

Renewable Energy Resources for Mathematics Learning: Windmills and Water Wheels at the Math Class

Kristóf Fenyvesi¹, Ho Gul Park², Kwang-Cheol Song², Zsolt Lavicza³, Mariana Back⁴

¹University of Jyväskylä, Finland – Experience Workshop, Finland-Hungary;
fenyvesi.kristof@gmail.com

²4D Mathematics and Science Creativity Institute, Korea; 4dland@daum.net

³Johannes Kepler University, Austria; lavicza@gmail.com

⁴Museum of Science and Technology – Nordic 4Dframe, Stockholm, Sweden;
mariana.back@tekniskamuseet.se

Abstract

The Finnish National Core Curriculum has been renewed in 2014 and the National Core Curriculum of Korea has been renewed in 2015. Although, the Finnish and the Korean educational culture is radically different from each other, they are both producing top results in international educational assessments and their renewed curricula contain some very similar components. The "multidisciplinary learning module" in Finland and the "STEAM framework" in Korea are both emphasizing the complexity of phenomena, which can be understood only in context and by employing multiple perspectives based on the combination of various subjects. In this workshop, we introduce how to construct windmills and water wheels at the math class. The program fulfills several requirements of the new Finnish and Korean curricula, and has proved to be successful in both educational cultures by providing opportunities to learn mathematics by doing.

Introduction: New Core Curriculum in Finland and Korea

Completed in 2014, Finland's new National Core Curriculum for Basic Education (FNCC) went into effect throughout all of Finland's schools beginning in 2016 [4]. Many of the elements contained in the FNCC address aspects central to a modern concept of pedagogy, a fact that garnered attention from the world press [3]. One of the most important elements among these aspects surrounds the concept of "phenomenon-based" and/or "topic-based" learning, a method that demands a multidisciplinary approach to education [4, p. 33].

FNCC introduces the student as an active participant in the learning process, one capable of reflecting upon not only the lessons learned, but also the experiences and emotions that emerged during the learning process. For the students, the interaction that takes place with their learning partners, teachers, other possible individuals, or the learning environment itself plays a fundamental role in mastering essential concepts. The learning process is grounded in the students' activity as they—either alone or together with others—think problems through, plans, discover and assess these processes according to various methods. As students learn together, they develop a sense of creativity, critical thinking, problem-solving skills and the ability to remain sensitive to and accepting of alternate opinions [4, p. 17].

A crucial element in multidisciplinary learning processes is the project method, throughout which students can actively participate in planning and selecting the lessons' learning content, the learning methods and practices to be applied. Maintaining the students' sense of motivation and engagement remains key to establishing their understanding of the goals and clear perception of the significance to learning about the given topic. It is additionally essential for this process to be conducted in small groups that may even be heterogeneous regarding the ages of students. Other than the teachers, experts in fields related to the area under examination may also participate in these groups. Another crucial aspect is for the knowledge gained in school to be linked to that acquired outside of school; the learning process must therefore make

room for intellectual curiosity, creative expression, the gaining of experience and the exploration of the various ways in which knowledge can be applied. Among the values stressed throughout this process, that of sustainability and its practices as a basis for individual and collaborative activity is also found [4, p. 34.].

Similar to Finland, Korea—in the forefront of international education ranking evaluations such as PISA, TIMSS, etc.—introduced its new National Curriculum in 2015, barely one year after Finland put its own curriculum into practice [9]. In spite of the radically different cultural traditions and social environments which define education in Korea and Finland, Korea’s new National Core Curriculum contains numerous elements that closely resemble those pedagogical considerations found in the Finnish model. While Finland’s Core Curriculum establishes the introduction of multidisciplinary learning as one of its goals, the Korean curriculum highlights the introduction of STEAM integration between the subjects as an important aim for its education system (see Korea Foundation for the Advancement of Science and Creativity’s [KOFAC] explanation on the policy background: https://steam.kofac.re.kr/?page_id=11269). One of STEAM integration’s important objectives is likewise the multiperspectival examination of phenomena that connects and unites various branches of study. In contrast to Finland’s emphasis on multidisciplinary learning, which maintains the traditional identity of each involved subjects, Korea’s concept of integration of various subjects (as well as knowledge gained outside of academic subjects) under STEAM establishes the goal of creating a model for developing a transdisciplinary model of learning.

