Available online at www.sciencedirect.com

ScienceDirect

Advances in Space Research 61 (2018) 478–486

ADVANCES IN SPACE RESEARCH (a COSPAR publication)

www.elsevier.com/locate/asr

Fostering research aptitude among high school students through space weather competition

M. Abdullah [a,c,*], R.A. Majid [b], B. Bais [c], N.S. Bahri [a], M.F. Asillam [d]

[a] Space Science Centre (ANGKASA), Institute of Climate Change, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia
[b] Department of Education and Community Wellbeing, Faculty of Education, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia
[c] Department of Electrical, Electronic and Systems Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia
[d] National Planetarium, Ministry of Science, Technology and Innovation (MOSTI), Jalan Perdana, 50480 Kuala Lumpur, Malaysia

Received 3 August 2016; received in revised form 19 August 2017; accepted 27 August 2017
Available online 2 September 2017

Abstract

Cultivating research culture at an early stage is important for capacity building in a community. The high school level is the appropriate stage for research to be introduced because of students' competitive nature. Participation in the space weather competition is one of the ways in which research aptitude can be fostered in high school students in Malaysia. Accordingly, this paper presents how research elements were introduced to the students at the high school level through their participation in the space weather competition. The competition required the students to build a system to detect the presence of solar flares by utilizing VLF signals reflected from the ionosphere. The space weather competition started off with proposal writing for the space weather related project where the students were required to execute extensive literature review on the given topic. Additionally, the students were also required to conduct the experiments and analyse the data. Results obtained from data analysis were then validated by the students through various other observations that they had to carry out. At the end of the competition, students were expected to write a comprehensive technical report. Through this competition, the students learnt how to conduct research in accordance to the guidelines provided through the step by step approach exposed to them. Ultimately, this project revealed that the students were able to conduct research on their own with minimal guidance and that participation in the competition not only generated enjoyment in learning but also their interest in science and research.

Keywords: Fostering research aptitude; High school student; Space weather; VLF; Solar flare

1. Introduction

Malaysia is preparing towards becoming a developed nation in less than three years from now. Hence, in the pursuit of becoming a developed country, Malaysia needs more of its citizens to contribute to the field of science and technology rather than merely becoming passive consumers of technology. Malaysia needs a pool of young scientists and technocrats who have the capabilities, creativity and innovativeness to take the lead in various fields, including in Science, Technology, Engineering and Mathematics (STEM). Generally, the aim of science education in Malaysia is to nurture science and technology, as well as culture among its young citizens by emphasising on the development of individuals who are not only competitive, dynamic, robust and resilient but also capable of mastering scientific knowledge and technological competency (Curriculum Development Centre, 2003). As the country is moving forward towards a developed nation status,

* Corresponding author at: Space Science Centre (ANGKASA), Institute of Climate Change, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia.
E-mail address: mardina@ukm.edu.my (M. Abdullah).

http://dx.doi.org/10.1016/j.asr.2017.08.028
0273-1177/

Malaysia needs to produce a generation of young people who has positive attributes such as creativity, innovativeness, and critical thinking so as to ensure that the country has a pool of talents that are scientifically oriented, knowledgeable and forward looking who could contribute to scientific and technological developments at the global scale in the future. This young generation should also possess the capability to manage natural resources in a responsible manner (Curriculum Development Centre, 2003).

Similar to other countries in the world, Malaysia is also finding it a challenge in gauging students' focus and commitment in the learning of science at the secondary level, all the more so given the crucial role of science in today's society. In order to realize this mission, the government of Malaysia has set up a goal to produce one million specialists in STEM related fields from the population of thirty million Malaysians by the year 2020. The government has taken serious action to realize this goal, for example through the launch of several new strategic programmes in 2010 such as New Economic Model, Economic Transformation Programme and the Government Transformation Plan. This is because STEM is closely linked to the country's economic development plan whereby the aim is to generate wealth and to prepare Malaysia towards attaining the status of a developed country by 2020 (Curriculum Development Division, 2016). Several approaches have been developed by the government to achieve these goals such as increasing STEM awareness among students, teachers, parents and the community, improving skills and competencies of teachers, emphasising the importance of using ICT in teaching and learning, inculcating innovative and engineering design thinking, and promoting higher-order thinking skills (HOTS) as one of the new approaches in the teaching and learning process in schools.

