Teaching the Experiments of the International Space Station by using the POE Strategy to Develop Secondary School Students' Attitudes towards Space Exploration and Their Scientific Explanations

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Abstract

The International Space Station (ISS) is the largest international scientific project in history. It serves as a microgravity and space environment research laboratory. The purpose of the present study is to examine the effectiveness of teaching the experiments of the ISS by using the Predict-Observe-Explain (POE) strategy to develop secondary school students' attitudes towards space exploration and their scientific explanations. A quasi-experimental pre-test/post-test experimental/control group design was utilized. The experimental group consisted of 38 grade 11 students, and the control group consisted of 37 students. A Likert-5 scale was created to measure attitudes towards space exploration. An open-ended scientific explanation instrument was prepared to measure students’ ability to construct scientific explanations. A unit and a teacher’s guide were prepared to help in teaching the ISS experiments by using the POE strategy. The data collection instruments were used as pre-tests before the implementation and as post-tests at the end of the implementation. Results indicated that using the POE strategy to teach the ISS experiments has a positive effect on learners’ attitudes towards space exploration and their scientific explanations.

Keywords: International Space Station (ISS), Predict-Observe-Explain (POE), attitudes towards space exploration, scientific explanations.

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Introduction

The International Space Station (ISS) is a unique space laboratory with a permanent crew of six scientists. It is used for research in such fields as life science, biology, biotechnology, natural science, materials technology, and space science. The microgravity environment on the ISS provides unique laboratory conditions that cannot be reproduced on Earth. From December 1998 to March 2013, more than 1500 scientific investigations, technology demonstrations, and educational activities have been conducted on the ISS. Over 1600 investigators from 69 countries have participated in research and educational activities. The ISS research has contributed to applications on Earth, expanded our knowledge, and helped prepare humankind for the next step in exploration. It has benefitted humankind in the areas of human health, Earth observation and disaster responses, and global education (Mayorova, Samburov, Zhdanovich, & Strashinsky, 2014; Thumm et al., 2014).

Educational content has been an established component of ISS activities since the planning stages of the ISS. Today, it is used as a modern educational aid in the system of aerospace education of high-school and university students, post-graduates, and young experts (Mayorova, et al., 2014). More than 43 million students, from kindergarten to graduate school, with more than 28 million teachers located in 49 countries have participated in some aspect of ISS educational activities. These activities include student-developed investigations, educational competitions, participation in ISS investigator experiments, ISS hardware development, educational demonstrations, and cultural activities. Through the various inquiry-based educational activities, students and teachers are encouraged to participate in the ISS program thus motivating the next generation of students to pursue careers in science, technology, engineering and mathematics (STEM) (Alleyne et al., 2012).

Getting students involved in today’s ISS activities is important not only for the space industry in terms of providing a talented work force for the future, but also for the public in general who are the voters and potential political supporters of space exploration. Wysession et al. (2012) claim that students who do not receive a commensurate education in the Earth and space sciences are less prepared for the challenges and opportunities that await them in adult life, whether in competing in the global job market or making informed personal and voting decisions on such vital issues as resource use, climate change, natural hazards, space exploration and Earth stewardship.

The National Aeronautics and Space Administration (NASA) Office of Space Science (OSS) has recognized the unique inspirational assets of the space science community to powerfully and positively impact the nation’s present and future K-14 science education and public outreach (E/PO) needs. The mission ‘‘To Inspire the Next Generation of Explorers’’ encompasses all of NASA's education activities to (1) inspire and motivate students to pursue careers in science, technology, engineering, and mathematics and (2) engage the public in shaping and sharing the experience of exploration and discovery. The OSS E/PO program is well aligned with these new Agency goals and is expected to make major contributions toward achieving them (Rosendhal, Sakimoto, Pertzborn, & Cooper, 2004).

In Egypt, the space science research has started since 1910 by measuring the solar constant as an indication of solar radiation at Helwan Observatory. In 1957, the solar sunspot studies and its influence on the Nile flooding was erected and operated in Helwan as the first solar station in Egypt. Space exploration had a boost around 1994, with the establishment of Egypt's National Authority for Remote Sensing and Space Sciences. A remote sensing satellite (EgyptSat1) program started in cooperation with Ukraine and was launched on the 17th of April, 2007 (Kassem & Ibrahim, 2013). Now, Egypt is investing in infrastructure and activities to advance its space exploration aspirations. Its efforts include: global monitoring of the environment, satellite data collection, radio telescope, astronomy education, space exploration policy development, and a variety of celebratory space exploration education (MacLeish, Akinyede, Goswami, & Thomson, 2012).

Space science education started in Egypt at the university level since 1936 at the Department of Astronomy and Meteorology at Cairo University. Now, the University degrees are given as follows: B.Sc. in Astronomy and Physics, B.Sc. in Astronomy and B.Sc. in Space Science. Master’s degree is awarded after at least two years of study in astronomy and space science. The Ph.D.-studies continue in Egyptian universities according to the international level (Hady, 2008). Different space courses (graduate and undergraduates) are offered in Egypt, such as: Attitude Dynamics and Control, Mission Analysis, Orbital Dynamics, Space Structures, Space Propulsion, etc. Different graduation projects are also executed such as: Moon-Sun Sensor, Gas Propulsion Thrusters, Solar Cells Cruse Sun-sensor, Mission Analysis Software, Orbital Propagator, etc. (Kassem & Ibrahim, 2013).

In secondary school, there is a lack of space education and a little effort has been made to develop a baseline for understanding space exploration. Space science is not necessarily a required part of the curriculum in secondary school and there is no specific curriculum for space science. The students may learn about space science in a few topics in physics at the 10th grade. Many secondary school science teachers do not have the background in space science and astrophysics needed to engage their students in learning about the space concepts. This lack of proper communication in the way space activities are presented to the students has been reflected on students' attitudes towards space exploration. Some researches (e.g. Fouda & Hussain, 2009; Mohamed, 2010) found that students have negative attitudes towards space exploration.

Moreover, the current practice of many experienced teachers tends to focus on students accumulating and repeating descriptive information about natural phenomena and engaging students in observational exercises or rudimentary experiments without pressing students toward scientific explanations (Osborne & Dillon, 2008). This practice has been reflected on the students' ability to explain scientific phenomena. Several researchers (e.g. Gotwals, 2006; Sandoval & Millwood, 2005; Wenk, Butler, & Bullard, 2012) found that students often have difficulty articulating and defending their claims and they do not fully understand what counts as evidence, or how to incorporate appropriate and sufficient evidence into their explanations. They also have difficulty regarding the reasoning component of scientific explanations in particular.

The previous challenges encourage science educators and researchers in Egypt to exert more efforts to overcome these problems by applying new strategies in teaching science such as the Predict–Observe–Explain (POE). It is one of the strategies corresponding to the theory of constructivism. This strategy is consistent with the fact that learners' participation throughout a lesson is characterized by predicting, observing and explaining the learning processes (Kala, Yaman, & Ayas, 2013; Kibirige, Osodo, & Tlala, 2014). The POE was adopted in this study because it enables learners to hypothesize, test their hypotheses and explain observations. It is also important since it demonstrates learners’ prior knowledge and thought processes.

The current study has two sides that work together: one is to develop attitudes towards space exploration among the students, help them understand space activities, and get them to support space activities; and the other is to train students who will later work in and for space activities of all kinds on different science processes such as scientific explanation. Therefore, the main purpose of this study is to explore the effect of using the POE strategy in teaching the experiments of the ISS on learners’ attitudes towards space exploration and their scientific explanations. A review of literature revealed that no studies have used the POE strategy to achieve this purpose.

Statement of the Problem

The problem of this study is specified in "the negative attitudes towards space exploration among secondary school students and the weakness of their ability to make scientific explanations". Accordingly, the researcher attempts to answer the following main question: "What is the effectiveness of teaching the experiments of the ISS by using the POE strategy in developing secondary school students' attitudes towards space exploration and their scientific explanations?"

