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EVALUATION OF CONCEPTUAL FRAMEWORKS IN ASTRONOMY

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Abstract

Even though astronomy is the oldest science, it is still an open question how to evaluate students' understanding in astronomy. In spite of the fact that some methods and evaluation tools have been developed for that purpose, the sources of students' difficulties in astronomy are still unclear. This paper presents an investigation of the changes in conceptual frameworks in astronomy among 50 engineering students as a result of learning a general course in astronomy. A special tool called Conceptual Frameworks in Astronomy (CFA), which was initially used in 1989, was adopted to gather data for the present research. In its new version, the tool includes 23 questions and five to six optional answers to each question. Each of the answers characterizes one of the four conceptual frameworks: pre-scientific, geocentric, heliocentric and sidereal. These four conceptual frameworks act as a taxonomical system that enables us to evaluate astronomical understanding. The paper describes the background of the CFA, its development, and discusses its validity and reliability. Using the CFA we were able to: (1) identify the students' conceptual frameworks at the beginning of the course and at its end, (2) to evaluate the students' paradigmatic change following the course. It was found that the measure of the students' improvement (gain index) was g = 0.37. Approximately 45% of the students in the course improved their conceptual frameworks in astronomy and 26% deepened their understanding of the heliocentric or sidereal conceptual frameworks. The CFA can also be applied as an evaluation tool in all schools and institutions that teach astronomy.
Key words: *astronomy education, conceptual framework, diagnostic tool, engineering students*.

Introduction

Students' Ability to Comprehend Astronomical Concepts

In the last thirty years, extensive study has been conducted with the aim of identifying difficulties involved in the comprehension of astronomical concepts by students of various ages (Diakidoy et al., 1997, Fingold & Pundak, 1991; Nussbaum, 1989; Sadler, 1998; Trumper 2000). From this research it appears that irrespective of students' cultural differences from different world locations, they tend to adopt attitudes that are inappropriate for astronomical scientific models. The research yielded insights concerning the types of difficulties that students encounter and different methods were suggested to deal with these difficulties. However, a large amount of the diagnosed difficulties or misconceptions obstinately refused to disappear.

A study that investigated the knowledge of 88 teachers of astronomy, in contrast to the knowledge of 7,599 students, exposed the teacher's tendency to overestimate the students' astronomical knowledge (Sadler et al. 2010). The students' misconceptions in astronomy refused to disappear even when they reached higher education. A study conducted in Maine University over a period of five years, from 2009 to 2013, followed 639 students who studied an introductory course in astronomy. The researchers identified 215 prevalent misconceptions in astronomy (Favia et al., 2014). They graded each of the students' misconceptions according to three levels; low-level misconceptions being relatively easy to correct after studying an astronomy course. The medium and third levels of misconceptions refused to disappear even after discussions and considerations of them during the course. Each of these misconceptions was given a level of difficulty from 1 to 3. The highest level of difficulty that emerged in the research was 2.54. An example of an obstinate misconception at the level of 2.54 is that "the sunspots cycle last 11 years" (Solheim et al., 2012).

Conceptual Frameworks in Astronomy

The development of conceptual frameworks in children (Piaget, 1973) and especially the development of conceptual frameworks for astronomy is a gradual process. Several stages or astronomical models can already be distinguished in young students (Calderón et al. 2013; Nussbaum, 1989; Vosniadou, 1994). In a study that dealt with the phenomena of day and night among Grade 1 to Grade 5 students, nine developmental stages were identified in the transition from a naïve explanation to a scientific explanation (Morik & Muhlenbrock, 1999). Another study conducted among elementary school students concerning their conceptualizations of the structure of the solar system, identified seven solar system models (Calderón et al. 2013). These studies indicate a process of model development in astronomy for children over the period of their studies. In the preliminary models children tend to adopt a pre-scientific mythical culture-dependent approach, while more advanced models represent a scientific approach based on the performance of observations and their interpretation.

Ancient human cultures explained the connection between life on earth and heavenly phenomenon. Findings from five thousand years ago testify to efforts to decipher the influence of astronomical phenomena on agriculture, river flow, volcanic eruption, ecological disasters and periods of abundance. Throughout human history, scientists and philosophers asked questions relating to astronomy such as: the source of starlight, reasons for the movement of the sun, moon and stars, moon phases and the appearance of comets. They were especially intrigued by the influence of astronomy on human life. The answers to these questions have undergone far-reaching alterations over the years. Five main astronomical conceptual frameworks can be noted in relation to the astronomical structure and the regularity that determines their interaction (Kuhn, 1962; Linton, 2004; Timberlake, 2013).

1. The pre-scientific approach – holds that the heavens are the home of the gods, and whatever happens there is due to the will of the gods and their consideration of man's actions. Evidence of this period is found from the third millennium BC till the beginning of the Ancient Greek period in 600BC.
2. The geocentric approach – holds that the earth is positioned in the center of the universe, and the sun, planets and stars circle around it. This perception was accepted from the 6th century BC till the 17th century AD.
3. The heliocentric approach – holds that the sun is located at the center of the universe and the planets and stars orbit around it. The invention of the telescope established the development of this perception. This was the accepted perception in the 17th century AD.
4. The sidereal approach – holds that the universe contains billions of stars and the sun is only one small star among the stars in the universe. The development of large telescopes and the improvement of understanding of the information that the light carries with it enabled the development of this perception in the 19th century and the beginning of the 20th century.
5. The galactic approach – arguing that the universe contains billions of galaxies and that in each of them there are billions of stars. Clusters of galaxies are the "building blocks" of the universe. This perception became established from the second decade of the 20th century.