STEM approach can educate students on how to solve problems encountered in the real world through an integrated manner by emphasising application of knowledge, skills and values from various disciplines. Through the STEM approach, students learn how to investigate, design, evaluate, carry out inquiry-based learning activities, innovate and reflect, and collaboratively engage with problem-solving activities. This approach also provides the opportunity for students to understand relevant issues, and promotes creative and critical thinking through the process of solving real world related problems. This form of learning is important as it would encourage students to learn and use technology independently, and prepare them to be more competitive and ready to face challenges at the global level. Research in the past two decades has recorded a decline in the number of student participation in STEM (Osborne et al., 2003; Barmby et al., 2008; Gottfried et al., 2009; Potvin and Hasni, 2014). Decline in enrolment may be attributed to the interest and confidence levels of the students. Many students have the impression that the STEM fields are difficult subjects to learn, and this sense of difficulty results in the students having low confidence in getting good results in public examinations, and thus, shying away from enrolling in STEM related subjects at the upper secondary school level or even in STEM courses at the university level.

In Malaysia, the space science syllabus is included in the science subjects and is taught to students from Year 4 (10 years old) at the primary school level and continues to be offered at the secondary school level. The main topic in the space science syllabus is earth and the universe which covers the earth, the sun, the moon, the solar system, lunar eclipses and constellations. At the secondary school level, students are taught about the earth and space exploration in more detail. Some of the space science activities involved in the investigation of our solar system have equally significant implications for understanding of the evolution of life on earth and how the earth has become and remains habitable. In particular, studies of the sun and the potential for life on other planets in our system provide examples of the linkages between space exploration and earth sciences (Chung et al., 2010). Thus, in the attempt to inculcate interest in STEM and foster research aptitude among high school students in Malaysia, a space weather competition organised by Space Science Centre, Universiti Kebangsaan Malaysia was introduced. This paper will present a description and discussion about the space weather competition which aimed to foster research aptitude among high school students in Malaysia.

2. Implementation of the competition

Previous research has shown that students understand scientific ideas best when they actively apply their knowledge while engaging in the practices of science. Learning through practice helps students of all ages understand how scientific knowledge develops and gives them an appreciation of the wide range of approaches that are used by scientists to investigate, model, and explain the world. Engaging in the practices of science also pushes students to use their knowledge and to reflect on their own understanding of scientific ideas. They thereby gain a more flexible understanding of scientific explanations of the natural phenomena and can develop a more critical perspective of scientific claims. Abrahams and Millar (2008) argued that students should be given the opportunity to carry out exciting experimental and investigative work. Thus, in the space weather competition, practical work or hands-on activities were included, not only to spark the students' interest in science but also to engage them in the learning process through active student participation and involvement.

The space weather competition was opened to all high school students in Malaysia who were between 16 and 17 years of age. These were form four (16 years old) and form five (17 years old) students in Malaysian secondary schools. The first phase of the competition required the students to answer a space science test which was conducted online through the National Space Science Centre website, www.angkasa.gov.my. However, only 152 students from 38 schools took part in this competition. Each school was rep-

resented by one team consisting of four students who were supervised by two teachers as their mentors. The teams were mixed gender groups. Based on the online test, only 20 teams (80 students) were qualified to enter the final stage. The space weather competition was a Science Research Based Competition (SRBC) and was considered as part of the extra-curricular activities that took place during non-school hours. SRBC is also known as a competition that encouraged active research, investigation or experimentation, involving innovation and new findings or knowledge of new improved product, ideas, processes or services (Amri, 2012).

The second phase involved education and innovation. The teachers who acted as mentors were trained in a workshop conducted by the organizer. The aim of the workshop was to train the teachers in using the modules provided. In doing so, it is expected that these teachers would be able to guide the participating students when carrying out the experiment so that the students would be able to obtain the expected data, and later interpret their findings. The students carried out the relevant activities for the competition for a period of four months. Each team then had to upload their proposal, two progress reports and a final technical report for the third phase of the competition which was the evaluation process. The evaluation was conducted by a panel of judges who visited the participating schools to observe the set up and to have a dialogue with the respective team members in each school that participated in the competition.

