing air and water pollution - Using chemical knowledge to make decisions - Assessing social, moral, economic, and environmental consequences of chemistry - Understanding the danger of chemicals for the planet - Appreciation From the science of chemistry and its applications - Respect for the role of chemists - Use of renewable resources - Concern for the environment - Attention to safety tips in chemical activities.	*	*	*	*	*
Correcting public misconceptions about chemistry.	*	=	=	=	=
Understand the role and generate new ideas in chemistry.	*	=	=	=	=
Simplify abstract science for students.	*	=	=	=	=
Communication skills for the 21st century.	=	=	=	*	=
Increase cooperation between government, education, and other stakeholders toward a sustainable approach	=	=	=	*	=
Respect for Chinese culture and pluralism in society.	=	=	*	=	=
Understanding the role of chemistry in sustainable agriculture and forestry	=	*	=	=	*
Knowing God, and a holistic view.	=	=	=	=	*

Table 8. The main similarities and differences in the content of the chemistry education curriculum for sustainability

content	USA	Nigeria	Hong Kong	Finland	Iran
Agriculture and chemistry - Greenhouse gases - Acid rain - Future global warming - Production of biodegradable plastics - Application of polymers - Healthy food - Green fuels - Esters - Polymers, durable or degradable - Detergents - Industrial wastewater entering the environment - Comparison of fossil fuels and biofuels - Comfort and well-being in the shadow of chemistry - The role of electrochemistry in clean energy supply - Use of metals - Misuse of knowledge and technology - Ammonia and agriculture - Green chemistry - Negative aspect of water chemical pollution, and its effects on humans, plants and animals.	*	*	*	*	*
Simulating the principles of green chemistry with everyday life.	*	=	*	*	=
Development of culture.	=	=	*	=	*
Evaluation of toxic substances in cosmetics - New chemical technologies in the production of cosmetics - Detection and analysis of drugs.	*	=	=	=	=
Freshwater supply in Hong Kong, not importing water - Steel industry - Production of fullerenes in electronic devices, and Pharmacy - Computer modeling to study the industrial process and control the production of a chemical plant.	=	=	*	=	=
Micro chemical-Entrepreneurship-Product Life Cycle.	=	=	=	*	=
Petrochemical industry, and the Persian Gulf.	=	=	=	=	*

Table 9. The main similarities and differences in the teaching-learning methods of the chemistry education curriculum for sustainability

teaching-learning methods	USA	Nigeria	Hong Kong	Finland	Iran
Lectures - Dramatic - Internet research – Problem solving – Questions, and answers - Class conversations and critical thinking.	*	*	*	*	*
Exploration - Discussion of the consequences of chemistry on the environment, society and ethics of science and technology - Laboratory activities - Software - Green research.	*	=	*	*	=
Film screening - Self-directed training - Doing group projects - System thinking skills - Website - Magazines.	*	=	=	*	=
Presence of chemists in schools.	*	=	=	=	=
E-learning and smart boards are the basis of teachers' work - much teacher freedom of action.	=	=	=	*	=

Table 10. The main similarities and differences in the evaluating methods of the chemistry education curriculum for sustainability

evaluation	USA	Nigeria	Hong Kong	Finland	Iran
Activity report-Observation of practical works written and test exams.	*	*	*	*	*
Results of laboratory activities - Article writing - Social activities - Class projects - Ability to discuss and work in groups - Research reports - Detailed observations in the use of devices and software.	*	=	*	*	=
Evaluation standards.	*	=	=	=	=
Emphasis on self-assessment- Lack of standardized tests-Very teacher's freedom of action.	=	=	=	*	=
Emphasis on the final test.	=	*	=	=	*

D) Comparison

Data have been studied and compared with each other and comparative analysis indicated below similarities and differences among selected countries:

- Teaching chemistry for sustainability in most countries - except Iran- is a national mission.
- Since in USA and Finland, universities play a leading role in the development of the new educational system, in the design of programs and textbooks, university researchers cooperate with the designers of the Ministry of Education.

- In the past and in the “goal” dimension of chemistry education, all countries’ educational system paid little attention to teaching concept of values, while chemistry education for sustainable development seeks to show the role, and importance of values.
- All the selected countries are aware of the importance of chemistry for sustainable development in life and environment, and for this reason, they have expanded and developed this subject in the school curriculum. Some countries such as Finland and USA are ahead of other countries in this field.
- Countries with a history of civilization and culture, such as Iran, and Hong Kong (China), emphasize the development of local culture through chemistry education for sustainable development in their educational objectives.
- By examining the educational objectives of chemistry for sustainable development, it is possible to understand the geographical, political, religious, economic position of the countries.
- The basic point of view in choosing the content of chemistry education for sustainability is a dynamic and constructive approach. The organization of content in all countries except Iran, and Nigeria is done in an integrated and interdisciplinary manner. In USA, the main approach of chemistry education for sustainability is laboratory-oriented, and in countries such as Finland, and Hong Kong (China), attention is paid to social functions.
- In USA, chemistry education is integrated in all chemistry subjects for sustainability without changing the structure of the main subjects in chemistry. In Hong Kong, this integration is mandatory and optional. In Iran, the structure of the main subjects in chemistry has been changed, and this consolidation has been done in a compulsory manner. In addition, integration has been done in secret in all countries, and openly in Iran.
- Teaching approach in chemistry education for sustainability is an active teaching approach that is based on qualitative judgment. Teaching is not isomorphic. The educational system of the countries completely controls the teaching methods, while in Finland, teachers have much more freedom in choosing the content and teaching method, and therefore only the teaching of formal knowledge is not original.
- In all countries, evaluation is carried out based on predetermined goals. Also, the evaluation method is different based on the educational system, teacher's role, teaching method, content, and educational goals in each country. In all chemistry curricula for the sustainability, attention is paid to all three areas of evaluation (cognitive, emotional and skill domain); although the share of these three domains of evaluation is different. It can be

concluded that in the USA curriculum, the evaluation of the skill domain dominates the other two areas.