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Table 1. Characteristics of five dimensions of each of the five conceptual frameworks for astronomy.

Dimensions	Pre-science	Geocentric	Heliocentric	Sidereal/ OR Stellar	Galactic
The space shape	Flat & infinite	Spherical earth surrounded by a finite sky	Sun at the center of finite universe	Shaped by stars, Sun is only one of it.	Shaped by galaxies, Milky-way is only one of them.
Order of magnitude	Hundreds of kilometers	Earth-Moon distance	Parsec	Millions of light years	Billions of light years
Life span of the universe?	Span of a human life	Some thousands of years	Tens thousands of years	Millions of years	Billions of years
Heavenly bodies	Moon, sun and stars	Moon, sun, planets and stars	Earth, moons, sun, planets and stars	Stars, nebulae, globular clusters, milky-way galaxy	Galaxies and galaxies' clusters.
Changes	Nothing changes in space	Changes occur only in Earth's vicinity	Changes occur only in solar system	Changes occur everywhere in space	Changes occur everywhere in space
Measurement tools	The eye and senses	The eye and geometry	The eye, geometry and telescope	Telescope and photo plate	Telescopes for all EM spectrum and satellites

The approaches presented above do not characterize all the people that lived during those periods, rather the scholars who dealt with astronomical issues. In the opinion of many scholars, students studying astronomy at different ages relate to the subjects studied out of one of these five conceptual frameworks or perceptions (Diakidoy et al., 1997; Finegold & Pundak, 1991; Morik, & Muhlenbrock 1999; Špelda, 2015). In some cases a student could be in a state of transition between two different approaches. Table 1 below displays each of the five conceptual frameworks for astronomy, in relation to six dimensions: the form of space, the proportions of the universe, the life span of the universe's existence, the celestial bodies, alterations that take place in the skies and astronomical measurement tools required for the development of a conceptual framework.

Methodology of Research

General Background of Research

In this research we examine students' attitudes regarding astronomy from a developmental perspective, investigating students' attitudes along the continuum of conceptual frameworks for astronomy that were developed over human history (Matthews, 1994). This perspective relies on children's cognitive development (Piaget, 1973) and the development of concepts in science (Redish & Smith, 2008). The present study stems from the need to examine these processes during the teaching of astronomy (Wittman, 2009; Duncan & Arthurs, 2012). In this spirit, in 1989, a special tool was constructed to examine students' conceptual framework for astronomy, called the Conceptual Frameworks in Astronomy Tool (CFA) (Finegold & Pundak, 1991). In 1995, The CFA was presented at the Internet School for Astronomy of the Kineret Academic College "Blossoms of Science" center (Pustil'nik & Pundak 2006). Using the CFA as an interactive tool on the Internet, we examined hundreds of astronomical perceptions that people use to interpret celestial phenomena (Conceptual Framework in Astronomy, 1995). The CFA tool introduced a different way to evaluate learning processes in astronomy. It stands in contrast to other approaches that focus on students' misconceptions when they learn astronomy (Sadler et al. 2010; Favia et al. 2014, Schneps et al. 2014), or evaluate the scope of their conceptual development in astronomy by asking them to respond to a diagnostic questionnaire in astronomy (Zeilik, 2002).

Sampling Method

The research population for the present research included a group of 50 engineering students who were studying an elective one-semester course in astronomy, in the spring semester 2015, at the Kinneret College, Israel. The students' average age was 28.6 years, S.D. 4.4 years. The relatively high age of the students is due to the fact that most Israeli students complete compulsory military service before beginning higher education. Additionally, most of the students were studying in the last year of their degree studies. The respondents were mostly men. The astronomy course was based on the book *Universe*, 9th edition (Freedman et al., 2011) and was studied in a single lesson once a week. Each lesson lasted two hours, and the course lasted 14 weeks. The CFA was administered to the students in the first week of the course as a pre-test and at the last week of the course as a post-test.

Development of the Research Tool

The first version of the research tool was, as noted, developed in 1989, as part of a doctoral dissertation on development of conceptual frameworks in astronomy (Pundak, 1991). In order to construct the questionnaire, 22 teachers were interviewed and with their assistance a set of questions was constructed to compose the questionnaire. 35 junior and senior high school students were then interviewed regarding questions related to astronomical phenomena that had been noted by the teachers in their interviews. This included phenomena such as: day and night, moon phases, the life span of the sun, moon and earth, and the source of starlight. The interviews permitted the identification of the students' naïve perceptions concerning ten subjects in astronomy. Based on the students' responses in the interviews multi-choice questions were composed. The multi-choice answers to the questionnaire questions were taken from the students' ideas collected during the interviews. Each question was given several answers. It was possible to assign each of the answers to one of the initial four conceptual frameworks that were described above. The questionnaire was developed in four stages, where at each stage the questionnaire was administered to different groups for evaluation. The answers that were not chosen as appropriate were replaced by other answers composed in a manner that would be appropriate for the respondents' thinking. The fourth version included 15 questions (Pundak, 1990). An example of one of the questionnaire questions appears in Table 2. The research questionnaire was administered in 1989 to 892 students in seven schools in Israel (543 students from junior high school and 349 from senior high school).

Table 2. Sample question in the research questionnaire including five possible answers: Each of the answers represents a conceptual framework in astronomy. The grade for the answer indicates which type of conceptual system corresponds with the chosen answer.