In attempting to answer this question, the following sub-questions were also answered:

1. What are the experiments of the ISS that should be taught to secondary school students?
2. What is the suggested form of the ISS experiments unit?

3. What is the effectiveness of teaching the experiments of the ISS by using the POE strategy in developing secondary school students' attitudes towards space exploration?
4. What is the effectiveness of teaching the experiments of the ISS by using the POE strategy in developing secondary school students' scientific explanations?

Objectives of the study

The objectives of the present study are:

1. Determining the experiments of the ISS that should be taught to secondary school students.
2. Preparing the suggested form of the ISS experiment.
3. Measuring the effectiveness of teaching the experiments of the ISS by using the POE strategy in developing secondary school students' attitudes towards space exploration.
4. Measuring is the effectiveness of teaching the experiments of the ISS by using the POE strategy in developing secondary school students' scientific explanations?

Definition of Terms

- ***International Space Station (ISS)*****:** it is a habitable artificial satellite which is maintained at an orbital altitude of between 330 km and 410 km. The ISS serves as a microgravity and space environment research laboratory in which experiments in different fields can be conducted (John, 2008).
- ***Predict-Observe-Explain (POE)***: it is a constructivist teaching strategy which requires three tasks to be carried out. First, this strategy helps to uncover individual students' predictions, and their reasons for making these predictions about a specific event. Second, students describe what

they see in the demonstration – observation. Third, students must reconcile any conflict between their prediction and observation – explanation.

- ***Attitudes towards space exploration*****:** they are expressions of favor or disfavor towards the benefits of space exploration, supporting budget increase of space exploration, being in the forefront of space activity, working in space exploration, and improving space education and public outreach.
- ***Scientific explanation*****:** it is an attempt to give the reason for or cause of a phenomena. it includes three components: a claim which makes a conclusion that addresses the problem about a phenomenon, an evidence that supports the student's claim using scientific data, and a reasoning that links the claim and evidence and shows why the data count as evidence to support the claim.

Limitations of the Study

The present study is limited to:

- A group of grade 11 students from Cairo governorate
- Five subcategories of the attitudes towards space exploration. These subcategories are: 1) benefits of space exploration, 2) supporting budget increase, 3) being in the forefront of space activity, 4) working in space exploration, and 5) improving space education and public outreach
- Three components of the scientific explanation. These components are: 1) claim, 2) evidence, & 3) reasoning

Research Hypotheses

To solve the study problem, the researcher tested the following hypotheses:

- There is a statistically significant difference between the mean scores of the experimental group in the pre-application of the instrument of the attitudes towards space exploration versus the post-application, in favor of the post-application.
- There is a statistically significant difference between the mean scores of the experimental group in the post-application of the instrument of the attitudes towards space exploration versus the mean scores of the control group on the post-application in favor of the experimental group.
- There is a statistically significant difference between the mean scores of the experimental group in the pre-application of the scientific explanation instrument versus the post-application, in favor of the post-application.
- There is a statistically significant difference between the mean scores of the experimental group in the post-application of the scientific explanation instrument versus the mean scores of the control group in the post-application in favor of the experimental group.

Significance of the Study

This study might be of importance to:

- ***Science teachers:*** this research will be very beneficial to teachers by guiding them to use the POE strategy in teaching science. It can grab their attention toward the importance of the International Space Station experiments and encourage them to increase their students' positive attitudes towards space exploration. This research may also provide teachers with the ability to enhance and evaluate their students' scientific explanations.

- ***Curriculum planners:*** this research can grab the attention of curriculum planners to place emphasis on the space education and use constructivist teaching strategies in science curricula.
- ***Students:*** the direct recipients of the output of this research are the students. Using the POE strategy to teach the ISS experiments may help students to gain positive attitudes towards space exploration and enhance their scientific explanations.

Theoretical Background

1. ISS Education Opportunities

The first piece of the ISS was launched in 1998 using a Russian rocket. After that, more pieces were added. Over the last two decades, The Canadian Space Agency (CSA), European Space Agency (ESA), Japan Aerospace Exploration Agency (JAXA), Federal Space Agency of Russia (Roscosmos) and the National Aeronautics and Space Administration (NASA) have worked together to assemble the ISS and conduct research on this orbiting laboratory. Collaboration is a hallmark of research investigations in order to maximize available resources (Thumm et al, 2011).

Throughout the history of the ISS, this space station has provided a unique platform for inspiring students to excel in science. It has a multitude of exciting opportunities for space education appropriate for both students and teachers. These opportunities help to foster the education of our next generation of students, teachers, and space explorers by using the station to teach them the science and engineering that are behind space exploration, increasing the level of scientific-technological knowledge via the “space research” component and using the capabilities of space systems to improve the quality of teaching natural sciences. The educational activities of the ISS increase motivation of high-school and university students to connect their future profession with space research, popularize the achievements of world space exploration, and increase attractiveness of space activity (Alleyne et al. 2012).

Several authors (e.g. Alleyne et al. 2012; Saenz-Otero, Katz, Mohan, Miller, & Chamitoff, 2010; Thumm et al., 2014) have mentioned a large number of educational experiments and programs that were conducted on board of the station during the 14 years of its operation. Each of these diverse experiments and programs falls into one of the following categories:

- **Educational Demonstrations and Activities.** Several demonstrations are performed to be used as teaching aids, to supply resource materials, or simply to provide additional mechanisms to inspire students. For example, crewmembers demonstrate how simple and familiar phenomena, such as static attraction in microgravity, to reveal an exciting new understanding of physics in space and allow students of all ages to pose questions to the crew on board of the station. These diverse activities provide numerous opportunities to connect with students and bring the ISS experiences into their lives.
- **Students Performing Classroom Versions of the ISS Investigations.** These experiments, performed by students in their classrooms, mimic experiments that are being conducted by researchers on the ISS. These experiments provide an opportunity for students to observe differences between their results and results from experiments being performed by crewmembers on the ISS. A typical example of these types of experiments is Tomatosphere-III, where students measure the germination rates, growth

patterns and vigor of growth of seeds flown on the ISS and compare these to the same values for seeds grown on Earth. Another example is the educational pilot project that sent two orb-weaver spiders and several painted lady butterfly larvae within special growth chambers to the ISS. This project compared the behaviors and life cycles of spiders and butterflies in microgravity to those of spiders and butterflies being studied by students on Earth.

- **Student-Developed Investigations.** These experiments, which are performed by students under the aegis of a teacher or scientist mentor, are created solely for the benefit of the students. One example of this is the Synchronized Position, Hold, Engage, and Reorient Experimental Satellites (SPHERES) – Zero-Robotics competition in which high school students write algorithms for the SPHERES to accomplish tasks relevant to future space missions. SPHERES began in 1999 by instructing the students to “build a satellite that flies inside the Space Shuttle” (later changed to the ISS). In 2000, the students flew for two weeks of reduced gravity aircraft campaigns to validate their designs. After a few modifications to meet NASA safety requirements, the SPHERES were delivered to NASA in 2003, and launched to the ISS in 2006.
- **Educational Competitions.** These educational activities involve a student design competition, and students usually have an opportunity to submit experiment proposals that will be assessed and judged. Crewmembers often conduct the experiments proposed by the winners of the competition on the ISS. One example of this is the competition of YouTube and Lenovo manufacturer of laptop computers in 2012. In this competition, out of the 2000 entries from 80 countries, six regional winners were selected from the US along with two global grand prize winners. The two grand

prize winners were from the US and Egypt. The US student winner examined the anti-fungal properties of Bacillus subtilis whereas the student from Egypt looked at the predatory behavior of a jumping spider in microgravity.