In this competition, the teams who qualified to enter the final stage had to go through several crucial steps in carrying out their research. The first step involved the writing of the research proposal. This included student identifying questions about the topic, identifying possible independent and dependent variables, researching ways in which connections have already been made between the variables and writing a hypothesis to test their idea. The second step involved review of literature. To complete the proposal writing process, they needed to carry out a review of past literature or what is known as literature review. This process required the students to embark on online research about the topic, as well as library research. The students were made aware that not all online information available is reliable, accurate, or appropriate. Therefore, they had to carefully evaluate each internet source. This process required guidance from the teachers or mentors so that students would be able to learn how to identify useful and relevant resources. Reading technically written literature in the field helped the students to become familiar with scientific writing and reports. Additionally, for this competition, the students were also given access to educational websites such as the *Space Weather Center* that is supported by the National Science Foundation (NSF) and National Aeronautics and Space Administration (NASA) so that they could obtain the latest and current information about space weather.

Based on the literature review and background research, students then had to identify major issues, problems, or questions about their projects and the relevant topics. This naturally led them to the task of formulating research questions for the research project. The goal of embarking in the research was for students to find answers to their research questions. In order to do so, the students had to develop research methods and procedures that would enable them to find answers to the research questions they formulated. Thus, the third step involved the students developing suitable research methods and procedures including conducting the experiment and analysing the data to understand the scientific phenomenon being studied. Consequently, it was also necessary for them to explain or interpret the results, and present these in their final report.

As mentioned earlier, the students were required to write a research proposal. The proposal included six essential subtopics as listed and described below.

(i) Title – This should be concise, descriptive, and reflect the focus of the research project.
(ii) Background and rationale – This section is essential as it would help to explain the background and the issues covered by the students' proposed research, as well as the justification for conducting and embarking on the research project. A brief description of the literature review on the relevant topics needs to be included to highlight the research gaps that require further investigation. This will lead to the statement of the problem about the topic to be researched.
(iii) Research questions – Students will have to formulate clear and concise research questions. The research questions need to be well defined and focused to facilitate investigation within the given time frame.
(iv) Theoretical framework for the methodology – Students will have to explain the theoretical foundation upon which the project was based on and the rationale for utilizing the resources in conducting the research project.
(v) Method – This is a very important section to relay information about the specific research process and procedures. The admissions committee requires this vital information on how the students plan to tackle their research problem. The method section includes the working plans and description of activities necessary to conduct and execute the research project. This section should consist of detailed description of how the participating students intended to conduct the research. Additionally, the students are also expected to demonstrate in this section their knowledge of alternative methods and to convince others that their approach is the most appropriate and most valid to address the research questions formulated. Participating students are expected to explain about the data they intend to collect, including how the data

are to be collected and analysed. Explanation also needs to be given in relation to the specific skill sets that the students need to have in order to conduct and execute this project. The students will need to explain whether they already possess the skills or require further training to proceed with the project. The following is a description of the methodology used by the students in this competition.

1. Antenna development

First, the loop antenna needs to be designed and built according to the specification provided. In the competition, the students were required to develop their own antenna. Students were free to shape their own loop antenna. Thus for the competition, the antenna did not need to be built to precise dimensional specifications nor its wire wound to exact tolerances, nor did it need to be assembled or constructed exactly as shown in the document provided to the students. This antenna is used to pick up the VLF signals reflected from the ionosphere that are transmitted from all over the world. The antenna is a wire loop antenna that can be built in various shapes and sizes. The shape can be rectangular, square, circle, hexagon to name a few. Larger antenna will have better signal reception (Wong et al., 2012; Abdullah et al., 2012).

Fig. 1. Students making the VLF loop antenna to capture the VLF signal from various VLF transmitter stations. This loop antenna is 1 m^2 in diameter, with 29 turns.