3. Has the Earth always existed?		
Answer/distractor	**Conceptual Frame-work**	**Value**
Yes, the earth has always existed.	Geocentric	2
No, before the earth was formed, it was covered in water.	Prescientific	1
No, it was created by volcanic eruption.	Prescientific	1
No, the sun was formed first.	Heliocentric	3
No, first the stars and other galaxies were formed.	Sidereal	4

In the middle of 2014, it was decided to conduct an experiment using the CFA (see Appendix) on engineering students studying a general course in astronomy in the Kineret Academic College, Israel. For this purpose the questionnaire was reexamined. In light of the many studies conducted since then on the conceptual learning of astronomy (Bailey et al., 2012, Favia et al., 2014, Sadler, 1998; Trumper, 2000, Wittman, 2009), it was decided to introduce additional questions to those included in the original questionnaire, while considering subjects that students may misconceive. For most of the questions (except Question 3) distractors were also set that helped to identify prevalent misconceptions among bachelor's degree students (Sadler, 1998). These distractors were composed so that they would represent a perception that belonged to one of the conceptual frameworks for astronomy. Table 3 shows the numbered questions with consideration of the misconceptions that are often made in their regard as defined by a group of researchers from the Maine University (Favia et al., 2014). These researchers ranked the difficulty involved in coping with these prevalent misconceptions from 1 to 3, whereby close to 1 are misconceptions that are relatively easy to correct, while 3 was given to misconceptions that it is very difficult to correct in the learning process. In Table 3 the relative difficulty of the misconceptions is noted by their rank. The right hand column of the table shows the astronomical conceptual framework to which the misconception belongs. It should be noted that in the particular conceptual framework, let's say the geocentric framework, an answer that appears to be correct is considered a misconception when examined in another conceptual framework, let's say the heliocentric framework.

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Table 3. Misconceptions on questions that appear in the CFA questionnaire adopted from the study at Maine University (Favia et al., 2014).

Question No.	Misconception	Symbol	Relative difficulty	Conceptual Framework
	The sun orbits the Earth	sA133	1.45	Geocentric
	Earth is at the center of the universe	sA115	1.49	Geocentric
	The earth has always existed			Geocentric
	The Earth will last forever	sA143	1.48	Geocentric
	The Sun is the brightest object in the universe	sA190	1.77	Heliocentric
	All stars are smaller than the Sun	sA17	1.62	Heliocentric
	The Sun is the only source of light in the galaxy	sA214	1.77	Heliocentric
	Earth is at the center of the universe	sA115	1.49	Geocentric
	The Sun is the brightest object in the universe	sA190	1.77	Heliocentric
	Because the Moon reflects sunlight, it has a mirror-like surface	sA96	2.00	Geocentric
	The sun orbits the Earth	sA133	1.45	Geocentric
	The Sun will burn forever	sA178	1.52	Heliocentric
	Stars in the Milky Way are as close to each other as planets are to the Sun	sA29	1.89	Heliocentric
	Stars just exist --- they don't make energy or change size or color	sA20	1.65	Prescientific
	The Moon changes physical shape throughout its cycle of phases	sA84	1.63	Prescientific
	The most important function of a telescope is magnification	sA271	2.14	Heliocentric
	Halley's comet will eventually hit Earth	sA131	2.17	Geocentric
	All stars are stationary --- fixed on the celestial sphere	sA22	1.92	Geocentric
	All of the stars are about as far away from the Earth as the Moon	sA3	1.62	Geocentric
	Gravity is the strongest force in the universe	sA259	2.33	Geocentric
	All stars are the same distance from the Earth	sA14	1.45	Geocentric
	Stars emit only one color of light	sA23	1.79	
	Stars are fixed in space	sA34	1.67	Geocentric
		average	1.73	

Note: The right hand column shows the conceptual framework for astronomy that is represented by the prevalent misconception and the next column shows the level of difficulty involved in coping with the misconception.

In the 2015 version of CFA there are 23 questions, each is given five-six possible answers. CFA gives preference to several pre-scientific and geocentric answers. The division of the answers according to percentages is: 32% pre-scientific answers, 32% geocentric answers, 17% heliocentric answers and 19% sidereal/scientific answers. The grade for each of the questions is determined in accord with the answer that is chosen, where the key is 1 for the pre-scientific answer; 2 for the geocentric answer; 3 for the heliocentric answer, 4 for the sidereal/scientific answer.

An example of this can be seen in Table 2 that presents a single example of one of the CFA questions. The average student's score for CFA testifies to the conceptual framework that is preferred by her. For example, the preferred conceptual framework for the student whose average score is 3.2 is the heliocentric conceptual system. The Standard Deviation testifies to the extent of consistency that the student maintains in her conceptual framework. The CFA can serve two purposes: (1) as a diagnostic tool regarding the student's level of knowledge in astronomy and (2) as a tool that enables the examination of the influence of learning in an astronomy course on alteration of the student's conceptual framework.

The questions in 2015 version of FCA underwent validation by four content experts. In a meeting conducted with the physics and astronomy staff we discussed the probability that engineering students would choose non-scientific answers. Several participants claimed that "it was not probable that students with a scientific background would choose an answer of this kind".

The overall reliability of CFA was tested by the measurement of internal consistency with Cronbach's α. Using factor analysis, the questionnaire was divided (see below the section on Research Results) into five subjects in the study of astronomy: the earth, astronomical measuring instruments, observational properties, the solar system, and properties of the stars. The reliability level of each of these components is presented in Table 4.