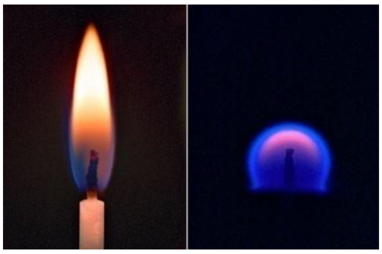
- **Students Participating in the ISS Investigator Experiments.** Many ISS investigators have enlisted students to help them with their experiments. Some of these experiments are performed solely to inspire the next generation of explorers. Others involve undergraduate and graduate students as well as postdoctoral fellows who are working under the guidance of investigators and university professors. An example of this category is Capillary Channel Flow (CCF), which is a research investigation, but involves students in the performance, evaluation, and computation of the experiment.
- **Students Participating in the ISS Engineering Education: Hardware Development.** These activities typically involve high school and college students developing hardware to support the ISS Program as they learn about and participate in space operations. The Agricultural Camera (AgCam) — a project that ran from 2005 to 2010 — is one example in which undergraduate and graduate students from the University of North Dakota designed, built, and operated ISS experiment hardware.
- **Cultural Activities.** Along with educational activities that have a technical component, there are activities that provide a cultural experience to the students. These include various cultural activities, such as dancing in microgravity or playing an instrument, performed by crewmembers on board of the ISS.

2- The P.O.E. Strategy

Space is a too dangerous environment to gain all experiences directly. The need for modeling the situation is a protection against avoidable losses and damages. Student cannot exist on the board of the ISS to participate in the scientific experiments conducted there. Scientists on the ISS have filmed these experiments. The videos of the experiments can be used in science teaching. One of the strategies that can use these videos to teach science is the POE (Prediction - observation - Explanation). The POE teaching strategy focuses on encouraging the elicitation of students' ideas to decide what existing ideas and beliefs are relevant to a situation, and on evaluating the appropriateness of these ideas and beliefs (Khanthavy & Yuenyong, 2009).

Table 1

A POE task to study the candle flame on the IS



Candle flames on Earth (left) have several different temperatures within the flame; on a space station (right), there is no buoyant convection, and the flame burns slower and hotter.

Predict (P). Predict what will happen to a candle flame on the ISS.

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Observe (O). Watch the movie of the burning candle on the ISS and observe what happens to the candle flame then record your observations.

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Explain (E). Compare your observation with your prediction. Are they in agreement or disagreement? Explain your reasons.

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The POE strategy probes student understanding by requiring students to carry out three tasks. First, students must predict the outcome of some event or presentation and must justify their prediction (P: Predict). Second, they describe what they see (O: Observe). Finally, they must reconcile any discrepancy between prediction and observation (E: Explain) (Costu, Ayas, &

Niaz, 2012). Unlike other strategies, such as concept mapping and interview, results obtained by POE can be easily interpreted. Therefore teachers do not require special training in this strategy (Teerasong, Chantore, Ruenwongsa, & Nacapricha, 2010). An example of a POE task is given in table1.

Prediction is important because it reflects students' preconceptions about scientific concepts and phenomena. Observation is an essential stage of POE strategy; this process requires all senses for collecting data (Oğuz-Ünver & Yürümezoğlu, 2009). Observation also induces students to concentrate on the experiment. Explanation allows the students to discuss their ideas (Teerasong et al., 2010).

The POE strategy is one of the approaches corresponding to the theory of constructivism. This strategy helps students justify the ideas that they bring into the classroom (prediction). When students find some conflicts during activity (difference between prediction and observation), their initial ideas are thus reshaped. Students are placed in active roles, using all senses for receiving or transmitting information (observation and discussion) and then constructing meaning from this information (explanation). In this strategy, the teachers do not provide information for the students to absorb, but rather they facilitate and respect the students’ roles by guiding useful information and allowing students to express ideas and opinions (Teerasong et al., 2010).

The use of POE strategy has been reported extensively in literature. It is used to investigate student understanding of a variety of concepts. İpek, Kala, Yaman, & Ayas, (2010) used POE strategy to investigate student teachers’ understanding of the effect of substance type on solubility. Ebenezer, Chacko, Kaya, Koya, & Ebenezer (2010) used the Predict – Explanation – Observation – Explanation (PEOE) strategy rooted in POE as an assessment tool integrated in the CKCM of conceptual change. Kala et al. (2013) used the POE technique in probing students' understanding about acid–base chemistry. The findings revealed that the POE strategy was effective in terms of gathering students' predictions and reasons for the prediction of outcomes in an open-ended format.

POE activities also serve as an instructional strategy, with a particular teaching/learning sequence. Chairam, Somsook, & Coll (2009) used POE tasks in the laboratory to shift students from passive learning to more active learning. Teerasong et al. (2010) used a demonstration together with (POE) strategy to teach the flow phenomena. The results showed that the students had positive attitude toward the new teaching strategy. The developed activity was well-fitted in a time period of classroom lecture. Kibirige et al. (2014) explored the effect of the POE strategy on Grade 10 Physical Sciences learners' misconceptions on how salt dissolves in water. The results show that learners in the experimental group (EG) taught using POE performed better in the post-test than their counterparts in the control group (CG) taught using traditional methods. Also, two new misconceptions were identified, namely: 1) salt dissolves in water when it is in 'fine' grains; and, 2) solid sodium chloride is not an ionic compound. These results highlight the need for educators and curriculum developers to include various elements of POE in the curriculum as a model for conceptual change in teaching science.

Some studies have investigated the use of the multimedia supported or computer-based POE tasks. Kearney (2004) used videos of real-life events to support POE strategy to engage meaningful learning. In this exercise, students worked collaboratively on computers. POE tasks motivated students' thinking and conversation, since the program was designed in a way that did not allow students to watch a video until they completed the prediction and reason. Hsu, Tsai, & Liang (2011) investigated the effects of implementing a computer game that integrates the POE strategy on facilitating preschoolers’ acquisition of scientific concepts regarding light and shadow. Results revealed that the students in the experimental group significantly outperformed their counterparts in the concepts regarding ‘‘shadow formation in daylight’’ and “shadow orientation’’. However, children in both groups, after playing the games, still expressed some alternative conceptions such as ‘‘shadows always appear behind a person’’ and ‘‘shadows should be on the same side as the sun’’. These studies showed the successful contribution of technology media-based POE strategy to teaching and learning in science classroom. Ercan (2014) study investigated the effects of using interactive computer animations based on the POE as presentation tools on primary school students’ understanding of the static electricity concepts. Results indicated that the interactive animations used as presentation tools were more effective on the students’ understanding of static electricity concepts compared to normal instruction.

3. Attitudes towards Space Exploration

Space exploration fires people's imaginations. Since the first human spaceflight in 1961, over 500 explorers from different nations have ventured into space, motivated by curiosity, the drive for knowledge, and the belief that space exploration can benefit people on Earth (Ochiai et al., 2014). Space exploration and its technologies have become an important part of the daily lives of citizens in a wide range of areas, including transport, agriculture, weather forecasting and security, to name just a few (European commission, 2014).

Space exploration has revealed the universe through a new perspective, opened up new worlds, and continued exploration for better understanding. It has given us fundamental new information about the origin and evolution of stars, planets, galaxies, and the universe itself. Furthermore, it has shown us that black holes really exist. It has opened up the tantalizing prospect of searching for life beyond Earth in programs such as search of extraterrestrial intelligences. Space exploration has demonstrated potential for strengthening interest in science and improving the quality of science, mathematics, and technology education in most countries (Zainuddin, 2008).

We are currently at the verge of transitioning to a new space exploration era targeting the Earth–Moon–Mars space. A number of robotic and human space exploration endeavors are currently in the planning stage to visit the Moon, Mars and Near Earth Objects (NEOs). The expansion of human presence in space will involve new stakeholders as well as a growing number of new countries leading to an internationalization of the space exploration context (Ehrenfreund, Peter, Schrogl, & Logsdon, 2010). This new era requires public support and, therefore, more consideration for public opinion (Entradas, & Miller, 2010).

