

# Action Research to Develop and Validate a Scheme of Work to Promote Creativity and Designerly Thinking Through Play

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## Abstract

The paper reports on a study of the development and validation of a Design and Technology Scheme of Work (SoW) that is facilitated by Engino assembly toys. Three initial case studies are described; one to assess the suitability of the Engino products for specific age groups; and two which took place in primary schools; one to evaluate the sequence of tasks designed for the action-research case study; and another to investigate if creativity can be promoted through the Engino products. Two further action research case studies were then completed with secondary school students, during which the SoW was further developed and elaborated to suit the needs of this age group. The final versions of the SoW were further validated during a dissemination seminar and professional development workshops involving primary and secondary school teachers. Having the importance of play in mind for enthusiastic and creative learning, the SoW was designed to fulfil a number of requirements from the Cypriot National Curriculum, covering 6 of the 9 areas. We discuss our findings with reference to promoting creativity in the context of Design and Technology as well as the possible roles that construction toys can play in this endeavour. The paper is illustrated with a picture gallery with indicative examples from student work.

## Key words

design and technology, scheme of work, Engino.net, educational, creativity, play, assembly toys, action research

## Importance of play

This paper reports on research conducted to investigate some aspects of learning and teaching using primarily tools which are traditionally developed to be used as toys. Construction kits were initially produced for entertainment purposes, until the importance of play was recognized in our educational system. Play is more than an aspect of our (*homo sapiens*) creative drive; it's a fundamental mode of learning which keeps us vital and alive (Elkind, 2007); it gives us enthusiasm for life that is irreplaceable; without it, life just doesn't taste good (Capocchione, 2002:). The importance of play during learning is also widely recognized and accepted. Play promotes development, learning, creativity and independence in children (Northern Ireland Curriculum, 1996; Baynes, 1992; Pellegrini, 2009; Bettelheim 1987). It allows for a creative dialogue between the inner and outer reality (Winnicott, 1971) in the same way as role play through

the confrontation of cognitive modeling with perceptions of the external world (Hope, 2008). Through play social coordination skills and sociability are developed (Smith & Pellegrini, 1998, Hope, 2008).

In all 5 case studies described in the paper, semi-voluntary events rather than formal learning environments have been developed and run with emphasis on construction kits as a primary teaching means promoting learning. Playing using toys (even improvised toys such as a stick used as a sword) allows children to try out new combinations and actions without external restrictions and can aid in the development of different skills such as psychomotor skills (movement, coordination, dexterity, grace, strength, speed) emotional maturity, self-confidence, literacy and numeracy as well as social and cognitive development and creativity (Baynes, 1994; Parker, 1997). Literature gives a distinctive difference between play and games. Play is defined by activities with no rules other than those imposed by the children themselves, including the free use of creativity and the lack of external goals. This type of play is usually less organised, allowing stress free and creative play time, building on personal and social skills. A different type of play activities, usually referred to as games, are commonly encountered within education or as children get older. Games are defined as activities which aim towards a specific outcome. Incorporating games as teaching tasks, differentiating the importance of the outcome, can bring fun and excitement to otherwise dull or routine based teaching tasks. This was the main path followed for all five case studies, as every task that was developed and run, was guiding the participants towards a desirable set goal. Children learn through experience and experimentation, building new knowledge on prior understanding towards completing the game at hand. This also reflects classic social constructivist pedagogy where knowledge is reconstructed by the learner working in social groups of adults and children, and building on their existing mental constructs. As Vygotsky (1978) argued, children will learn if the context provided by the teachers and the learning environment enables the child to be in their Zone of Proximal Development. This is the task that the SoW must fulfil. As the children are engaged in activities facilitated by Engino products (<https://enginotoys.com>) the pedagogy might be more accurately described as social constructionism (Papert, 1991).