Table 4. Division of the questionnaire according to astronomical subjects, with reliability of each subject examined.

No.	Component Name	No. of Items	Cronbach's Alpha
1	Planet Earth	6	0.609
2	Astronomical Instruments	3	0.464
3	Observational Properties	3	0.486
4	Solar System	7	0.689
5	Stars' Properties	4	0.402

Research Questions

The research focused on three questions:

1. To what extent is there a correlation between the results of this study, which related to students in academia and the research results collected with a similar tool from students in junior and senior high schools?
2. Which conceptual frameworks in astronomy are characteristically held by engineering students?
3. To what extent does an elective course in astronomy lead to a change in engineering students' conceptual frameworks in astronomy?

Results of the Research

The first research question investigated the correlation between the junior high and senior high school students' conceptual frameworks in astronomy and those of college students. The high schools students' understanding was tested by the original version of CFA in 1989, and the conceptual frameworks in astronomy of engineering students, most of whom were in the last stages of the bachelor's degree studies, as measured by the upgrade version of CFA, constructed in 2015. Despite the time gap between the two measurements of approximately 25 years, the research tool used for the measurement was developed out of the same fundamental theoretical approach. It should be noted that the engineering students had a broad academic background in sciences and mathematics, while the school students were chosen randomly and it can be assumed that their background in sciences and mathematics was quite restricted. None of the respondents had formally studied astronomy. Figure 1 shows the distribution of the conceptual frameworks in astronomy in the three research groups. The graph indicates two trends: (1) approximately 90% of the respondents adopt one of two conceptual frameworks – geocentric or heliocentric. (2) When the age of the respondents is lower, the percentage of students who hold a geocentric approach increases and correspondingly the percentage of students who hold a heliocentric approach decreases. The reference to Figure 1 also allows us to point up two additional points: (1) It was only the junior high school students who adopted the pre-scientific approach. (2) In all three research groups there is a relatively small proportion of students who adopt the sidereal approach.

The second research question investigated which conceptual frameworks the students used to interpret astronomical phenomena, before learning an astronomy course. From Figure 1 it can be seen that most of the students (84%) adopt the heliocentric approach to relate to astronomical phenomena presented in the research questionnaire. The graph indicates that there is a trend toward strengthening of the heliocentric approach with an increase in the respondents' age.

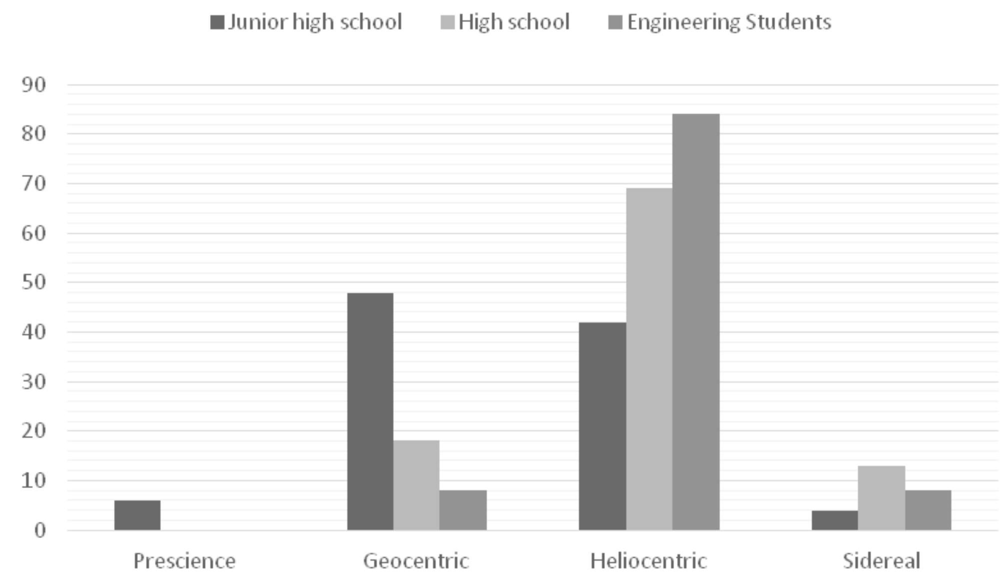

Figure 1: Distribution of conceptual frameworks in astronomy held by students in junior and senior high schools (measured in 1989) and in an academic college (measured in 2015). Respondents had not formally studied astronomy.

The third research question investigated the influence of an elective course in astronomy on the conceptual frameworks of engineering students. The CFA was administered twice during the course. Figure 2 displays the distribution of the students' attitudes given in the pre-course questionnaire and in the post-course questionnaire. Measurement of the improvement after the course (the gain index) according to Hake (1998) was $g = 0.37$. A t-test found a significant difference between the results of the pre-course test ($M=3.03$, $SD=0.36$) and the results of the post-course test ($M=3.39$, $SD=0.34$) where $p<0.000$, $t(98)=4.66$.