Fig. 1 shows students making the VLF loop antenna to capture the VLF signal from various VLF transmitter stations. The loop antenna is 1 m^2 in diameter with 29 turns.

2. Preamplifier assembly

Next, the electronics components need to be assembled on the PCB and soldered to build the preamplifier. The preamplifier is used to amplify the VLF signal as the signal received from the antenna is typically very low in amplitude (0.1 mV). This will amplify the signal a thousand times so that it can be detected by the sound card in the data logger. The sound card's task is to convert the signal from analogue to digital. The original preamplifier designed by Stanford University is in the form of double layer printed circuit board (PCB). This type of layout is not suitable for manual assembly; therefore, we simplified the PCB to a single layer layout (Wong et al., 2012; Abdullah et al., 2012). Then, a program which is provided that runs on the personal computer (PC) tracks the VLF transmission signal strengths and processes the data. Since the reflected radio signals are strongly influenced by the Sun's radiation, plotting the signal strengths over time should tell the students when there is a solar flare on the Sun (Stanford University, 2007). Fig. 2 shows the PCB layout and the PCB after being assembled with the components.

3. Software installation, system testing and data collection

The next stage is the software installation and testing. The participating students had already learnt basic electronics during their third year in secondary school. This part of the experiment was also explained in the module provided. Data was collected continuously to monitor the occurrence of the solar flare. The third segment was a data logger which consisted of a computer with a sound card and configuration software. It was recommended that the sound card is a High Definition audio card with a minimum sampling rate of 96 kHz. This signal would be processed by the software and the output signal would then be plotted (Wong et al., 2012; Abdullah et al., 2012). Students had to run all these processes carefully to ensure that the SID system functioned fully and properly.

4. Collecting and analysing data

Once the system was already completed, the students had to analyse the data. Students were required to plot the data in local time to detect its diurnal variation. They also had to carry out a comparison

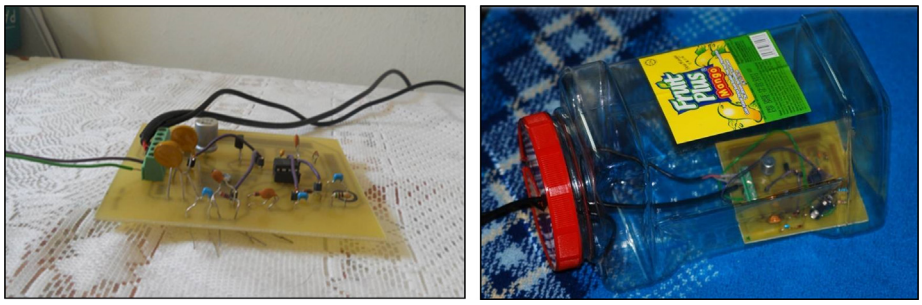

Fig. 2. PCB layout and the PCB after being assembled with the components.