# Action Research to Develop and Validate a Scheme of Work to Promote Creativity and Designerly Thinking Through Play

## Introduction to Engino.net and the research project

Engino.net is an innovative Cypriot company established by a Design and Technology (D&T) teacher in order to focus on facilitating children in designing educational toys through the assembly of kit components. The company is new to the worldwide market, and has as prime competitors companies such as LEGO. In an effort to support and guide the efforts of the company towards producing fun, educational material accessible to schools, a research project has been completed by Engino.net in collaboration with the University of Cyprus and the Research Promotion Foundation of Cyprus supported by European Union structural funds. The Engino assembly products already feature in all primary schools in Cyprus within the context of the D&T subject area, and are mostly used during D&T lessons to enhance understanding in structures and mechanisms. In order for all teachers to be able to use the Engino material effectively, even without being a specialist in the subject area, fully developed teaching material was required, complete with lesson plans, tasks and evaluation methods, which was the focus of this research.

## Action research

Action research was used for this research in order to allow the development of a successful intervention with the introduction of a new initiative into an existing teaching practice. Even though research on assembly toys within education has been completed in the past (Campbell et al, 2001; Knagge & Raftery, 2002; LeGoff, 2004; National Research Council, 1996), this was the first time the specific type of assembly toys were being used as the main teaching material rather than just a way to reinforce newly gained knowledge. It was also the first use of a concept emerging from Design and Technology (D&T) to be used in this way in Cypriot schools. Practical solutions were being sought, and hence the research environment was designed so as to gather evidence of how the intervention influenced the context (Whitehead, 1985). There were 2 questions to be answered prior to the development of the teaching scheme:

- The appropriateness of the age range of the Engino SolarPro products; and
- the potential for creative behaviours leading towards creativity through the Engino products.

With these questions resolved, the aim of the research was to bring about development in the proposed practice (Carr & Kemmis, 1986) through constant thought; action and reflection (McKernan, 1991). It was also of importance to identify elements for change based on informed rather than intuitive judgement and decisions.

## Description of material to be produced

Having as a main focus the area of renewable energies, and more specifically solar power, the Engino SolarPro Design and Technology Scheme of Work has been developed at the University of Cyprus by academics specialising in teaching D&T. The SoW is designed for children aged 11-15 years old and is around the design process, promoting skills such as creative behaviour, designerly thinking and graphicacy along with subject specific knowledge such as levers, mechanisms, structures, forces, environmental studies, renewable energies, material and their properties and graphic design techniques. The final product is a complete teaching guide with a range of teaching material supporting fun and creative projects for a minimum of 5 double teaching periods which can be taught in any of the year groups where D&T is currently taught in Cyprus. D&T has been merged with Science for the ages 6-11; hence the material has been developed for ages 10 – 15. After the age of 15, the subject area becomes optional in secondary education. The SoW is provided as a helping tool rather than a prescriptive manual, which can be modified by the teacher to suit the age range of the student i.e. by introducing isometric drawing for students aged 14+ or by giving themes for construction i.e. for ages 10-11 build a robot, ages for 12-13 build an agricultural machine and for ages 14-15 build a mechanical Lunar park.

The Engino.net Company had placed age recommendations appropriate for each package founded on assumptions based by the company's owner, designers' prior experiences and other similar products currently in the market. The ages set for the SolarPro packages start from 8 years old. In order to check the suitability of the SolarPro package for different age ranges, case study 1 was designed to investigate how children of different ages deal with the products. Case study 2 was aimed to develop and test the sequence of tasks designed to lead towards the development of the students' own model design. Case study 3 tested the material developed in case study 2, within the school environment, involving students of the same ages for whom the SoW was to be developed. An additional aim of this study was to validate that the Engino products were appropriate for the age range, and additionally, to investigate if creativity could be promoted through this material for children of that age. Further action research (case study 4) was then completed with a secondary school class to test the complete SoW developed. Modifications and amendments to the SoW were completed where necessary, and the revised version was put to the test with a different class (case study 5) of secondary school students. The final outcome was disseminated during a seminar (case study