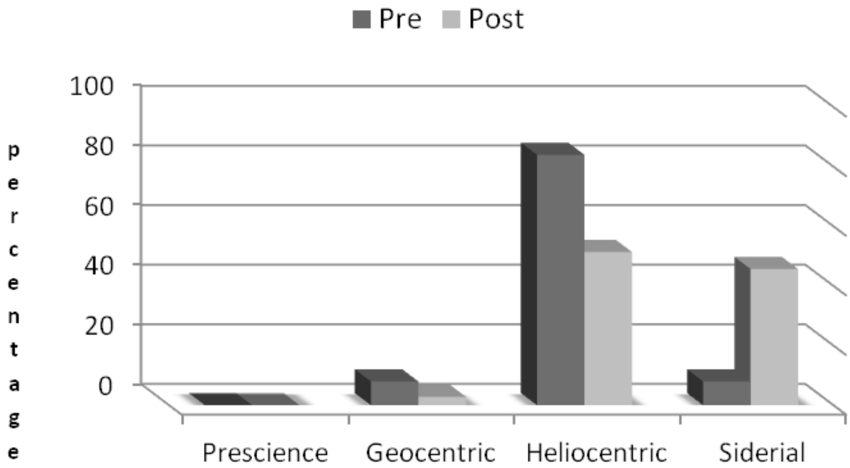

Figure 2: Conceptual frameworks in astronomy held by engineering students at the beginning and end of a course in astronomy, as emerged from the research questionnaire (CFA).

To what extent was there a change in the students' attitudes concerning the questions that were presented in the research tool following the elective course in astronomy? A comparison was drawn between the attitudes of the students concerning each of the 23 questions in the research tool as they emerged from the pre-course test and the post-course test using t-tests. It was found that there was a significant improvement in the students' attitudes (more advanced conceptual framework) for 12 out of the 23 questions in the post test questionnaire. For another ten questions there was a non-significant improvement. For only one question there was a significant regression. This was question 6 that related to the grading of celestial bodies from the largest to the smallest. In the pre-course questionnaire more students noted that the Northern star is larger than the sun than in the post-course questionnaire. As is well known the Northern star has 4.6 times the mass of the sun and a radius 46 times larger than that of the sun. In contrast to question 21 that dealt with the distance of stars in the Orion constellation from the earth, in the pre-course questionnaire most of the students used a pre-scientific or geocentric approach. At the end of the course the students preferred a heliocentric sidereal approach. Figure 3 shows the students' attitudes towards the CFA questions. The mean of the students' attitudes was calculated for each question. The graph allows us to see that the students' attitudes before the course were distributed between the geocentric and heliocentric approaches, while at the end of the course most of the students used a heliocentric or a sidereal approach.

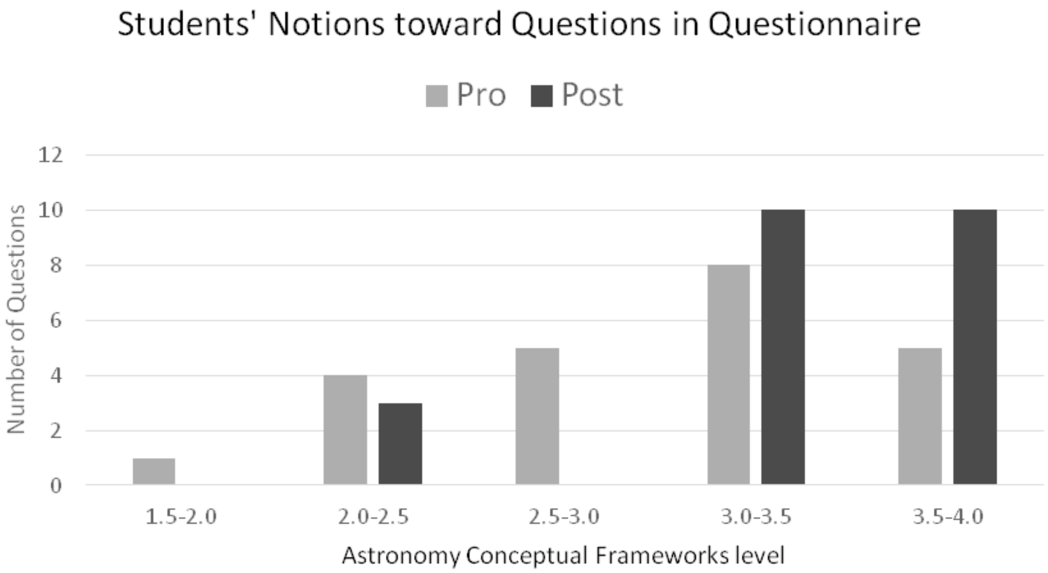

Figure 3: Change in students' attitudes towards the CFA questions from the pre to the post-course. The conceptual frameworks are represented by the values: 1 = pre-scientific, 2 = geocentric, 3 = heliocentric, 4 = sidereal.

Discussion

As part of the development of astronomy, there have been various stages in the comprehension of the universe (Špelda, 2015), from a pre-scientific approach to a geocentric and later heliocentric and then sidereal approach. These stages were described in this paper through four conceptual frameworks. This same development was found to occur along the path that the students take during their elementary studies in astronomy (Morik & Muhlenbrock, 1999). Just as these transitions were met with resistance over the course of paradigms history (Kuhn, 1962), thus, the students too, who began to organize the concepts in astronomy, found that they needed to cope with the different approaches adopted towards the structure of the universe and the structure of its components (Sadler, 1998). The results of the present research support the hypothesis that studies in astronomy require suitable knowledge in sciences and mathematics. Scientific knowledge is usually acquired over years of study in schools and colleges. The results of this research and a previous study (Pundak, 1990), which were collected with the CFA research tool, indicate that an improvement occurred in the adoption of conceptual frameworks in astronomy with the development of knowledge in sciences. It is known that a broad scientific background cannot ensure that a student will not adopt non-update astronomical approaches (Shneps & Sandler, 1988). However, the research results indicate that a scientific background enabled the respondents to undergo a paradigmatic change (Kuhn, 1962). This was especially so with regard to the transition from a geocentric to a heliocentric approach (Figure 1), and especially from a heliocentric to a sidereal approach (Figures 2 and 3). Transitions like these require familiarity with different subjects in science and mathematics such as: gravity laws, optics, theories of heat, atomic structure etc. Without fundamental understanding in these fields the student will find it difficult to abandon an intuitive approach that sees earth as the center of the universe and the other celestial bodies as its additions. This approach is best expressed in the geocentric approach, which clearly reflects the daily experiences of a human living on earth.

