# Enhancing Aviation High School Students' Interest in Physics and Engineering: An Interdisciplinary Program on Aviation Weapon Systems

Aharon Gero
Department of Education in Technology and Science, Technion – Israel Institute of Technology, Technion
gero@technion.ac.il

***Abstract:*** *The study program "Introduction to aviation weapon systems" was first offered in 2012 by a leading Israeli high school that is affiliated with the Israeli Air Force. This interdisciplinary program integrated physics and engineering, emphasizing the strong affinity between the two disciplines and focusing on the structure and principle of operation of weapon systems used in aviation, such as laser-based systems and thermal systems. The program was attended by twenty 12th graders majoring in mathematics and physics who were designated to serve, upon post-graduation enlistment, in the Israeli Air Force's technological support system. The program aimed to enhance the students' interest in physics and engineering and encourage them to continue with advanced studies in these disciplines. The study described here used qualitative tools to characterize changes in students' attitudes towards physics and engineering as a result of their participation in the program. The research indicated that following the program, the students' interest in physics and engineering increased, as did their desire to continue with more advanced studies in the subject.*

**Keywords:** engineering education, physics education, interdisciplinary education, high school students

## 1. Introduction

Many high-school programs integrate engineering principles into their science and mathematics studies (Harwood & Rudnitsky, 2005; Ewers, 2010; Bagaria et al., 2011). The goal of such curricula is to enhance the students' interest and encourage them to develop careers in these areas, especially in light of shortages in engineering professionals (NSB, 2008), which stem, among other things, from a lack of exposure to engineering during the high school years (Rockland et al., 2010).

The interdisciplinary study program "Introduction to aviation weapon systems" was first offered in 2012 by a leading Israeli high school that is affiliated with the Israeli Air Force. The program integrated physics and engineering and focused on the structure and principle of operation of weapon systems used in aviation, such as laser-based systems and thermal systems. The program comprised three weekly sessions, for a total of 10 study hours, and was attended by twenty 12th graders majoring in mathematics and physics who were designated to serve, upon post-graduation enlistment, in the Israeli Air Force's technological support system. The program aimed to enhance the students' interest in physics and engineering and encourage them to continue with advanced studies in these disciplines.

The research presented here characterized changes in students' attitudes towards physics and engineering as a result of their participation in the program.

## 2. Theoretical Background

Interdisciplinarity is the cooperation between experts from different disciplines in order to create interaction between the disciplines or reorganize concepts and methodologies taken from the said disciplines (Piaget, 1972). According to Klein (1990), the more pronounced characteristic of interdisciplinarity is integration or synthesis of knowledge from different disciplines. Thus, interdisciplinarity differs from multidisciplinarity, which is defined as the presentation of several disciplines without attempting to integrate them.

Ivanitskaya et al. (2002) propose a four-stage interdisciplinary learning model:

- Unidisciplinarity, in which the learner focuses on one relevant discipline and acquires unidisciplinary knowledge;
- Multidisciplinarity, in which the learner focuses on several disciplines and addresses each one of them separately. At the end of this stage, the learner has acquired multidisciplinary knowledge;
- Limited interdisciplinarity, in which the learner integrates several disciplines around a central topic;
- Extended interdisciplinarity, in which the learner is able to transfer the interdisciplinary knowledge structure to new subjects.

Evaluations of high school study programs that integrate engineering with science indicate an improvement in the learners' attitudes toward science and engineering (Nugent et al., 2010; Rockland et al., 2010) and an enhancement of the learners' desire to continue studying these subjects (Brand et al., 2008).

At the same time, interdisciplinary teaching also attracts criticism that stems from a concern that such teaching focuses on the interdisciplinary aspects at the price of a more shallow treatment of the disciplinary content. In addition, it is also important to note that teachers who teach interdisciplinary subjects must contend with teaching a discipline (or disciplines) they were not trained to teach (McComes & Wang, 1998). Thus, it may be concluded that the development and implementation of interdisciplinary programs involve fundamental challenges and that not all such programs will end successfully (Panaritis, 1995). Spelt et al. (2009) review the conditions necessary for an interdisciplinary program to be successful. Among these conditions, we note curiosity on the part of the learner and a syllabus that balances the interdisciplinary and disciplinary components.

## 3. The Program

The program focused on the structure and operation principle of weapon systems used in aviation, such as laser-based systems and thermal systems. The program, which integrated engineering and physics, can be classified as a limited interdisciplinary program (Ivanitskaya et al., 2002). In light of the challenges involved in developing interdisciplinary curricula, as specified in the theoretical section, we made sure to balance the interdisciplinary components of the program with its disciplinary components, as illustrated in Table 1. In addition, to ensure the teacher's mastery of the different disciplines, the teacher who was selected holds advanced academic degrees in electronic engineering and in physics.

The teaching approach in the program was based on problem solving with the objective of demonstrating to the students how engineers work (Harwood & Rudnistsky, 2005). The books "Introduction to electronic defense systems" (Neri, 2001) and "Creative problem solving and engineering design" (Lumsdaine et al., 1999) were used in the development of the program.