# Action Research to Develop and Validate a Scheme of Work to Promote Creativity and Designerly Thinking Through Play

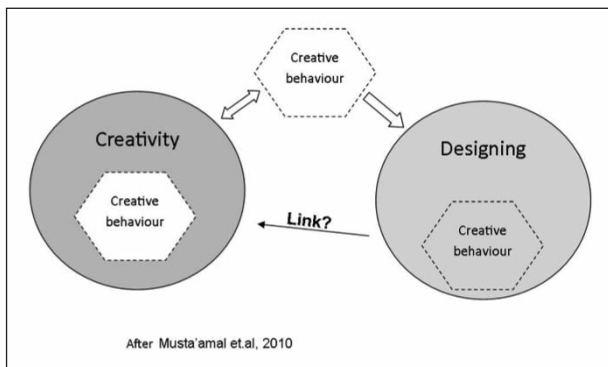


Figure 1 The connection between Creativity, Creative behaviours, and Designing.

6) for primary and secondary education teachers. This process allowed the material to be developed and tested with children of the targeted age range as well as the teachers who would potential use the material in schools.

### Creativity and creative behaviours

Creativity is an elusive area to measure, and a highly controversial one in research. It cannot really be measured in the classroom as it depends on the evaluation of outcomes and the making of value judgment on what is creative which depend on the values of the people and what they believe to be important. These issues would make identifying creativity during this research very difficult, so instead, the focus was placed on identifying behaviours that cognitive psychologists have suggested lead to creative outcomes (Figure 1).

In order to be able to provide a definition of creative behaviours, a literature review on cognitive psychology was completed by Musta'amal (2010) identifying a number of creativity characteristics (e.g. (Cromptley 1967; Gilchrist 1972; Amabile 1983; De Bono 1994; Balchin 2005). These have been long-listed and grouped into seven categories by Musta'amal et.al, 2009a, as shown in Table 1. The seven categories identified were *novelty, appropriateness, motivation, fluency, flexibility, sensitivity, and insightfulness* and these categories could be further developed. (For detailed descriptions of each one, see Musta'amal et.al, 2009a).

This was not claimed to be an exhaustive list of possible references, but sufficient to generate the majority of the creative behaviours that have been reported. No attempt was made to select or rank these creative behaviours; they were simply noted and classified.

The analytical framework resulting from the literature has been named as the Creative Behaviours Model (CBM) and is shown in Figure 2. The seven categories (competencies) are shown each with three descriptors which help to explain the meaning of the seven terms chosen.

### The development process

Throughout the development process of the SoW, there was an on-going analysis and evaluation based on the work created during the action research studies by the participants along with participants' comments, questionnaire responses gathered at the end of each study and experts' observations.