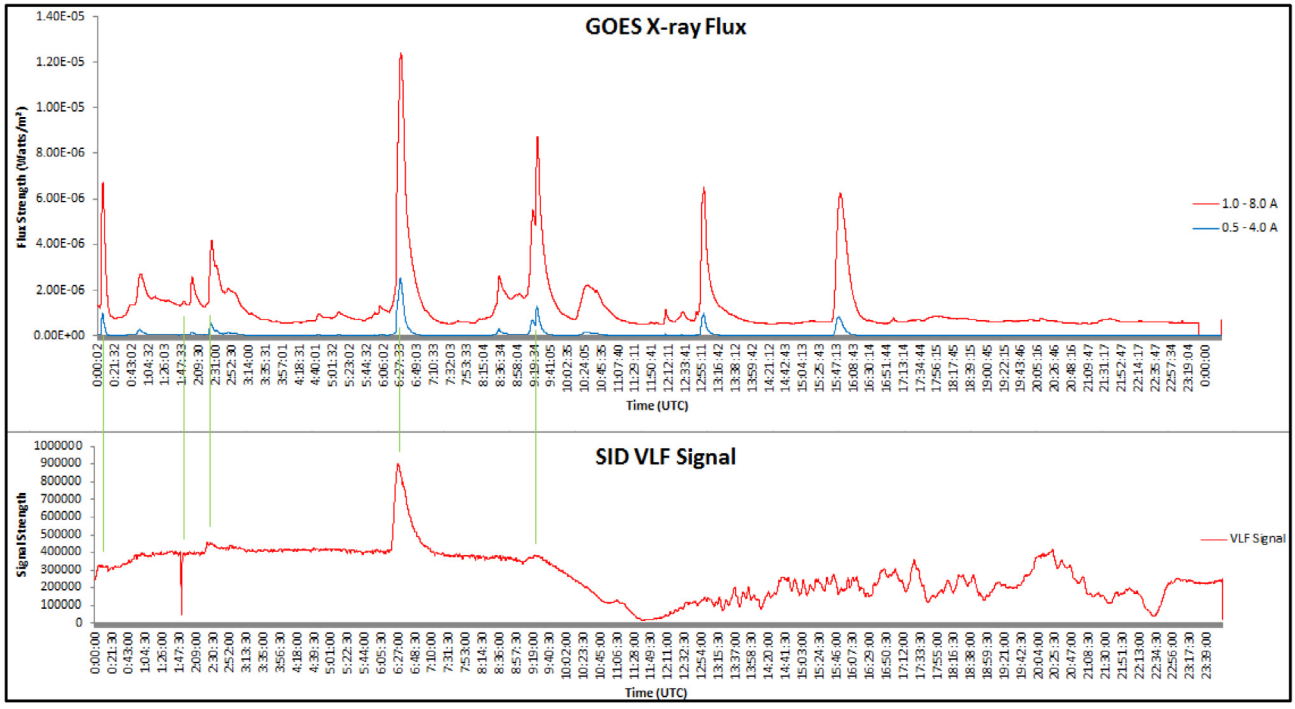

Fig. 3. Data taken with the SID monitor by students and comparison of data with GOES satellite.

between the Geostationary Operational Environmental Satellite (GOES) data, which is available online with the data they received. This process is important to validate that the system can detect solar flares. Fig. 3 shows data taken with the SID monitor by the students and comparison of data with GOES satellite.

5. Presenting the result

One of the most important aspects of research is sharing what have been learnt. When students share their research, they are contributing to the scientific process by adding more information to a larger body of knowledge about a given topic. Students will also learn how to write and format their research report. In this competition, the students had to share their findings with others through oral presentations. Indirectly, this sharpened their communication skills. Fig. 4 shows some of the students presenting their research findings.

(vi) Timescales – This is better known as the milestone for the project which is not only important but crucial. It maps out a reasonable schedule of the students' research work to facilitate all involved in the monitoring of their progress and in managing the project effectively. The milestone is a measure of students' research progress with the intended finishing date so that all those involved would not underestimate the amount of time required for them to finalise their drafts into a completed research.

Throughout the competition, it was clear that the students demonstrated behaviours associated with high motivation such as being proactive in planning their projects, initiating problem solving activities, and dealing with school staff to assist them in setting up the antenna. They asked a lot of questions to the teachers and organizers whenever they faced problems that they could not solve on their own. The students took responsibility for their own learning. The students took charge of their own activities in conducting this project in their effort to win the

Fig. 4. Students presenting their project.

competition. In some cases, the students worked beyond the required topics. The students had a sense of ownership for their own learning. They spent more time solving problems related to this project than on traditional assignments. However, a drawback of this approach was that of limited cooperation observed between the team members of a team. Nevertheless, the participating students had to overcome this limitation because after the competition they were required to carry out presentations where they had to share their ideas, innovations, and solutions. Additionally, the novelty of the competition is that students may simply appreciate and like responding to an authentic challenge. When students have a meaningful purpose of doing something, they would be intrinsically motivated to complete the challenge. In the case of the space science competition, its aim was to promote awareness and better understanding of space weather among high school students in Malaysia, in addition to cultivating students' interest in research through the usage of UKM's SID Ionospheric monitor.