Conclusions

The elective course in astronomy that was studied here is divided into three parts: introduction to observational astronomy, the solar system, and development of the stars. From the results regarding the second research question it is possible to see that there was a significant change in the way students' interpreted phenomena related to the properties of stars and viewing the sun as a star. Studies that examined college students' difficulties when dealing with stellar phenomena (Bailey et al., 2012; Favia et al., 2014; Zeilik, 2002), found a long list of such difficulties and misconceived assumptions. Fox example: all stars are smaller than the sun; the sun is the only source of light in the galaxy; the sun is the brightest object in the universe; the sun will burn forever; stars in the Milky Way are as close to each other as planets are to the Sun, and so on. Dealing with these difficulties requires systematic presentation of the development of observations accompanied by the development of theoretical models that support the abundance of data collected by astronomers. The course emphasized that astronomy is a continuously dynamic active and developing science, in which questions generate responses of improved observation and astronomical models. An actual case in 2016 is the 100 years old question about gravitational waves (Miller, 2016).

The data that appear in Figure 2 testify that 39% of the students who used a heliocentric approach at the beginning of the course adopted a sidereal approach by the time it ended. In addition, 6% of the students who used a geocentric approach at the beginning of the course adopted a heliocentric approach at the end of the course. In a t-test comparing students' conceptual frameworks in astronomy before the course and after the course, it turned out that the sidereal approach strengthened among all students who studied the course.

This research applied an upgraded tool, the CFA, which evaluated students' attitudes concerning astronomy. The CFA joins the rich collection of existing tools for the diagnosing and evaluating students' knowledge in astronomy, such as: the Astronomy Diagnostic Test (ADT), Star Properties Concept Inventory (SPCI), Newtonian Gravity Concept Inventory (NGCI), Astronomy and Space Science Concept Inventory (ASSCI.). The unique contribution of CFA is that it identifies conceptual frameworks in astronomy so that it becomes possible to assess the change in astronomical approach after learning astronomy courses. The CFA relies on work done by other researchers who discovered and identified naïve conceptualizations and misconceptions in astronomy. In its design, the CFA adopted the "distractor-driven" multiple-choice (DDMC) approach. In addition to the advantages of these tools, the CFA facilitates identification and follow-up of changes in paradigms prevalent among students studying astronomy.

Learning astronomy demands conceptual understanding in several different fields, such as sky orientation, celestial bodies, light and the information it carries, nuclear reaction, spectroscopy, particles theory, and so on. Students need a frame of reference or an organizing framework, which enables them to observe and build a model of the universe and arrange all the information they learn in astronomy. This research presents taxonomy of four different conceptual frameworks, which allows the instructor to evaluate the students' orientation in astronomy. Each conceptual framework presents a different approach toward the universe. The research found that students might use the same terminology while relating to totally different ideas that reflect different conceptual framework in astronomy. Beside the theoretical approach, the paper presents a valid and reliable tool to evaluate students' conceptual frameworks in astronomy - CFA. This study applied the CFA on engineering students who studied astronomy as an elective course. The CFA indicated a significant change in conceptual frameworks in astronomy as result of this course. The assumption is that the CFA can be applied as an important evaluation tool in learning astronomy in elementary schools, high schools and the university. Further studies are needed to support this assumption.

The Research Limitations

This research was conducted on a small group of students (N=50) with specific characteristics, engineering students, most of whom were in their fourth year of studies. It would be interesting to conduct follow-up research on a larger scale among different student populations, using the CFA in order to improve the tool and enable its use for systematic study.

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Appendix

Conceptual Frameworks in Astronomy (CFA) Questionnaire

The astronomy questionnaire below is composed of 23 questions. Each question has several answers (5 or 6). Please choose the answer that in your opinion is the most appropriate answer. Your answers on this questionnaire will not influence your course grade in any way, but are intended solely for research purposes. Before choosing an answer it is important to ascertain that the question is clear to you. Often students do not accurately read the question and so they do not choose the most appropriate answer according to their opinion. A full response to the questionnaire will be considered as a presentation of a course assignment.

Thank you for your cooperation
The course research and teaching staff

Question 1

When the sun sets and night comes, is it dark all over the world?