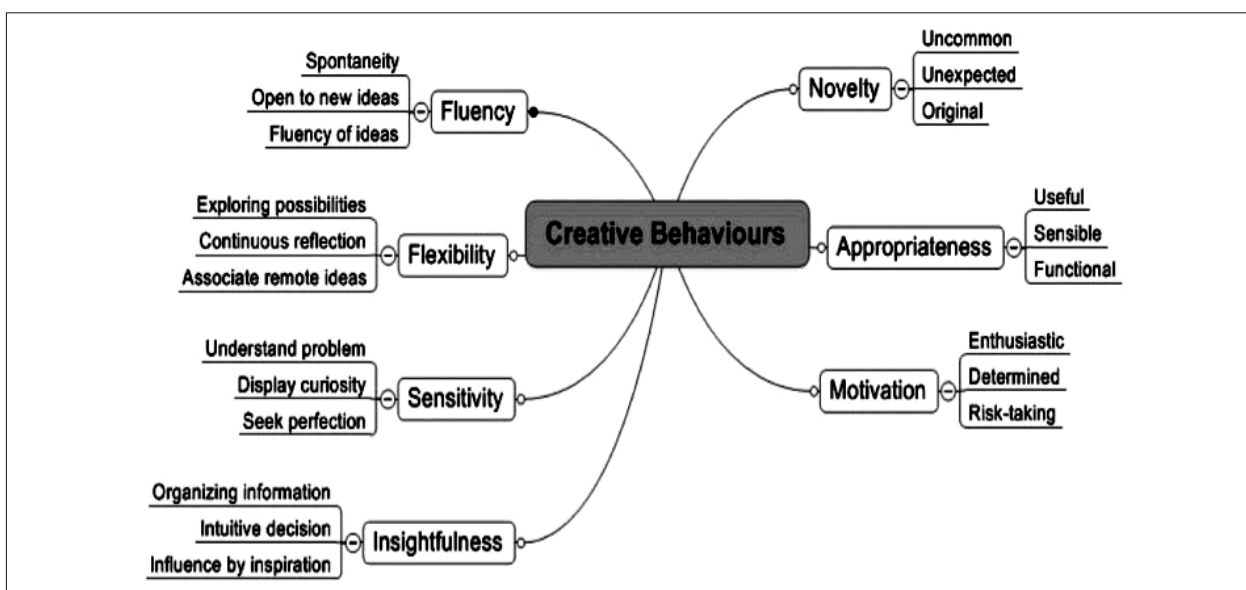


Figure 2: Creative behaviours model and its descriptors (Musta'amal et.al, 2009b: 60)

# Action Research to Develop and Validate a Scheme of Work to Promote Creativity and Designerly Thinking Through Play

Age	Gender	Education level	Time to completion	Successful completion	Level of difficulty experienced	Rate of interest shown
7	Female	Primary school	76'	No	High	None
12	Male	Primary school	56'	Yes	Low	High
16	Female	Secondary school	45'	Yes	None	High

Table 1 Summary of Pilot 1 results

The case study was conducted with 3 different aged children (Table 1), to explore the suitability and interest children of various age ranges would show towards the Engino products. The results gave a first indication of what could be expected when providing children with an Engino SolarPro package for the first time, and some questions and difficulties that might arise.

With some indications concerning the ages for which Engino products were suitable, case study 2 was undertaken. The participants were research associates who would act as class helpers (CH) in case study 3. They were asked to complete all tasks as planned for that case study, including building models using the Engino products. This step was considered important as the CH

should be in a position to understand the experience students were about to have, including the difficulties, confusion, excitement etc. All participants were able to complete the tasks and create their own model which confirmed the appropriateness of the sequence of the tasks developed. The overall time required to complete each task was noted, as well as specific areas to be raised during the instructions such as: use only one motor for the entire model; avoid complex and intricate ideas; work in an organised manner within the group by appointing roles etc.

Case study 3 was designed as a competition which took part in a primary school open to all students in Years 5 and 6 (ages 11-13). The SoW was developed to include

Parts of the competition	Time	Short description	Aim
1. Introduction	40'	8 islands with 4 different tasks related to Engino structures and mechanisms	i. Offer examples of possible structures and mechanisms built using the Engino products ii. Allow time for all students to arrive iii. Note all students' names iv. Help students' mind-sets to be aligned to Engino related tasks
2. Getting to know the Engino parts	30'	Introduction Demonstration Tasks 1 - 3	i. Description of the sequence of the day's events ii. Understand how the Engino pieces attach and detach iii. Experience constructing working models with moving mechanical parts and modifying them to fulfil set specifications.
- Break time 20' -			
3. Free construction	60'	Create an adjustable sling shot	i. Building on the knowledge gained so far during the day mixed with imagination and creative behaviours, construct a product fulfilling a given specification
- Break time 15' -			
4. Final competition	30'	Putting it to the test (rounds 1 & 2)	i. Test each construction. ii. The top 3 teams move onto round 2 and compete until the end

Table 2 Structure of the day

## Action Research to Develop and Validate a Scheme of Work to Promote Creativity and Designerly Thinking Through Play

1. Find a way to attach the balloon on the propeller to make it spin for more than 45 seconds.
2. Adjust the height of the slide to allow the ball to attain the appropriate speed so that it touches a (paper) wall without making it fall.
3. Using the correct ball (from a wide selection available), release it from the correct height to make the catapult tap the table in a gentle manner.
4. Engino Master Set, fun constructions. Students were allowed up to 5 min to build anything they like using the Engino products. Step-by-step guides for assistance were also available but students also had the freedom to experiment with the pieces without following the guide.