This is the first time a national competition on space weather for educational purpose has been proposed in Malaysia. The aim of the competition was to create awareness among high school students and to attract them to carry out research. Learning space weather through research and competition enhanced the high school students' interest in space science education. This competition provided the students with the opportunity to conduct experiments after class hours. This competition also allowed the students to learn essential team-building and problem-solving skills and provided more opportunities for the students to participate in hands-on and project-based learning. Clearly, they were able to carry out scientific research, discuss, identify and develop their own strategies to finish the tasks given. This competition naturally involves 'showing' learners' things, or putting them into situations where students can see for themselves the things, ideas or concepts being learnt. These enrichment activities are perceived as important and critical as it allowed the students to learn in depth about solar activity and explore means of detecting solar flare by using the UKM SID kit and their self-built antenna. Thus, knowledge of the solar system which they had learnt theoretically in its abstract form became more meaningful.

3. Discussion

Nowadays, exposure and experience in the field of science and technology are needed in nurturing interest among students who are involved in this field. The advantages of experience based learning which includes hands-on activities and on-site learning are that it empowers students to take charge and to play an active role in their own learning (Tuan and Meerah, 2013). In today's world, to make science interesting and to capture students' interest in the subject, science must be taught across disciplines and be presented in exciting, lively forms (Wallis and Steptoe, 2006). Improving the state of science education in Malaysia has become a national priority. One response to this problem has been the implementation of STEM enrichment programmes designed to increase the number of students' enrolment in graduate programmes in science. Current research indicates that these enrichment programmes have positive effects on students' performance, degree completion, interest in science and graduate enrolment. Through these kinds of programmes, students are encouraged to

become responsible in their own education and to develop a passion and joy for learning. As students pursue creative enrichment opportunities, they learn to acquire communication skills and enjoy creative challenges (Renzulli and Renzulli, 2010). Many informal education encounters in the environment provide learners with opportunities to manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world. In fact, most science and nature centres are built around the concept of exploration. Visitors are not given one correct scientific explanation of a natural phenomenon. Rather, they are presented with a phenomenon and then led through a process of asking questions and arriving at their own answers which may then be verified against current scientific explanations. Similarly, through participation in the space weather competition, the students' interest in the area of science increased as they were given the opportunity to learn actively on their own through hands-on activities and real world tasks with guidance from the teachers who acted as their mentors.

Throughout the competition, students had to design their own antenna using new or recyclable materials. They have learnt about antenna in the content of their form four Physics, and learnt about electronics in their form three Live Skills Education subject. Students have also learnt about the solar system in the Science subject when they were in form three. For the competition, they needed to study a bit deeper on the theories behind solar flares to understand the essence of solar flare detection. These processes nurtured the students' research skills, particularly in solving problems about solar flare detection. Participating students also had to plan their research procedures, analyse the data, and interpret the results. They were also required to systematically analyse and analytically interpret the results obtained from their research based on previous findings and other related literature. Consequently, a systematic approach to the development of students' soft skills trains them to be independent in problem solving activities and polish their lifelong learning skills. Through exposure to research process skills, students will (i) become familiar with the steps required for research, (ii) understand a framework that supports search for information, (iii) internalize a variety of research procedures for independent use; and (iv) adapt suitable procedures to find solutions to the situation. Fig. 5 presents students test result before and after the competition. The test was more of general questions about space science and SID. The findings show that the students improved their knowledge about space science after the competition.

The students who participated in this competition were interviewed in focus groups after the competition ended. Based on data from the interview and observations, it can be concluded that the students enjoyed embarking in this challenge and in conducting research on solar flare. Interestingly, the students also suggested that this programme should be continued in the future as research activities can cultivate their critical and creative thinking skills. The following excerpts from the interview sessions revealed that the students enjoyed participating in the competition and perceived learning more than just 'knowledge' during the competition.