Like the Finnish curriculum, the Korean model similarly emphasizes involving students in directing the learning process, from defining the topic to selecting the method of study. In this case, the objective is also to enhance student motivation. A different emphasis, however, can be found in the Korean vs. the Finnish model as the former provides a far greater role for technology. While the Finnish model only details the pedagogical aspects related to creating a multidisciplinary learning environment, Korea’s National Core Curriculum precisely defines a STEAM learning framework.

Korea’s STEAM learning framework contains three, essential steps: (1) introducing the *context* of the studied topic, (2) *creative planning* for plotting out the solution, (3) establishing the conditions necessary for the *emotional involvement* into the problem-solving process. Focused as they are on the student’s role and phenomenon-based and multidisciplinary methods, these aims and opportunities transform the learning process, thereby impacting the education environment as well as the traditional concept of student-teacher roles. Finland’s model of phenomenon-based, multidisciplinary learning similarly carves a definite path for STEAM integration, the inclusion of which would provide not only the appropriate tool for creating connections subjects in adherence to multidisciplinary methods, but also enable cooperation among educators teaching different subjects.

In response to the challenges posed by its new curriculum, during the 2016/2017 year teacher training programs in Finland were adapted to reflect the attitude of the new curriculum. As regards those educators already present in the field, how these issues were to be solved was—in a nod to the trust placed in the autonomy of teachers and educational institutions—essentially the responsibility of each school’s community. Various local foundations and European Union programs provide assistance in this effort. Korea, in contrast, went one step beyond merely altering its teacher training programs: in Korea’s case, support for STEAM integration was made available via an entire system of advisory institutions that extended both vertically as well as horizontally in Korean education.

Environmental Awareness and Renewable Energy Resources in the Finnish and Korean Core Curriculum

According to Finland’s National Core Curriculum, the necessity for leading a sustainable way of living and environmental awareness are essential values. Participation and involvement in building a sustainable future figures among the topics listed as ones that appear in different subjects in the school. As the means for addressing these topics appear among the goals laid out for separate subjects, these “transversal” themes form an excellent foundation for creating various modules in multidisciplinary learning within the Finnish education system. In complete consensus with its Finnish counterpart, Korea’s STEAM framework

similarly establishes environmental topics as an area for actively exploring complex problems demanding the application of a creative solution developed by students either at the primary or secondary level [9, p. 8.].

The Workshop's Structure

The foremost aim of our proposed workshop program is to enable the practical development of mathematical knowledge and skills applied in environmental studies via the kinds of examples that are already familiar to the students. This reason is precisely what prompted us to select the theme of the discovery of water and wind energy through some basic activities for our workshop. As topics, both the need to promote environmental awareness and the issue of renewable energy sources are not only emphasized in Finland's National Core Curriculum, but also questions that can be explored in detail within the STEAM education framework developed in Korea. In fact, a variety of suggestions for related themes and materials can be found on KOFAC's webpage: <https://steam.kofac.re.kr>.

Our workshop allows students to discover these topics using multidisciplinary or STEAM approaches and is recommended for grades 3-9. If the workshop is held not as a part of a math class, but as an extra-curricular activity, then we additionally suggest that various age groups be allowed to work together, since our program develops skills and reinforces aspects of knowledge that are relevant to the entire spectrum of this broad age group of 3-9-graders. This paper mainly emphasizes how our workshop program intersects the fields of mathematics education and visual arts pedagogy. The exercises and problems we offer for investigating the topics related to the workshop activities are primarily related to mathematical and aesthetic issues and in this paper we are not going into details regarding further STEAM fields, which on the other hand are necessary comes into discussion during the realization of this workshops program.

Throughout the workshop, students use the Korean 4DFrame toolkit, which was previously described in various articles [2, 5, 6, 7, 8], including papers related to environmental studies [1]. The advantage to applying the 4DFrame set lies in its ability to enable students in investigating the problems under examination with the help of a realistic, practical model that is additionally flexible enough for students to rework and adjust their solution to the issue based on their own and their partners' creativity [10].

While participation in the workshop does not necessarily require students to have been previously exposed to the topic of wind and water energy, it is still highly recommended that a brief multidisciplinary introduction be provided before beginning the task. An excellent starting point is offered by studying pictures and videos of windmills and water wheels—both traditional and modern—of how people in different cultures and ages have harnessed wind and water energy. The ensuing discussion highlights the students' observation of the differences and similarities of the constructions both from functional and aesthetic design aspects and what these imply.