The general public plays a critical role in the decision-making process about many political issues. This generation of young adults will soon be the one making policy decisions. Positive attitudes towards space exploration are vital in the development of public policies as tax payers are ultimately the ones who fund the space program (Cook, Druger, & Ploutz-Snyder, 2011). Recent reports (e.g. ISECG, 2007; British National Space Centre (BNSC), 2008; Space IGS, 2011) have called for the development of sustained programs of public engagement with space science and the involvement of the public in policy decisions about the future of space exploration. these reports emphasized that today's students are tomorrow's work force, and thus students should participate in the global space education activities so that they will feel motivated to follow space careers, work in the space domain, and create a generation that is literate in science and educated in space matters. This will lead to a continuously regenerated workforce that will benefit from the injection of new ideas and initiatives.

Empirical research shows that there are substantial differences in the level of attitudes towards space exploration among the general public and school students (Entradas & Miller, 2010). Recent researches, in the US, indicate that interest among younger generations has decreased in the last few years. The so-called ''Mars Generation'', as named by NASA in its campaign for Mars exploration, does not seem as interested in human missions as was the Apollo generation four decades ago (Safwat, Stilgoe, & Gillinson, 2006). A 2006 survey reported that young adults (18–24 years) were generally disengaged from and not supportive of human space flight. Only 29% of the respondents were interested in returning to the Moon, most were neutral (45%) and 23% were uninterested. The young adults' most important concerns were jobs, the current 'war on terrorism' and personal relationships, while space exploration ranked near the bottom of their priorities. The young respondents were also opposed to human missions to Mars, but more than half of them supported robotic missions, such as the Mars rover (Dittmar, 2006).

In Europe, Almost six out of ten Europeans (57%) think that investing in human space exploration can lead to medical progress. More than seven out of ten think that space activities can have a positive impact on environmental protection and more efficient agricultural activities (72%), predicting weather factors (74%) and understanding climate change (73%). Almost six out of ten (58%) think that space activities contribute to job creation in the EU. More than half of all Europeans (55%) would be interested in using information derived from observing the Earth from space to help plan travel and outdoor activities. Almost three-quarters of them think that including subjects linked to space activities in educational materials would encourage students to choose careers in science, technology, engineering and mathematics (73%), and that teaching subjects linked to space activities at school can help children to better imagine the society of the future (71%). Almost half of all Europeans (48%), a relative majority, would be ready to use automated vehicles guided by satellite systems in 20 years' time. More than one-third of them (37%) say that the future combination of observations from satellites and unmanned aerial vehicles will improve security in the EU, while 25% think this will be a threat to privacy, and 20% think that both of these statements are true (European commission, 2014).

Over 200 school children in eight schools in the east of England were surveyed to determine their interest in space exploration and awareness of current space activities. Of those surveyed, 33% were interested in space to 'discover a new planet', and 24% to 'find life on another planet'. When asked to list space exploration organizations, 77% listed NASA. Six of those surveyed listed ESA ($<$0.5%). The data bring starkly to light, despite the Huygens landing on Titan and Mars Express, the lack of awareness of the existence of ESA among the new generation of European school children. These data suggest that further surveys are merited to determine the factors that influence interest in space sciences and related disciplines among school children, and the source of their information (Jones, Yeoman, & Cockell, 2007).

In Egypt, there is a limited number of surveys of students' and public attitudes towards space exploration despite the continuous surveys in many countries (e.g. the USA and UK) over the last three decades. Such surveys are needed, in Egypt, to develop sustained programs of students' and public engagement with space science and to respond to the calls strongly focused on engagement of the general public. Moreover, surveys appear to be of greater importance at a time when public views on the future direction of science and technology and public engagement have become an increasingly used source in science policy.

4- Scientific Explanation

Science is fundamentally about explaining phenomena by determining how or why they occur and the conditions and consequences of the observed phenomena. For example, astronomers may try to explain the phases of the Moon based on the relative positions of the Sun, Earth, and Moon; or ecologists may try to explain why species diversity is decreasing in an ecosystem (McNeill & Krajcik, 2008). Many say that explanation is one of the central aims of science; a few add that it is the central aim. So it is no wonder that much attention has been devoted to an analysis of the nature of explanation within the philosophy of science for at least the last 60 years (Nola, 2011).

Many philosophers of science broadly conceptualize scientific explanations as attempts to move beyond descriptions of observable natural phenomena into theoretical accounts of how phenomena unfold the way they do (Braaten & Windschitl, 2011). The new College Based Science Standards (College Board, 2009) defined a scientific explanation as a statement that is composed of the following: at least one claim, the evidence that is related to the claim, and the reasoning that makes clear the nature of the relationship between them.

Scientific explanations for natural phenomena often involve unseen entities such as atoms or forces, underlying processes such as genetic drift or oxidation, statistical or probabilistic patterns, or broad scientific theories to account for natural phenomena. For example, a description of condensation appearing on the outside of a cold glass of water differs from an explanation for condensation in that it emphasizes observable features of the phenomenon such as the cooler temperature of the water in the glass and the presence of droplets on the outside of the glass. In contrast, an explanation for condensation emphasizes unobservable processes such as molecular motion and energy, employs key scientific ideas and theories, and often seeks underlying causes of a commonly observed phenomenon (Braaten & Windschitl, 2011).

An explanation should make sense of a phenomenon based on other scientific facts. Thus, explanations begin with a statement of the explanandum - the feature or phenomenon to be explained that is often phrased as a question, for example, why did dinosaurs die out or why do we have seasons? A defining feature of an explanation is that the phenomenon to be explained is not in doubt. Nobody disputes that dinosaurs no longer exist or that seasons occur. Explanations therefore are essentially answers to questions and they “explain by describing how the explanandum came to be”. From this perspective, explanations consist of a subset of descriptions where new entities or properties are brought into being or invented to provide a causal account. Thus, dinosaurs became extinct because an enormous meteorite threw a large amount of dust and ash into the atmosphere (a descriptive statement) that caused a sudden temperature drop on the Earth's surface (a descriptive statement). Such explanations "work" because they generate a feeling of increased understanding accounting for the genesis of the phenomenon. From a philosophical perspective, they are coherent with the known data. Given that a defining characteristic of school science is the offering of well-established explanatory accounts of the material world, one measure of its quality then is the extent to which it achieves this sense of increased understanding (Osborne, & Patterson, 2011).

As previously mentioned, the explanation framework includes three components: a claim, evidence, and reasoning. The claim makes an assertion or conclusion that addresses the original question or problem about a phenomenon. The evidence supports the student's claim using scientific data. This data can come from an investigation that students complete or from another source, such as observations, reading material, or archived data, and needs to be both appropriate and sufficient to support the claim. By appropriate, we mean data that are relevant to the problem and help determine and support the claim. 'Sufficient' refers to providing enough data to convince another individual of the claim. Providing sufficient evidence often requires using multiple pieces of data. The reasoning links the claim and evidence and shows why the data counts as evidence to support the claim. In order to make this link, students must often apply appropriate scientific principles (McNeill & Krajcik, 2008).

For example, if a teacher is planning a unit on matter, the following would take place: By having students observe solids and liquids; the teacher has helped them define matter as something that has mass and takes up space. The next step is that students start thinking about air: "I'm curious, is it matter? Or something else?" The students are now driven by a need to explain if air is or is not matter. Next, the teacher can ask his students what data they need to answer the question “is air matter?”, and how they can collect that data. Students will need to determine if air has mass and/or takes up space. Perhaps they will suggest that they weigh a basketball multiple times as they use a pump to add more air. Once students conduct the investigation and have data, they can create an explanation. But what does a good explanation look like? The students might suggest the following explanation: *Air is matter* (claim). *We found that the weight of the ball increases each time we pumped more air into it* (evidence). *This shows that air has mass, one of the characteristics of matter* (reasoning). The explanation could be made more complete by including evidence and reasoning related to air taking up space (Brunsell, 2012).