1. Yes, because the sun has gone to a distant place and cannot emit light to the earth from there. (pre-scientific)

2. Yes, because the sun has collected its light in the evening and will not shine its light until the morning of the next day. (pre-scientific)
3. No, because the earth goes around the sun. (heliocentric)
4. No, because the earth turns on its own axis. (geocentric)
5. No, because the sun does not stop spreading light either by day or night. (sidereal/scientific)

Question 2

Can it be assumed that the earth is at the center of the solar system?
1. Yes, each component of the solar system moves around the earth. Including: the sun, the moon and the planets. (geocentric)
2. Yes, the earth is exactly in the center of the path between the sun and the margins of the solar system. (geocentric)
3. No, the earth is the nearest planet to the sun. (pre-scientific)
4. No, the sun is in the center of the solar system. (sidereal/scientific)
5. No, the structure of the solar system is not fixed and each time a different celestial body is in the center. (pre-scientific)
6. No, the structure of the solar system and its arrangement are determined by God's will that alters from time to time. (pre-scientific)

Question 3

Has the earth always existed?
1. Yes, the earth has always existed. (pre-scientific)
2. No, before it became the earth, it was covered in water. (pre-scientific)
3. No, it was created by volcanic eruption. (pre-scientific)
4. No, the sun was created first. (heliocentric)
5. No, first the stars and other galaxies were formed. (sidereal/scientific)

Question 4

Will the earth continue to exist forever?
1. Yes, the earth is a body with immense dimensions that does not alter over time. (geocentric)
2. Yes, it is part of the solar system, a stable system that operates for billions of years. (heliocentric)
3. No, in the future a comet or meteor will hit the earth and then it will cease to exist. (pre-scientific)
4. No, there is extreme heat in the center of the earth and it will erupt in the future and tear the earth into pieces. (pre-scientific)
5. No, the earth and the sun will cease to exist in billions of years. (sidereal/scientific)

Question 5

Why do we not see the stars during the day?
1. The stars are only on the dark side of the earth. (pre-scientific)
2. During the day the stars move behind the sun and so they cannot be seen. (heliocentric)
3. The stars are in the same place during the day as they are during the night, but the sunlight is many times stronger than their own light. (sidereal/scientific)
4. The stars are in the same place during the day as they are during the night, but then

they cease to shine. (pre-scientific)
5. During the day the stars do not reflect the sunlight in the direction of the earth. (geocentric)

Question 6

What is the correct order for the following bodies – from the largest to the smallest?
1. Sun, Earth, Mediterranean Sea, Moon, North Star, Saturn. (heliocentric)
2. North Star, Sun, Saturn, Earth, Moon, Mediterranean Sea. (sidereal/scientific)
3. Sun, Saturn, Earth, North Star, Moon, Mediterranean Sea. (heliocentric)
4. Earth, Sun, Mediterranean Sea, Moon, Saturn, North Star. (geocentric)
5. Earth, Mediterranean Sea, Sun, Moon, Saturn, North Star. (geocentric)
6. Sun, Earth, Moon, Saturn, North Star, Mediterranean Sea. (heliocentric)

Question 7

What do you think a star is?
1. A star is made of material which only shines at night. (pre-scientific)
2. A star is a body of solid material that was created and which reflects the sun's light. (geocentric)
3. A star is a place where it is possible to live. (pre-scientific)
4. A star is a body of burning material like the sun. (sidereal/scientific)
5. A star is a point that shines in the sky at night. (pre-scientific)
6. A star is made of shining material similar to crystal glass or a diamond. (pre-scientific)

Question 8

Why do stars remain up in the sky and don't fall onto the earth?
1. The stars move around the earth as does the moon and so like the moon they do not fall. (geocentric)
2. The stars are too far away and so earth's gravity force does not influence them. (geocentric)
3. The stars are very far away and far larger than the earth and some of them are even larger than the sun. (sidereal/scientific)
4. Other forces act on the stars that balance the forces acting on them from the sun and the earth. (heliocentric)
5. The stars stay up in the sky because that is their natural place. (pre-scientific)

Question 9

When we compare the amount of energy that is emitted by sunlight to the amount of energy needed by humans on earth it becomes clear that:
1. The sun emits <u>far less</u> energy in comparison to the energy needed by humans. (pre-scientific)
2. The sun emits <u>less</u> energy in comparison to the energy needed by humans. (pre-scientific)
3. The sun emits a similar amount of energy to the amount of energy needed by humans. (geocentric)
4. The sun emits <u>more</u> energy in comparison to the energy needed by humans. (heliocentric)
5. The sun emits <u>far more</u> energy in comparison to the energy needed by humans. (sidereal/scientific)

Question 10

Does the earth emit light from away like the moon?
1. No, the earth does not emit light like the moon, otherwise we would see that at night. (pre-scientific)
2. No, because the earth differs from the barren moon since it is mostly covered by water, forests and snow that do not reflect light. (geocentric)
3. Yes, light reaches earth, mainly from the stars, and the earth reflects the light. (geocentric)
4. Yes, sunlight reaches earth and like the moon it reflects that light. (sidereal/scientific)
5. No, from a distance the earth looks similar to the sun and not the moon. (geocentric)

Question 11

Why do both the sun and the moon rise in the east and set in the west?
1. This is the natural movement of astronomic bodies. (pre-scientific)
2. The sun draws the moon after it and they both move around the earth. (geocentric)
3. All the stars, like the sun and the moon circle around the earth. (geocentric)
4. Because of the rotational movement of the earth on its axis it seems as though the sun and the moon are moving around it. (sidereal/scientific)
5. The sun is the largest astronomic body and it drags all the other stars in a circular movement after it. (heliocentric)

Question 12

Will the sun continue to emit light forever?
1. After a long time the sun will use up all it's "fuel" and it will be extinguished. (sidereal/scientific)
2. The sun will explode in the future because it will collide with other celestial bodies. (geocentric)
3. The sun has an infinite store of "fuel" and it will light up forever. (heliocentric)
4. The sun shines due to supernatural powers and they can cause the cessation of sunlight. (pre-scientific)
5. The sun, like the earth will continue to exist forever. (pre-scientific)