- In most countries, qualitative and dynamic evaluation is used, which is intertwined with the teaching/learning process, while in Iran's educational system, evaluation is done descriptively.

Table 11. The amount of common and different dimensions of chemistry curriculum for sustainability in Iran with other studied countries

Curriculum elements	Similarities	Differences
Logic	10	9
Objectives	11	8
Content	20	13
Teaching-learning methods	7	19
Evaluation methods	5	13

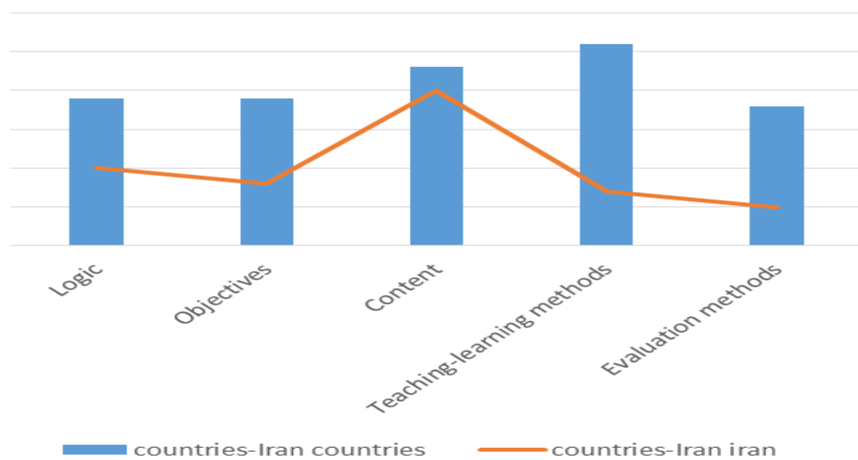

Figure 1. Amount of common and different dimensions of chemistry curriculum for sustainability in Iran with other studied countries

- As shown in Figure 1, the highest amount of common features of chemistry curriculum for sustainability in Iran with other selected countries is in the dimension of Objectives and the least in the dimension of content.
- The main logic of countries to provide chemistry education for sustainability is based on UNESCO goals (2030). Explicit logical reasoning as in other countries - is not seen in the Iran chemistry curriculum.
- The content of chemistry education curricula for sustainability in most of the studied countries is very diverse, while Iran's educational system lacks this breadth of content (UNESCO, 2017).

5. Conclusion

The aim of this research was to investigate the five elements of the chemistry education curriculum for sustainability (logic, objectives, content, teaching-learning, and evaluation methods) in order to improve, and promote chemistry education in Iran's educational system. The present researchers believe that according to the growth and development of science, and technology in the world, and its undeniable role in sustainable development none of the subjects have undergone as much evolution as chemistry. Based on this idea, in all the studied countries, chemistry education has become one of the most important infrastructure activities in sustainable development. Therefore, the curriculum planners try to make all students familiar with the concepts of chemistry and scientific literacy to gain the necessary knowledge as a desirable citizen. It is obvious that the structure of educational and political systems of countries has a direct impact on the role of chemistry education for sustainable development.

The comparison of curriculum components indicated that the main logic of chemistry education for sustainability in most countries is a global action to improve and promote a sustainable future. Every country has prioritized the expectations, and Objectives of chemistry education for sustainability according to the basic laws, facilities, national needs, and cultural and expectations of their society. In fact, the goal of curriculum planners in chemistry education for sustainability is to establish a balance between knowledge, skill, and attitudinal objectives, although in Nigeria and Iran the emphasis on the role of "skill objectives" is weak. Teaching approaches in chemistry education for sustainability do not follow any set guidelines.

In USA and Finland, the teacher acts as an artist, and researcher, with the difference that in Finland, teachers have much more freedom in choosing content, and teaching than American teachers, and textbooks are not the focus. Iran's educational system is mainly based on theoretical principles, and students may be familiar with theories, but this does not lead to solving practical problems. Also, the content of chemistry education courses for sustainability in Iran's curriculum has similarities with other countries, while the weakness of inefficient teaching-learning methods still remains. Based on these findings, it is suggested that the relationship between sciences should be taken into consideration in the design, and compilation of science curricula. Sciences are related to each other, and it is not possible to consider teaching chemistry for sustainability without other sciences. Subjects such as biology, chemistry, geology, and physics provide many opportunities to connect knowledge with the dimensions of environment, economy, society, and politics. The most appropriate way to provide education for sustainable development is to create a common relationship between science disciplines. Also, this method gives learners the opportunity to develop practical skills related to scientific research. Since such a model has not been followed in Iran's educational system, it is recommended to educational planners:

- Consolidation and integration of chemistry education for sustainability's content in the main parts of chemistry books
- Designing indoor and outdoor activities related to chemistry education for sustainability for students
- Holding training courses in person, video conference, offline, and virtual formats
- Setting up an educational site and electronic software to teach about education for sustainable development, preferably by experts.

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