Engaging students in the construction of scientific explanations is a central aspect of science education, research, and policy. Several science education researchers (e.g. Duschl, Schweingruber, & Shouse, 2007; Osborne & Dillon, 2008; Sandoval & Reiser, 2004) emphasize the importance of having students construct evidence-based scientific explanations as essential to scientific inquiry. Reform documents (e.g. American Association for the Advancement of Science (AAAS), 2011; National Research Council (NRC), 2012) call for more emphasis on scientific explanation in science classrooms. They push educators to move away from science educational practices focused on describing, measuring, and reporting observable events or practices focused on transmitting countless discrete facts to students. They call for inclusion practices that represent a shift in focus from learning as understanding of specific content knowledge to learning as an integration of disciplinary core ideas with opportunities to participate in authentic scientific practices.

Explanation is one of the most important tasks of science which has always attempted to elucidate objects and events. Researches (e.g. McNeill, Lizotte, Krajcik, & Marx, 2006; Songer, Kelcey and Gotwals, 2009) demonstrate that students who engage in the development of evidence-based explanations about science content can gain numerous benefits such as, improving their understanding of scientific concepts, their understanding of appropriate use of evidence, and their ability to provide coherent and logical arguments. In addition, the use of an explanation task provides us with an integrated approach to measuring students' ability to understand and communicate their science knowledge, using appropriate literacy skills to convey that knowledge. Under this model, learning science also becomes learning to use the specific linguistic features and structures that help communicate scientific principles, knowledge, and ideas (Fang, 2004).

Constructing explanations may help change students' views of science. Students often view science as a static set of facts that they need to memorize. They do not understand that scientists socially construct scientific ideas and that this science knowledge can change over time. By engaging in this inquiry practice, students can also improve their ability to justify their own written claims (McNeill et al., 2006). Moreover, the explanation architecture helps them evaluate explanations that appear in newspapers, in magazines, and on the news to determine their credibility and validity. That capability allows students to make informed decisions (McNeill & Krajcik, 2008).

Several studies have been conducted to asses and develop the students' scientific explanation. Federer, Nehm, Opfer, & Pearl (2014) used a constructed-response instrument to explore the effects of item position and item features on the assessment of written scientific explanations. Results suggest that as assessments in science education shift toward the measurement of scientific practices (e.g., explanation), it is critical that biases inherent in these types of assessments be investigated empirically. Peterson & French (2008) examined the ways in which preschool teachers support the development of children’s explanatory language through science inquiry. Results revealed that teachers engaged children as conversational partners and as scientific investigators responsible for their own learning.

Although scientific explanation is an essential learning goal, students often have difficulty articulating and defending their claims. For example, they often struggle with articulating clear claims based on the data that they have and often do not fully understand what counts as evidence (Sadler, 2004), or how to incorporate appropriate and sufficient evidence into their explanations (Sandoval & Millwood, 2005). Middle school students also have been shown to have particular difficulty with the reasoning component of scientific explanations (Gotwals, 2006). In addition, students have a hard time presenting evidence in a convincing way which indicates that students do not provide reasoning to indicate why the evidence is appropriate. Students will often make claims, but will not back up the claims with evidence or reasoning (Wenk et al., 2012). The previous results indicate that there is a need to use new effective strategies to help students to improve their scientific explanations such as the (POE) strategy.

Methodology

1. Research Design

The study employed a pre/post-test quasi-experimental design in collecting data from learners of similar socioeconomic backgrounds. This design was selected because it would allow the researcher to compare the performance of two groups after using POE strategy to teach the experiments of the ISS for one group and the traditional teaching approach for the other group.

2. Participants

Seventy-five Grade 11 students at El-Aliaa private school in Maadi Educational Administration in Cairo participated in the study. Participants are students in two different classrooms, coded as A and B and their ages ranged from 15 to 17 years. Learners from class A (38) acted as the experimental group (EG) whereas the control group (CG) consisted of (37) learners from class B. The learners were purposively sampled. Having been drawn from the same geographical set up, the learners were of the same socio-cultural practices.

3. Instruments

A Likert-5 scale was created to measure attitudes towards space exploration. Respondents could select one of five responses ranging from strongly disagree to strongly agree. The initial draft of this instrument consisted of six subcategories, each subcategory included five items. To test the instrument’s validity, the initial draft was validated by seven experts in the field of science education. They were asked for modifications to the ambiguous aspects of the instrument. They confirmed that the instrument could be useful after the modifications they suggested were done. The feedback obtained from this step was used to modify the instrument. The final instrument consisted of five subcategories with a total of 20 items so that the total score was 100 points.

For reliability, the final instrument was piloted over a period of two weeks on a group of Grade 11 learners in a secondary school; this group is not part of the participants previously mentioned. Any questions that were not clear were changed to reduce ambiguity. Test-retest Pearson correlation coefficient was 0.81 and the reliability coefficient obtained for the instruments was 0.895. The instrument took approximately 25 minutes for students to complete.

Table 2

The components of the attitudes towards space exploration instrument

Subcategory	**Brief description**	**No. of Items**	
		Positive	**negative**
Benefits of space exploration	Measures the attitudes towards the importance of space exploration for the human knowledge, economic development, protection of the Earth and creating jobs	2	2
Supporting budget increase	Measures the attitudes towards supporting an increase of the space exploration budget even if taxes increased	2	2
Being in the forefront of space activity	Measures the attitudes towards the importance for Egypt to be in the forefront of space activity	2	2
Working in space exploration	Measures the attitudes towards working in the space exploration field	2	2
Improving space education and public outreach	Measures the attitudes towards increasing the attention towards space education and public outreach	2	2
	Total	20	

An open-ended scientific explanation instrument was prepared to measure students' ability to construct scientific explanations. The instrument consisted of eight items which ask the students to write scientific explanations for different content areas (i.e.: physical science, biological science, environmental science, and Earth and space). A base explanation rubric was developed to assess the student skills of writing evidence-based scientific explanations. This explanation rubric included the three components of a scientific explanation; i.e. claim, evidence, and reasoning, to see if greater learning occurred regarding one component compared to another. The rubric offered guidance for thinking about different levels of student achievement for each of those components. The rubric included three levels: zero scores = level 1, one score = level 2, and two scores = level 3. The score for each item was six points (two scores × three components). Experts confirmed that the instrument could be useful after the modifications they suggested were done. The final instrument consisted of eight items so that the total score was 48 points. A reliability test was applied on 11th grade students who were not part of the sample. The scientific explanation instrument was scored using the rubrics. All questions were scored by one rater. Cronbach's alpha was calculated. It was 0.892 which suggests that the explanation items represent a valid measure of students' explanations. The instrument took approximately 45 minutes for students to complete.

Table 3

Base explanation rubric

Components	**Level 1 = 0**	**Level 2 = 1**	**Level 3 = 2**
Claim: a sentence that answers the scientific question	Does not make a claim, or makes an inaccurate claim	Makes an accurate but incomplete claim	Makes an accurate and complete claim
Evidence: data or observations that support the claim	Does not provide evidence, or only provides inappropriate evidence (that does not support the claim)	Provides appropriate, but insufficient evidence to support the claim; may include some inappropriate evidence	Provides appropriate and sufficient evidence to support the claim
Reasoning: Using scientific principles to show how the evidence supports the claim	Does not provide reasoning, or only provides reasoning that does not link the evidence to the claim	Provides reasoning that links the claim and evidence; repeats the evidence and/or includes some scientific principles, but is not sufficient	Provides reasoning that links evidence to claim; includes appropriate and sufficient scientific principles

After studying all the experiments conducted on the board of the ISS and the characteristics of zero-gravity environment, a list of experiments that should be studied on the secondary school was prepared. This initial list contained 28 experiments. Seven experts in the field of science education were asked for determine if these experiments were suitable for secondary school students. They removed six experiments so that the final list consisted of 22 scientific experiments.