Question 13

As is well-known, the solar system consists of eight planets. How do these planets differ from other stars?
1. There is no substantive difference between the planets and other stars. (pre-scientific)
2. Planets are not connected to groups of stars but instead they move between them. (geocentric)
3. Planets do not create light while the stars emit light like the sun. (sidereal/scientific)
4. Planets are in movement, while the other stars are fixed and do not move. (pre-scientific)
5. Planets are close to the earth's atmosphere while the rest of the stars are very distant from the earth. (geocentric)

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Question 14

How are stars created?
1. Reflection of sunlight. (heliocentric)
2. From phosphorescence of the material from which they are made. (pre-scientific)
3. Burning when they pass through earth's atmosphere. (geocentric)
4. Nuclear reactions at its core. (sidereal/scientific)
5. Burning on the surface of the stars. (geocentric)
6. Reflection of lightning and lights created by humans. (pre-scientific)

Question 15

What causes the changes in the appearance of the moon?
1. The change in the amount of light created on the moon at any moment. (pre-scientific)
2. Clouds on its face that hide part of the light that it emits. (pre-scientific)
3. The shadow cast by the earth on the moon. (geocentric)
4. The amount of light reaching the moon from the sun alters periodically. (heliocentric)
5. Half of the moon is always lit by the sun, but sometimes only part of it faces towards the earth. (sidereal/scientific)

Question 16

When we look at the stars in the sky through a telescope …
1. They look far larger than they appear to us. (geocentric)
2. They look very small but slightly larger than they appear to us without a telescope. (geocentric)
3. They still look like a small point. (sidereal/scientific)
4. There is a big difference in magnification between the stars, some seem very large and others remain without change. (pre-scientific)
5. You can see hills and mountains on them and if they are very near, even people. (pre-scientific)
6. They seem like small suns. (heliocentric)

Question 17

A comet is a phenomenon whereby a large white smear is seen in the skies for several weeks or months. When comets are clearly visible they are:
1. Close to the earth. (geocentric)
2. Close to the moon. (geocentric)
3. Close to the sun. (sidereal/scientific)
4. Close to the North Star. (pre-scientific)
5. Close to the center of the galaxy. (pre-scientific)

Question 18

Sometimes we can watch a variable star. This is a star that changes its brightness. Sometimes its brightness is stronger than its regular strength and sometimes weaker. These variations in the star's brightness stem from:
1. The influence of supernatural powers. (pre-scientific)
2. Changes in the amount of light reaching the star from the sun. (heliocentric)
3. Changes in burning processes within the star's core. (sidereal/scientific)

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4. The movement of the star through dust clouds. (geocentric)
5. The movement of the star through the atmosphere. (geocentric)

Question 19

Astronomers report a phenomenon known as the Supernova. This phenomenon occurs when a very bright star suddenly appears in the sky that was not seen before. The phenomenon of the Supernova stems from:

1. The need to warn residents of the earth of a danger. (pre-scientific)
2. Processes occurring in the earth's atmosphere. (geocentric)
3. Processes occurring near the moon. (geocentric)
4. Processes connected with the sun. (heliocentric)
5. Processes occurring in the star's core. (sidereal/scientific)

Question 20

To which distance does the earth's gravity have an effect?

1. Approximately ten kilometers above sea level. (pre-scientific)
2. To the end of the atmosphere – approximately four hundred kilometers above sea level. (geocentric)
3. Up to the moon – approximately four hundred thousand kilometers from the earth. (geocentric)
4. Up to the sun – approximately a hundred and fifty million kilometers. (heliocentric)
5. To infinity. (sidereal/scientific)

Question 21

The Orion constellation is a group of stars. How can we describe the stars in this group?

1. The stars in this group are very close to one another in space. (pre-scientific)
2. The stars in this group are at a similar distance from the sun. (heliocentric)
3. The brightest stars in the Orion group are the stars closest to the earth. (geocentric)
4. The stars in Orion are only in this order for part of the time during the year. For the rest of the year they alter their position in relation to each other. (pre-scientific)
5. The physical size of most of the stars in Orion is small in comparison to the size of the earth. (geocentric)
6. The stars in Orion are located at almost same direction, but their distances from Earth are very different. (sidereal/scientific)

Question 22

How can scientists know what stars are made of?

1. Stardust reaches the earth and can be analyzed. (geocentric)
2. Astronomers succeed in collecting samples from stars and bringing them to earth. (geocentric)
3. Astronomers succeed in understanding what the sun is made of and can thus explain what stars are made of. (heliocentric)
4. Astronomers succeed in analyzing the light arriving from the stars and thus can know their composition. (sidereal/scientific)
5. The stars are so distant that nothing from them reaches the earth and so it is impossible to know their composition. (pre-scientific)

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Question 23

To what extent do the stars in the sky change their shape over time?

1. The stars in the sky do not change their shape. They remain unchanged. (pre-scientific)
2. There are insignificant changes in the stars but in principle their shape remains fixed over time. (geocentric)
3. The stars change to a certain extent over time when their color becomes light blue to dark red. (pre-scientific)
4. Over billions of years stars change their shape in a significantly, but they do not cease to emit light. (heliocentric)
5. Over billions of years stars are liable to disappear and new stars may be created. (sidereal/scientific).

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