The program began with an introductory session that included a review of mechanical waves and electric and magnetic fields, topics that were already studied in physics class in the past. Next, the topic of electromagnetic waves was taught and the electromagnetic spectrum was described. The second session, which dealt with laser-based weapon systems, addressed the physics of lasers (properties and principle of operation), radiation detectors, and aviation-engineering applications, such as laser-guided weapons. The final session focused on thermal weapon systems. After exploring the physics of black body radiation, engineering methods for cooling detectors were reviewed, addressing the concept of the "signal-to-noise ratio". Finally, the structure and principle of operation of thermal imaging systems and of the various generations of heat-seeking missiles were described. Table 1 presents the program curriculum in detail.

It should be mentioned that during the sessions, emphasis was placed on the strong affinity between physics and engineering, and the engineer's work as a problem-solver was demonstrated. Thus, for instance, while describing the development process of heat-seeking missiles and the appropriate countermeasures, we used the black body radiation law. In this context, students were asked to suggest, on the one hand, countermeasures to avoid heat-seeking missiles, and on the other hand, possible defense mechanisms that are resistant to such countermeasures. A similar discussion was held on the topic of laser-guided weapons, in which the students were asked to suggest, based on physical principles, engineering methods to disrupt the function of such weapons.

The research presented here characterized changes in students' attitudes towards physics and engineering as a result of their participation in the program.

Table 1 Study contents in the program "Introduction to aviation weapon systems"

| Session | Subject | Description |
|---|---|---|
| 1 | Introduction | A. Mechanical waves (review): wave, amplitude, wavelength, period, frequency, propagation velocity*<br>B. Fields (review): electric fields and magnetic fields*<br>C. Electromagnetic waves*<br>D. The electromagnetic spectrum* |
| 2 | Laser-based weapon systems | A. Properties of lasers: directionality, monochromaticity, coherence*<br>B. Light-matter interactions: atomic energy levels, absorption, spontaneous emission, stimulated emission*<br>C. Laser structure and principle of operation: pumping, population inversion, resonators, continuous-wave and pulsed lasers*<br>D. Radiation detectors**<br>E. Laser-guided weapons: structure and principle of operation, laser designators, countermeasures*** |
| 3 | Thermal weapon systems | A. Black body radiation: ideal radiator, radiation laws*<br>B. Signal-to-noise ratio**<br>C. Methods for cooling radiation detectors**<br>D. Thermal imaging systems: structure and principle of operation, generations of thermal imaging systems***<br>E. Heat-seeking missiles: structure and principle of operation, generations of heat-seeking missiles, countermeasures*** |

* Disciplinary component (physics)

** Disciplinary component (engineering)

*** Interdisciplinary component

## 4. Methodology

The study population included twenty 12th grade students from a leading Israeli high school that is affiliated with the Israeli Air Forced. As mentioned, these students, majoring in mathematics and physics, are designated to serve, after their post-graduation enlistment, in the Air Force's technological support system. It is important to note that the students had not been exposed to interdisciplinary teaching prior to their participation in this program. Since the research focused on characterizing students' attitudes and on changes they underwent during the course of the program, the constructivist-qualitative methodology was selected (Patton, 1980).

The students were requested to fill out open questionnaires both at the beginning and at the end of the study. In addition and to complete the information obtained through the questionnaires, five semi-structured interviews were held with students both at the beginning and at the end of the program. The questionnaires and interviews focused on the students' attitudes towards physics and engineering. Finally, classroom observations were made throughout all sessions of the program.

## 5. Findings

One of the questions on the **preliminary** questionnaire was: "What do you think about physics studies?" Analysis of the findings shows two components in the students' attitudes – cognitive and affective. In terms of the cognitive component, all students noted the great importance of physics studies: "They are important because they enable us to understand the world around us," and "It is important to study physics because it is the basis for all sciences." In terms of the affective components, about two thirds of the students wrote that physics studies were boring while the rest thought they were interesting. Excerpts from student interviews held at the beginning of the first session enable to trace the sources of the negative affective component of the majority of students:

*"The studies are too theoretical and dry… I can't see the connection to aviation and it bothers me."*

The preliminary questionnaire also included the question: "What do you think about engineering studies?" Answers to this question revealed that attitudes had only a cognitive component: All students (100%) claimed that engineering is important and rationalized that "the modern world is based on engineering," but 70% of them added that they "have no clear concept of what it means to study engineering at university."

In the final questionnaire, students were posed two separate questions regarding their opinion about physics studies and engineering studies. Ninety percent of them answered that the program enhanced their interest in these subjects: "The program made me want to invest more in physics and be more interested in it," and "I now understand what engineering is and it interests me." About two thirds of the students added that the program increased their desire to study physics and/or engineering in an academic setting: "Now I will want to study advanced physics and engineering" and "Thanks to the program, I am considering studying engineering."