A unit about the experiments of the ISS was prepared. This unit consisted of four lessons covering force and motion, fluid physics, heat transfer and chemical properties. Each lesson discussed some ground-based and space-based experiments to show the effect of the microgravity environment on some natural phenomena. The content of the unit is shown in the following table.

Table 4

The unit of the experiments of the ISS content

Lessons	**Concepts**	**Brief descriptions**	
		On the ground	**On the ISS**
Force and motion	The acceleration of gravity	A free-falling object has an acceleration of 9.8 $m/s^{2.}$	Objects in orbit are in a continuous state of free fall, resulting in an apparent zero acceleration.
	Weight	The weight of an object is the product of the mass and the magnitude of the local gravitational acceleration.	There is an apparent state of weightlessness.
	Electric force	A stream of water that falls down near a charged plastic comb will bend towards the comb.	Droplets of water will be attracted to a charged needle in an orbital fashion.
	Magnetic force	If two magnets are configured with their like poles facing each other and one magnet floats above the other, forces due to magnetic repulsion and gravity are balanced.	Effects of gravity are eliminated and magnetic repulsion dominates.
Fluid physics	Liquid pressure	Liquid pressure increases with depth. This is explained in terms of the weight of the	The weight of the liquid equals zero, so that the pressure would not be

Lessons	Concepts	Brief descriptions	
		On the ground	On the ISS
		liquid column.	applicable.
	Buoyancy	An object submerged in a fluid experiences greater pressure at the bottom than at the top. This difference in pressure results in buoyancy.	Buoyancy becomes insignificant because of the weightlessness.
	Surface tension	Fluids have surface tension which results from the cohesive force that acts to minimize the surface area.	The surface tension has a great impact because of the weightlessness.
	Capillary Phenomena	Gravity keeps the liquid from rising further so that fluid in a tube will rise to a specific height.	The effects of gravity on the fluid are reduced and the capillary action pulls the fluid higher.
	Gravity-Density Gradients	The fluid that has a higher density sinks below the fluid that has a lower density.	There is no restoring force when the interface between phases is disturbed.
Heat transfer	Convection	As the fluid heats, gravity-induced buoyant force sends the hotter molecules of the fluid upwards.	There is no convection. Without buoyancy, the hotter molecules remain attached to the heater.
	Conduction	Internal energy transfer by microscopic diffusion and collisions of particles.	Heat conduction in solids and liquids is not affected by gravity. Heat conduction in gases is reduced because gas density reduces.
	Radiation	Energy is transmitted in the form of waves or particles through space or medium.	Thermal radiation is not affected by gravity.
Chemical properties	Combustion	Gravity-driven buoyant convection causes a candle flame to be teardrop-shaped and carries soot to the flame's tip, making it yellow.	Convective flows are absent, so that the flame is spherical, soot-free, and blue.
	Crystal growth	Convection may cause microscopic gas/solution inclusions and fluctuating dopants incorporation and other defects in the crystals.	Convection is greatly reduced. Crystals tend to grow bigger in microgravity.
	Alloys	Convection causes fluid flows in the alloy, leading to the formation of irregular dendrites that weaken the alloy or metal structure.	Absence of the gravity and convection makes the end product consist of an evenly dispersed, multiphase structure.

A teacher's guide was prepared to help in teaching the experiments of the ISS by using the POE strategy. Each teaching activity was divided into two parts: (1) an illustration of the ground-based experiment, (2) using video to show the same experiment on the board of the ISS. For each part, the three steps of POE, i.e., prediction, observation and explanation were used before, during and after the demonstration, respectively. During the application, POE worksheets were given to the students who were expected to guess the answers and write their predictions. Then the observation step of the POE was performed. The responses of the students were checked during the application and they were instantly asked for oral explanations about the vague points. As an example, the details of one activity which lasted for 90 minutes are shown in table 1. The teacher acted as a facilitator to give necessary information and encourage students to form ideas.

Table 5

An example of one activity based on the use of POE strategy

The teaching activity	**Steps of POE**		**Duration**
Part1: ground-based experiment	Prediction	Students are asked to independently foresee what would happen when a stream of water falls down near a charged plastic comb.	10 min.
	Observation	Teacher performs the demonstration, while students observe and record what they see.	10 min.
	Explanation	Groups of three students discuss together. They are asked to amend or add explanation, reflect and re-shape their understanding.	10 min.
Part2: Space-based Experiment	Prediction	Students are asked to independently foresee what would happen when droplets of water are squirted out of a syringe in close proximity to a charged nylon needle, in space.	10 min.
	Observation	Teacher displays the movie which demonstrates this experiment on the board of the ISS, while students observe and record what they see.	10 min.
	Explanation	Students share and articulate ideas with peers, leading to consensual conclusion.	20 min.
Groups of students present their conclusion to the class. Whole-class knowledge is constructed through discussion and negotiation.			20 min.

4. Procedures

Students participated in the study during regular classroom sessions throughout a school day. The experimental group students studied the experiments of the ISS by using the POE strategy, while the control group studied the regular traditional lessons. The attitudes towards space exploration and the scientific explanation instruments were administrated to both groups before the intervention, to determine the equality of the two groups. The treatment was lunched on October 12, 2014 and lasted for eight weeks. Upon completion of instruction, post-tests were conducted to determine the difference between the groups. The data was submitted into SPSS. The t-test was used to determine statistical differences between the two groups.

Results

The instrument of the attitudes towards space exploration was applied to determine the effect of teaching the experiments of the ISS by using the POE strategy on the students' attitudes towards space exploration.

Table 6

Attitudes towards space exploration: means, standard deviations and t-values of the pre-test scores for the CG and EG

Subcategories	**Total scores**	**CG**		**EG**		**t-value**	**P**
		M	**SD**	**M**	**SD**		
Benefits of space exploration	20	10.97	3.54	10.24	3.45	0.91	0.37
Supporting budget increase	20	7.59	3.83	6.89	2.33	0.96	0.34
Being in the forefront of space activity	20	9.24	2.93	8.68	3.62	0.73	0.47
Working in space exploration	20	10.14	3.63	9.82	3.49	0.39	0.7
Improving space education and public outreach	20	9.84	3.23	9.92	3.44	0.11	0.91
Total	100	47.78	12.54	45.55	9.37	0.87	0.39

df = 73 p > 0.5 Not significant

As shown in table 6, the pre-test revealed that there was no significant difference between the mean scores of the CG (47.78; i.e. 47.78%) and EG (45.55; i.e. 45.55%) in the attitudes towards space exploration. The p value (0.39) is higher than (0.05). For the subcategories, the mean score of the CG in the attitudes towards "benefits of space exploration" (10.97; i.e. 54.8%) is close to the mean score of EG (10.24; i.e. 51.2%); the mean score of the CG in the attitudes towards "supporting budget increase" (7.59; i.e.37.9%) is close to the mean score of EG (6.89; i.e. 34.4%); the mean score of the CG in the attitudes towards "being in the forefront of space activity" (9.24; i.e. 46.2%) is close to the mean score of the EG (8.68; 43.4%); the mean score of the CG in the attitudes towards "working in space exploration" (10.14; i.e. 50.7%) is close to the mean score of the EG (9.82; i.e. 49.1%); and the mean score of CG in the attitudes towards "improving space education and public outreach" (9.84; i.e. 49.2%) is close to the mean score of EG (9.92; i.e. 49.6%).