> *"Through this competition, we have gained a lot of knowledge especially about the space, which we usually don't have the chance to learn from our daily classes"*

> *"To build the antenna, we have faced many problems or hurdles. For example, lack of time because of preparing for exams. Without full cooperation from all the members, we would not make this project a success. Cooperation is very important in whatever we do, when we are stepping into society, we need to cooperate with other people, and through this project, we had really learned the important of cooperation"*

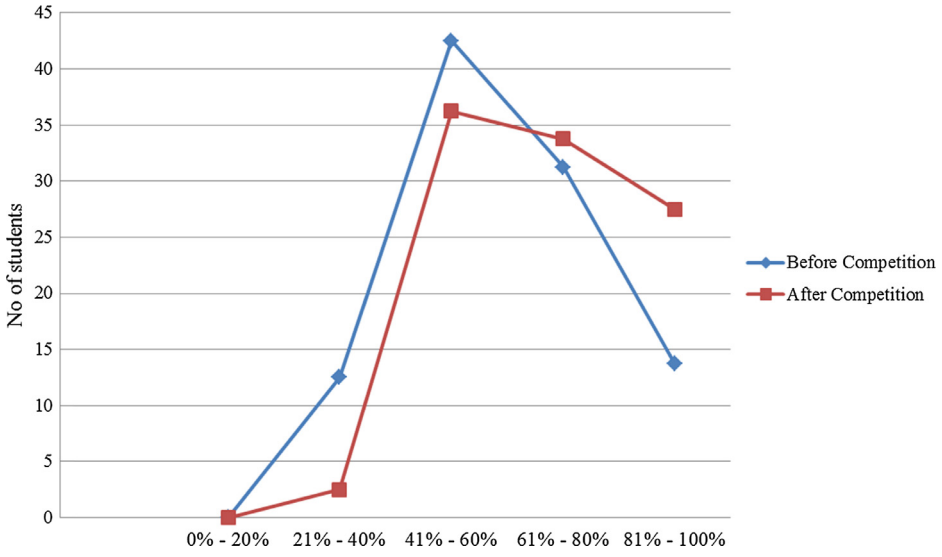

Fig. 5. Students' test results before and after the competition.

"We learn that in whatever things we do, we ought to learn from our mistakes. When we were carrying this project, we made many mistakes. When we make mistakes, we try our best to solve the problems. We learn from our mistakes and sit together thinking of the solutions for the problems we faced".

"This project makes us know more about sun and what happens on it by detecting the flare. This project also makes us more independent by finding ways how to solve the problems that we encountered by our own."

Ultimately, the competition has helped develop many important skills in the students who participated. The students had to read beyond textbooks and carry out investigations about solar flare before they carried out the project. It developed skills related to self-study, such as the ability to use the library and computerized communications or the ability to follow up information through the website, books and magazine. Writing up their research report helped to promote the development of important study skills such as preparing and writing reviews and summary, drawing and presenting tables and graphs, and technical and proposal writing skills. These tasks also gave the students opportunity to acquire skills related to research and development such as gathering data, executing simple experiments, reaching conclusions, writing descriptions and reporting, developing the ability for observation and conducting field work activities. It also developed important soft-skills such as skills for working and cooperating in a team, taking personal and group responsibility for carrying out tasks and developing good habits of work, cleanliness, precision and so on. Students agreed that this competition also developed their interest and desire to expand and deepen their knowledge in space science and solar activities. Practising research skills in this meaningful context empowered the students to become active and responsible learners.

4. Conclusion

By enabling students to produce and analyse real scientific data from their own instrument, it will encourage more young people to become interested in the exciting field of Space and Earth. The skills that students accumulate as they develop and carry out their own research project can be used in their future studies and professional life. Ultimately, the goal of this competition is to help students acquire useful, transferable skills such as critical and creative thinking, data collection and analysis, technical writing, team work and oral communication skills which are all relevant skills for the job market in the 21st century. Students mentioned that they have gained various types of experience and knowledge; for example, they learnt how to effectively work in a team as well as how to support their opinion both in writing and orally through the proposal writing and the presentations they conducted. Thus, this program is important to nurture research enthusiasm among high school students. At the same time, it can increase their interest in becoming scientists or researchers who are capable of innovating and introducing new products in the global market in the future.