Support for the change in the affective component of the students' attitudes may be found in excerpts from their interviews:

*"The program is completely different from what I'm learning in high school… It's much more interesting… My opinion about physics studies has changed for the better since the program presented the engineering part and showed how physics is related to aviation."*

*"The program made me treat physics and engineering studies differently… It helped me look at the study material in a different way… It showed that there are interesting fields in these subjects and that it can be really fun to study them… This is why my desire to study higher physics and engineering has become stronger."*

The behavioral component of the students' attitudes manifested itself at the end of the final session. Five students (25%) approached the teacher, who is a faculty member at the Technion, and expressed interest in the enrollment process there.

In addition to changes in the affective and behavioral components described above, the students exhibited enhanced recognition of the importance of physics and engineering in general, and in aviation in particular, following the program:

*"Only now, thanks to the program, have I understood that physics and engineering are the basis of aviation."*

## 6. Conclusions

The paper presented an interdisciplinary study program on aviation weapon systems that was developed and first implemented in 2012 in a leading Israeli high school that is affiliated with the Israeli Air Force. The program aimed to enhance the students' interest in physics and engineering and encourage them to continue with advanced studies in these disciplines. The program's teaching method was based on problem solving , with the objective of demonstrating to the students how engineers work (Harwood & Rudnistsky, 2005).

An effort was made in the development of the program to address the main challenges involved in the development and implementation of interdisciplinary study programs (Panaritis, 1995; McComes & Wang, 1998; Spelt et al., 2009) by ensuring an appropriate balance between the program's interdisciplinary components and its disciplinary components and by selecting a teacher with advanced academic degrees in physics and electronic engineering.

The research shows that following the program, the students' interest in physics and engineering increased, as did their desire to continue with higher studies in these fields. These findings are consistent with findings of other studies on high school interdisciplinary programs, that indicated an improvement in the learners' attitudes towards science and engineering (Nugent et al., 2010; Rockland et al., 2010) and an increase in students' desire to continue studying these subjects (Brand et al., 2008). In terms of the cognitive aspect, the research indicates that the program sharpened students' perception of the importance of physics and engineering in general, and in aviation in particular.

The contribution of this study may be seen in the implementation of the research conclusions when designing study programs in such fields. This potential contribution is strongly validated in light of the shortage in engineering professionals (NSB, 2008) and the many efforts made to attract high school graduated to these fields (Rockland et al., 2010).

## References

Bagaria, H. G., Dean, M. R., Nichol, C. A., & Wong, M. S. (2011). Self-assembly and nanotechnology: Real-Time, hands-on, and safe experiments for K-12 students. *Journal of Chemical Education, 88*, 609-614.

Brand, B., Collver, M., & Kasarda, M. (2008). Motivating students with robotics. *Science Teacher, 75*, 44-49.

Ewers, T. G. (2010). Idaho robotics opportunities for K-12 students: A K-12 pipeline of activities promoting careers in science, engineering, and technology. *Journal of Extension, 48*, Article 1IAW2.

Harwood, J., & Rudnitsky, A. (2005). Learning about scientific inquiry through engineering. Proceedings of the 2005 ASEE Annual Conference, Portland, OR.

Ivanitskaya, L., Clark, D., Montgomery, G., & Primeau, R. (2002). Interdisciplinary learning: Process and outcomes. *Innovative Higher Education, 27*, 95-111.

Klein, T. J. (1990). *Interdisciplinarity: History, theory and practice*. Detroit: Wayne State University Press.

Lumsdaine, E., Lumsdaine, M., & Shelnutt, W. J. (1999). *Creative problem solving and engineering design*. McGraw-Hill.

McComas, W. & Wang, H. (1998). Blended science: The rewards and challenges of integrating the science disciplines for instruction. *School Science and Mathematics, 98*, 340-348.

National Science Board. (2008). Science and engineering indicators. Arlington, VA: National Science Foundation (NSB-08-1).

Neri, F. (2001). *Introduction to electronic defense systems.* Norwood, MA: Artech House.

Nugent, G., Barker, B., Grandgenett, N., & Adamchuk, V. I. (2010). Impact of robotics and geospatial technology interventions on youth STEM learning and attitudes. *Journal of Research on Technology in Education, 42*, 391-408.

Panaritis, F. (1995). Beyond brainstorming: Planning a successful interdisciplinary program. *Phi Delta Kappan, 76*, 623-627.

Patton, M. Q. (1980). *Qualitative evaluation methods*. Beverley Hills: Sage Publications.

Piaget, J. (1972). The epistemology of interdisciplinary relationship. In L. Apostel, G. Berger, A. Briggs, & G. Michaud (Eds.), *Interdisciplinarity: Problems of teaching and research in universities* (pp. 127-139). Paris: OECD.

Rockland, R., Bloom, D. S., Carpinelli, J., Burr-Alexander, L., Hirsch, L. S, & Kimmel, H. (2010) Advancing the "E" in K-12 STEM education. *Journal of Technology Studies, 36*, 53-64.

Spelt, E. J. H., Biemans, H. J. A., Tobi, H., Luning, P. A., & Mulder, M. (2009). Teaching and learning in interdisciplinary higher education: A systematic review. *Educational Psychology Review*, *21*, 365-378.