Table 7

Attitudes towards space exploration: means, standard deviations and t-value of the pre-test and post-test scores for the EG

Subcategories	**Total scores**	**Pre-test**		**Post-test**		**t-value**	**P**
		M	**SD**	**M**	**SD**		
Benefits of space exploration	20	10.24	3.45	17.50	2.53	15.4	0.00
Supporting budget increase	20	6.89	2.33	14.74	2.82	12.8	0.00
Being in the forefront of space activity	20	8.68	3.62	14.87	2.96	12.9	0.00
Working in space exploration	20	9.82	3.49	16.58	4.04	9.06	0.00
Improving space education and public outreach	20	9.92	3.44	15.82	2.88	11.2	0.00
Total	100	45.55	9.37	79.5	8.04	23.8	0.00

df = 37 $p < 0.01$ significant

For the EG, the results of the analysis presented in Table 7 show that the difference between the attitudes towards space exploration pre-test mean score

(45.55; i.e. 45.55%) and post-test mean score (79.5; i.e. 79.5%) is significant (t = 23.8, p <0.01). For the subcategories, the results show that the mean score of the attitudes towards "benefits of space exploration" after treatment (17.5; i.e. 87.5%) is higher than before treatment (10.24 i.e. 51.2%). These means are significantly different (t=15.4; P<0.01). The mean score of the attitudes towards "supporting budget increase" after treatment (14.74; i.e. 73.7%) is higher than before treatment (6.89; i.e. 34.4%). These means are significantly different (t=12.8; P<0.01). The mean score of the attitudes towards "being in the forefront of space activity" after treatment (14.87; i.e. 74.35%) is higher than before treatment (8.68; i.e. 43.4%). These means are also significantly different (t=12.9; P<0.01). The mean score of the attitudes towards "working in space exploration" after treatment (16.58; i.e. 82.9%) is higher than before treatment (9.82; i.e. 49.1%). These means are significantly different (t=9.06; P<0.01). The mean score of the attitudes towards "improving space education public outreach" after treatment (15.82; i.e. 79.1%) is higher than before treatment (9.92; i.e. 49.6%). These means are significantly different (t=11.2; P<0.01).

Effect size:

In this study, effect size was reported to recognize the magnitude of the treatment effect on students' learning using Cohen's d, The criteria for identifying the magnitude of an effect size is as follows: (a) A trivial effect size is below 0.2 standard deviation units; (b) a small effect size is between 0.2 and 0.5 standard deviation units; (c) a medium effect size is between 0.5 and 0.8 standard deviation units; and (d) a large effect size is 0.8 or more standard deviation units (Sheskin, 2004). The effect size calculation indicated that the Cohen's d index is large (d= 7.8). These results proof that teaching the experiments of the ISS by using the POE strategy is effective in developing secondary school students' attitudes towards space exploration.

Table 8

Attitudes towards space exploration: means, standard deviations and t-value of the post-test scores for the CG and EG

Subcategories	**Total scores**	**CG**		**EG**		**t-value**	**P**
		M	**SD**	**M**	**SD**		
Benefits of space exploration	20	11.08	3.56	17.50	2.53	9.01	0.00
Supporting budget increase	20	8.11	3.2	14.74	2.82	9.54	0.00
Being in the forefront of space activity	20	9.92	2.93	14.87	2.96	7.28	0.00
Working in space exploration	20	10.7	2.29	16.58	4.04	7.68	0.00
Improving space education and public outreach	20	10.3	3.32	15.82	2.88	7.73	0.00
Total	100	50.1	8.25	79.5	8.04	15.6	0.00

df = 73 $p < 0.01$ significant

As shown in table 8, the post-test revealed that there is a significant difference between the mean score of the EG (79.5; i.e. 79.5 %) and CG (50.1; i.e. 50.1%) in the attitudes towards space exploration (t = 15.6, p <0.01). For the subcategories, the mean score of the EG in the attitudes towards "benefits of space exploration" (17.5; i.e. 87.5%) is higher than the mean score of CG (11.08; i.e. 55.4%). These means are significantly different (t=9.01; P<0.01). The mean score of the EG in the attitudes towards "supporting budget increase" (14.74; i.e.73.7%) is higher than the mean score of the CG (8.11; i.e. 40.55%). These means are significantly different (t=9.54; P<0.01). The mean score of the EG in the attitudes towards "being in the forefront of space activity" (14.87; i.e. 74.35%) is higher than the mean score of the CG (9.92; 49.7%). These means are significantly different (t=7.24; P<0.01). The mean score of the EG in the attitudes towards "working in space exploration" (16.58; i.e. 82.9%) is higher than the mean score of the CG (10.7; i.e. 53.5%).

These means are significantly different (t=7.68; P<0.01). The mean score of the EG in the attitudes towards "improving space education and public outreach" (15.82; i.e. 79.1%) is higher than the mean score of the CG (10.3; i.e. 51.5%). These means are significantly different (t=7.73; P<0.01).

Effect size:

The effect size calculation indicated that the Cohen's d index is large (d= 3.7). These results proof that teaching the experiments of the ISS by using the POE strategy is effective in developing secondary school students' attitudes towards space exploration.

The scientific explanation instrument was applied to determine the effect of teaching the experiments of the ISS by using the POE strategy on the students' explanations.

Table 9

Scientific explanation: means, standard deviations and t-value of the pre-test scores for the CG and EG

Components	**Total scores**	**CG**		**EG**		**t-value**	**P**
		M	**SD**	**M**	**SD**		
Claim	16	7.56	4.96	8.42	5.56	0.7	0.49
Evidence	16	6.27	5.7	6.74	5.1	0.37	0.71
Reasoning	16	4.97	5.11	5.26	4.66	0.26	0.8
Total	48	18.8	14.75	20.42	13.24	0.5	0.62

df = 73   p > 0.5   Not significant

As shown in table 9, the pre-test revealed that there is no significant difference between the pre-test mean score of the CG (18.8; i.e. 39.2%) and EG (20.42; i.e. 42.5%) for the scientific explanations. The p value (0.49) is higher than (0.05). For the components, the mean score of the CG regarding ‘claim’ (7.56; i.e. 47.3%) is close to the mean score of the EG (8.42; i.e. 52.6%); the mean score of the CG regarding ‘evidence’ (6.27; i.e. 39.2%) is close to the mean score of the EG (6.74; i.e. 42.1%); and the mean score of the CG regarding ‘reasoning’ (4.97; i.e. 31%) is close to mean score of the EG (5.26; 32.9%).

Table 10

Scientific explanation: means, standard deviations and t-value of the pre-test and post-test scores for the EG

Components	Total scores	Pre-test		Post-test		t-value	P
		M	**SD**	**M**	**SD**		
Claim	16	8.42	5.56	14.3	3.3	5.98	0.00
Evidence	16	6.74	5.1	12.63	4.4	5.72	0.00
Reasoning	16	5.26	4.66	11.37	5.1	5.52	0.00
Total	48	20.42	13.24	38.3	11.4	6.45	0.00

df = 37 $p < 0.01$ significant

For the EG, the results of the analysis presented in Table 10 show that the difference between pre-test mean score (20.42; i.e. 42.5%) and post-test mean score (38.3; i.e. 79.8%) for the scientific explanation is significant (t = 6.45, p <0.01). For the components, the results show that the mean score regarding ‘claim’ after treatment (14.3; i.e. 89.3%) is higher than the mean score before treatment (8.42 i.e. 52.6%). These means are significantly different (t=5.98; P<0.01). The mean score regarding ‘evidence’ after treatment (12.63; i.e. 79%) is higher than the mean score before treatment (6.74; i.e. 42.1%). These means are significantly different (t=5.72; P<0.01). The mean score regarding ‘reasoning’ after treatment (11.37; i.e. 71%) is higher than the mean score before treatment (5.26; i.e. 32.9%). These means are significantly different as well (t=5.52; P<0.01).

Effect size:

The effect size calculation indicated that the Cohen's d index is large (d= 2.1). These results proof that teaching the experiments of the ISS by using the

POE strategy is effective in developing secondary school students' scientific explanations.