In order to design a windmill, it is first necessary to identify and plan the structure's separate parts. This is followed by discovering the 4Dframe system through free play, then measurements and selection of the needed elements from the set. The selection and grouping of each element by their characteristics can be realized according to the level of measurements and calculations most appropriate for the given age group (Figure 1).

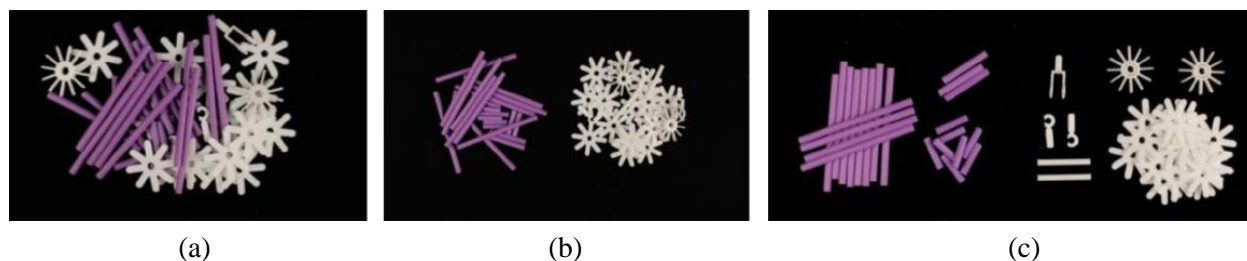


Figure 1: Grouping 4Dframe components: (a) unclassified pile, (b) classification by color and (c) classification by measurements, counting and typology.

Constructing Windmill and Water Wheel

In the course of the workshop, the model pictured below will be prepared step-by-step (Figure 2).

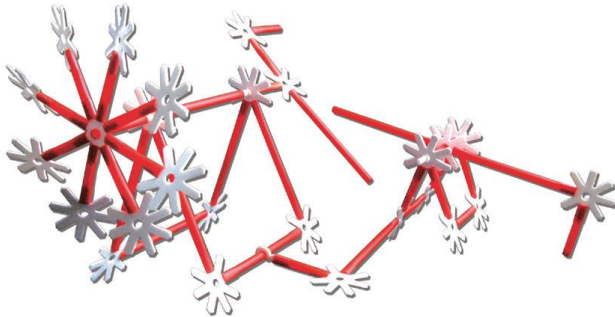


Figure 2: *4Dframe's Windmill model designed by 4Dframe's inventor, Ho Gul Park.*

individually or as a group—think of ways to alter the structure's functional and aesthetic design (Figure 3). They can recognize that the construction's degree of effectiveness can be either increased or decreased by changing the angle of single paddles or the length of arms that hold the paddles (Figure 4). For the comparison of the wheel-types by number of revolutions, e.g. a paper cup can be installed underneath the small hammer part of the structure for making simple measurements since one hit on the cup marks one complete revolution of the wheel. Interesting discoveries can be done when the number of revolution is compared to the paddles and the included angle created by the paddle wheel's plane. By placing a xylophone underneath the hammer it makes possible to experiment with creating different melodies and rhythms or even to create a mechanical music instrument.

The number of arms and their position is yet another factor to examine, just like the function and properties of the structure's small "hammer" part, which model how wind energy can be transformed into work. For the creative redesign of the model, it is worth taking various measurements (Figure 5), which can lead to various calculation problems, e.g. measuring the radius of the wheel can lead to calculation of the wheel's area and circumference, etc. It can be fruitful to experiment with how these features affect the structure's more complex physical properties, like mechanics, revolution, friction, power and energy, depending on the age of the workshop participants.

After familiarizing themselves with the fundamental principles, unique, custom-designed windmills and water wheels can be created in order to demonstrate various physical or aesthetic characteristics (Figure 6). These may then be designed and compared according to mathematical calculations and measurements. Combining the model with the same structure or even difference structures will also increase the number of further solutions while guiding students to further realizations. A further, equally important experiment can be conducted based on the fact that the windmill can be turned into a water wheel by simply altering the angle of the paddles, which can lead to important discoveries about the connections between aero- and hydrodynamics. At the Bridges workshop we are focusing on the exploration of the above listed opportunities from the mathematics and art teachers' perspective. In addition to build various windmills and water wheels by following the program introduced above, participants will also realize and analyze their own designs. The Bridges workshop provides a prominent platform to discuss and collect more ideas on how teachers of mathematics and arts can work together with each other and with teachers of other subjects on the realization of this project and other similar multidisciplinary programs.