Clearly, the space science competition not only helps students to develop their understanding of science, it also helps them to appreciate that science is based on evidence. They are able to acquire hands-on skills that are essential to progress in science. Through the competition, the students are given the opportunity to learn and polish their research skills, such as asking questions and defining problems, planning and carrying out investigations, analysing and interpreting data, using information and computer technology, constructing explanations, engaging in argument from evidence, and obtaining, evaluating and communicating information. To conclude, research skills in science education are important for students who are the future generation of Malaysia, especially in meeting the demands of work in the 21st century. Students should therefore be given the opportunity to do exciting and varied experimental and investigative work as part of their learning process in science education in the effort to inculcate interest in STEM and foster research aptitude among our younger generation.

Acknowledgment

The authors would like to express their appreciation to the teachers and students in Malaysia for their participation in this project. Gratitude is also extended to the Ministry of Education Malaysia, National Space Agency Malaysia, Stanford Solar Center and Society of Amateur Radio Astronomers of Stanford University for their support. Special thanks is mentioned to Dr. Deborah Scherrer for the kind support. The project was funded by UKM's internal grant (Komuniti 2012-016) and the Ministry of Science, Technology and Innovation (MOSTI) grant (KK 2013-008).

References

Abdullah, M., Bais, B., Hasbi, A.M., Abd Majid, R., Yatim, B., Mohd Ali, M.A., Bahari, S.A., Mat Daud, N., Mokhtar, M.H., Mohd Zain, A.F., Asillam, M.F., 2012. Development of UKM-SID teaching module for space science education. Proc. – Soc. Behav. Sci. 102, 80–85.

Abrahams, I., Millar, R., 2008. Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. Int. J. Sci. Educ. 30 (14), 1945–1969.

Amri, N.S.R., 2012. The Effects of Science Research Based Competitions on High School Students "Responses to Science". Doctoral thesis, University of York, Heslington, UK. Available from <http://etheses.whiterose.ac.uk/4626/7/The%20Effects%20of%20Science%20Research%20Based%20Competitions%20on%20High%20School%20Students%27%20Responses%20to%20Science%20edt.pd>.

Barmby, P., Kind, P.M., Jones, K., 2008. Examining changing attitudes in secondary school science. Int. J. Sci. Educ. 30 (8), 1075–1093.

Chung, S., Ehrenfreund, P., Rummel, J., Peter, N., 2010. Synergies of space exploration and Earth science. Adv. Space Res. 45, 155–168.

Curriculum Development Centre, 2003. Integrated Curriculum for Secondary Schools: Curriculum Specifications Science Form 1. Ministry of Education, Putrajaya.

Curriculum Development Division, 2016. Ministry of Education, Sharing Malaysian Experience Participation of Girls in STEM Education. UNESCO International Bureau of Education (IBE), Geneva, Switzerland.

Gottfried, A.E., Marcoulides, G.A., Gottfried, A.W., Oliver, P.H., 2009. A latent curve model of parental motivational practices and developmental decline in math and science academic intrinsic motivation. J. Educ. Psychol. 101 (3), 729–739.

Osborne, J., Simon, S., Collins, S., 2003. Attitudes towards science: a review of the literature and its implications. Int. J. Sci. Educ. 25 (9), 1049–1079.

Potvin, P., Hasni, A., 2014. Analysis of the decline in interest towards school science and technology from grades 5 through 11. J. Sci. Educ. Technol. 23, 784–802.

Renzulli, J.S., Renzulli, S.R., 2010. The schoolwide enrichment model: a focus on student strengths & interests. Gifted Educ. Int. 26 (2–3), 323–352.

Stanford University, 2007. SID Users Manual Solar Sudden Ionospheric Disturbance Monitor. Available from <http://solar-center.stanford.edu/SID/docs/SID_Manual.pdf>.

Tuan, S.T.M., Meerah, T.S.M., 2013. Outdoor education: an alternative approach in teaching and learning science. Asian Soc. Sci. 9 (16).

Wallis, C., Steptoe, S., 2006. How to Bring Our Schools out of the 20th Century. Available from <http://www.time.com/time/prinout/0,8816,1568480,00.html>.

Wong, P.W., Abdullah, M., Hasbi, A.M., Bahari, S.A., 2012. Development of a VLF receiver system for Sudden Ionospheric Disturbances (SID) detection. In: IEEE Asia-Pacific Conference on Applied Electromagnetics, pp. 98–103.