Table 11

Scientific explanation: means, standard deviations and t-value of the post-test scores for the CG and EG

Components	**Total scores**	**CG**		**EG**		**t-value**	**P**
		M	**SD**	**M**	**SD**		
Claim	16	7.78	5.16	14.3	3.3	6.54	0.00
Evidence	16	6.7	5.17	12.63	4.4	5.35	0.00
Reasoning	16	5.2	5.07	11.37	5.1	5.24	0.00
Total	48	19.68	13.67	38.3	11.4	6.4	0.00

df = 73 $p < 0.01$ significant

As shown in table 11, the post-test revealed that there is a significant difference between the mean score of the EG (38.3; i.e. 79.8%) and CG (19.68; i.e. 41%) for the scientific explanation (t = 6.4; P<0.01). For the components, the mean score of the EG regarding ‘claim’ (14.3; i.e. 89.3%) is higher than the mean score of the CG (7.78; i.e. 48.6%). These means are significantly different (t=6.54; P<0.01). The mean score of the EG regarding ‘evidence’ (12.63; i.e.79%) is higher than the mean score of the CG (6.7; i.e. 42%).These means are significantly different (t=5.35; P<0.01). The mean score of the EG regarding ‘reasoning’ (11.37; i.e. 71%) is higher than mean score of the CG (5.2; 32.5%). These means are significantly different (t=5.24; P<0.01).

Effect size:

The effect size calculation indicated that the Cohen's d index is large (d= 1.48). These results proof that teaching the experiments of the ISS by using the POE strategy is effective in developing secondary school students' scientific explanations.

Discussion

The results show that teaching the experiments of the ISS by using the POE strategy was effective on the students' attitudes toward space exploration. After treatment, The EG attitudes towards space exploration became very positive (79.5%), while the CG attitudes towards space exploration did not (50.1%). For the subcategories of the attitudes towards space exploration, figure 1 shows that the EG outperformed the CG in all subcategories. The subcategory "supporting budget increase" had the lowest percentage for the CE and EG. The current poor economic and social conditions in Egypt may be the main reason that makes students think it is not important to invest in space exploration because there are other pressing issues from their points of view.

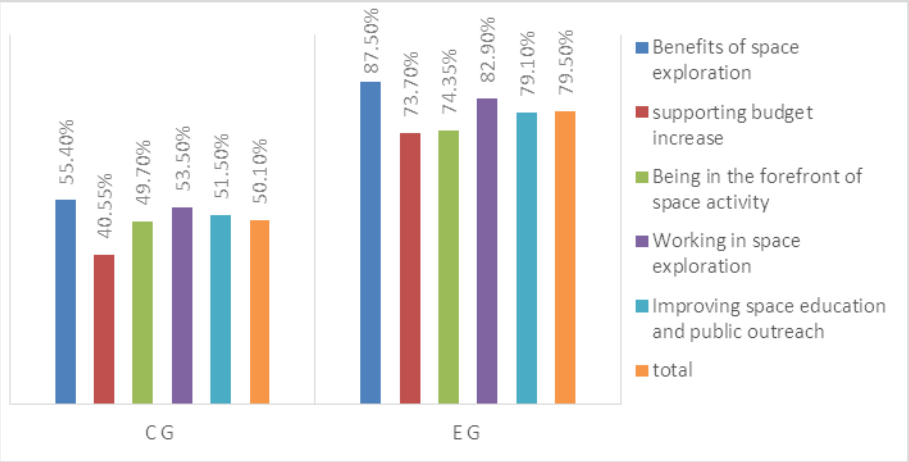

Figure 1. Comparison between the post-test results of the CG and EG attitudes towards space exploration

The differences among the mean scores obtained by the two groups suggest that POE learners outperformed others. Thus, the POE strategy could enhance learners' performance. POE emphasizes the use of learners' prior knowledge as the basis for their learning. The importance of learners' prior knowledge is also emphasized by Piaget (1970) and Vygotsky (1986) in social constructivism where the learner is the constructor of new knowledge and an active participant throughout their learning processes. Using the EG students' prior knowledge helped them to understand the difference between ground-based and space-based experiments and convinced them with the importance of such space activity in prosperity of human kind.

The results also show that teaching the experiments of the ISS by using the POE strategy was effective on the students' scientific explanations. After treatment, the EG achieved significant learning outcomes for scientific explanation as a whole as well as for each component. Figure 2 shows that creating claims was the most straightforward aspect of constructing an explanation, while generating an explicit reasoning link between claim and evidence was the most challenging aspect of explanation building. In this study both prior knowledge, group work and class discussions were incorporated. On the other hand, the traditional teaching strategy used by the CG was educator-centered and learners were mostly passive during the learning process.

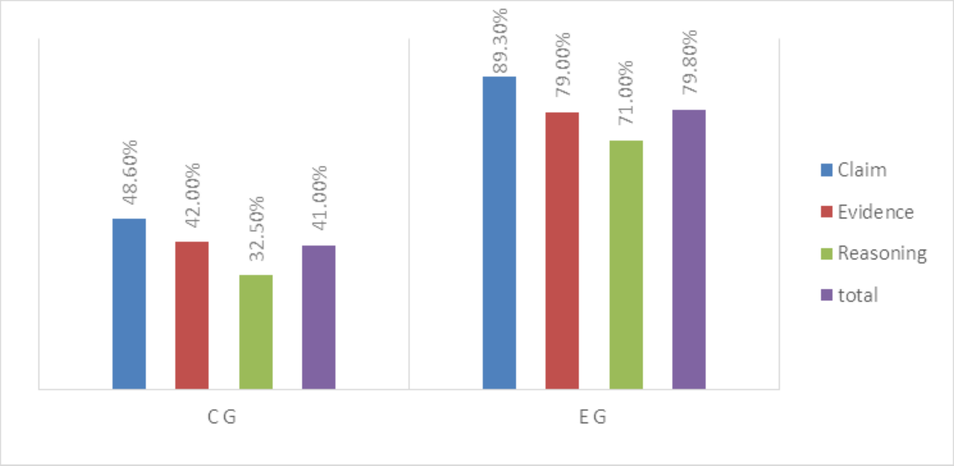

Figure 2. Comparison between the post-test results of the CG and EG in scientific explanation

The POE is viewed as a strategy which takes into consideration the constructivist approach that includes reflective teaching processes and active participation unlike the traditional approach which emphasizes chalk and talk. Each step in the POE strategy helped developing the components of the scientific explanation. ‘Predict’ step trained the students on using their prior knowledge in a new experience and this improved their ability to make a claim. ‘Observe’ step helped the students determine the useful quantitative data or qualitative information and this was reflected on their ability to write evidence. ‘Explain’ step gave the students opportunities to practice writing an evidence-based scientific explanation.

Conclusion

The study aimed at finding out the effect of teaching the experiments of the ISS by using the POE strategy on learners’ attitudes towards space exploration and their scientific explanations compared to traditional strategies. The POE strategy was found to be useful in the teaching process. In POE, learner-centered teaching acknowledges the social construction of knowledge and the basis of all learning, that is, ‘learner’s prior knowledge’. Using this strategy to teach the ISS experiments had a positive effect on learner's attitudes towards space exploration and scientific explanations. The strategy helped the EG use their sense to study the ground-based and space-based experiments and explain the conflicts between the results of these two types of experiments. The strategy also helped the students to construct meaning about space activities and the benefits resulted from these activities. The implication of these results is that science educators, curriculum developers, and textbook writers should work together to include elements of POE in the curriculum as a model for conceptual change in teaching science in schools. The experiments of the ISS and other space activities should be emphasized in science curriculum and more attention should be paid to space education and developing the attitudes towards space exploration in the Egyptian schools. Measuring and developing the scientific explanation need more attention in education and public outreach.

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