Rather than listing each steps of construction in detail in this paper, we emphasize the importance of posing problems throughout the 20-45 minute construction process in order to stimulate students' progress while additionally bridging the steps and tasks involved in solving the exercise. Throughout the construction, basic concepts such as "vertical", "horizontal", "parallel" and "symmetrical" can be explored in practice. Measurements, proportions as mathematical aspects of design can be also creatively explored in this workshop, just like Buckminster Fuller's concept of ephemeralization.

After constructing the windmill and testing the structure by blowing, or using a fan or hair dryer, the students can then—either

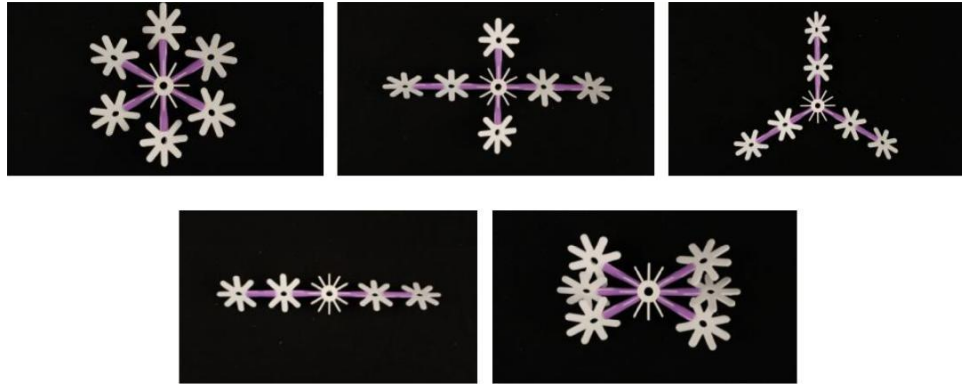


Figure 3: *Different wheel types.*

Degree of wings	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
Number of revolution										
Analysis										

Structure					
Number of revolution					
Analysis					

(a)

(b)

Figure 4: *Studying the effect of (a) degree of wings and (b) structure of different wheel types.*

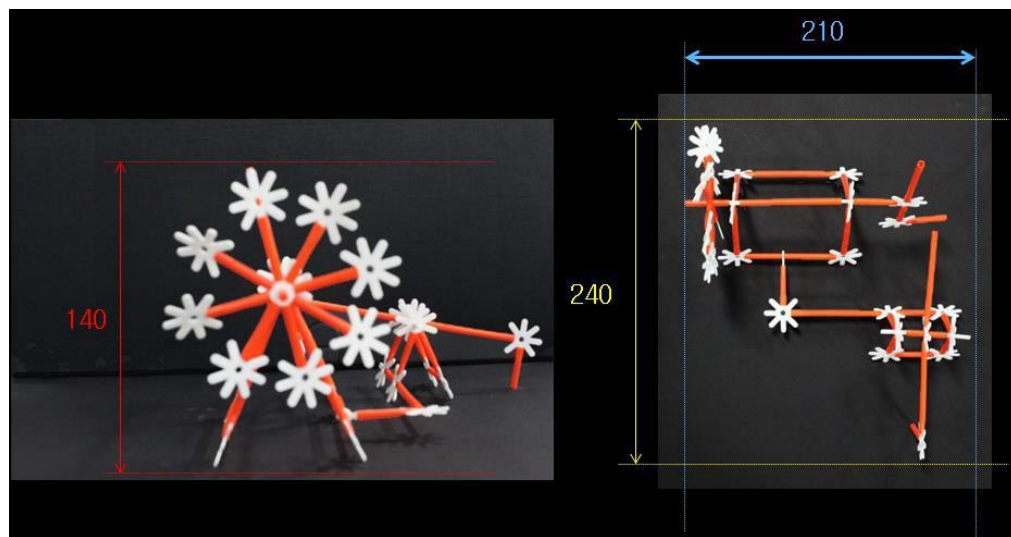


Figure 5: *Basic dimensions of the 4Dframe Windmill.*

Further inspiration for designing unique windmills can be found in architecture as well, such as the three enormous wind turbines—capable of producing more than 10% of the building’s entire energy needs—fastened to the bridges that connect the twin towers of the World Trade Center built in Manama, Bahrain, in 2008.



Figure 6: Variations for windmill. Experience Workshop's windmill building activity led by Ildikó Szabó in Hungary. Photo: László Tóth.

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