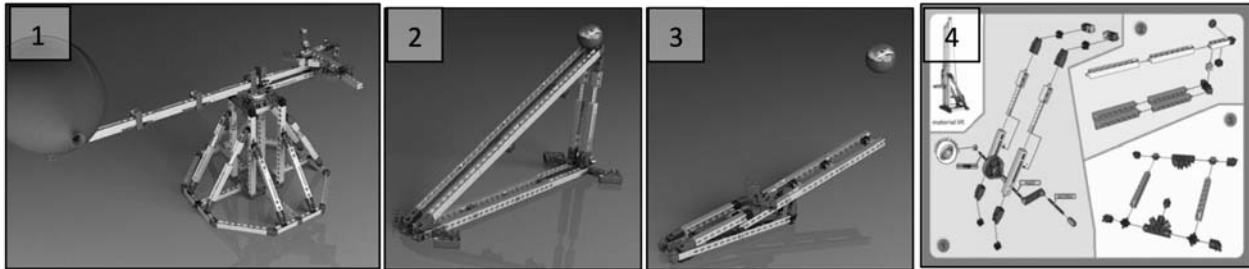


Figure 3 Tasks 1-4

young students of this age, thus this action research was also testing the suitability of the material to be designed. Thirty six students of mixed and diverse backgrounds participated in the event. The event was divided into 4 parts, as described in Table 2. All tasks were designed so as to introduce new elements building on the skills and knowledge gained in the previous activity, and preparing the students for building their own structure.

The models in Figure 3 were used during the introduction. Having such tasks set at the beginning of the day helped in getting the children to become actively involved and draw their interest. These models were chosen due to specific simple mechanisms and features incorporated in their design which could inspire the construction of the students' models later on (Task 3). Model 1 used an adjustable fulcrum to the lever for where the balloon was attached, which changed the speed and time of its rotation during the deflation of the balloon; Model 2 was using simple features enabling the adjustment of the height of the ramp; Model 3 allowed the experimentation of force with different balls (sizes, materials etc) and Model 4 provided a specially designed platform for the ball to be safely rested on. These features amongst others, could aid primarily help to develop *fluency* (open to new ideas, fluency of ideas) *flexibility* (associate remote ideas) and *sensitivity* (display curiosity) during the design

and development of their own model following a set specification list.

The first team-task was designed to provide knowledge and understanding of the potential of the Engino set (Figure 4). Students were required to build a model following the Engino guide. This was building the part of the knowledge and understanding required, included in the creative behaviour of *sensitivity*. Observations indicating each group's level of capability relating to model making using the Engino products were conducted. These provided evidence towards verifying the manufacturer's claim of the product's suitability for children of that age. The students were then asked to modify the model using a set of Engino materials. The third step required the team to modify the model further to fulfil specific specification points. Students had to explore the everyday stationary material available to them and find a suitable solution to the problem set. The first stage provided a model with a platform on which a base could slide in a linear direction. The second stage allowed the students to explore different ways of slinging the ball in one direction. The third model was guiding the students to identify the features of the pieces provided, by creating a re-enforced adjustable base. The students had limited time to complete the tasks, thus *spontaneity* (*Fluency*), *intuitive decisions* (*Insightfulness*), *enthusiasm risk taking* (*Motivation*), *sensitivity and functionality* (*Appropriateness*) were important creative behaviours for the successful completion of the task.

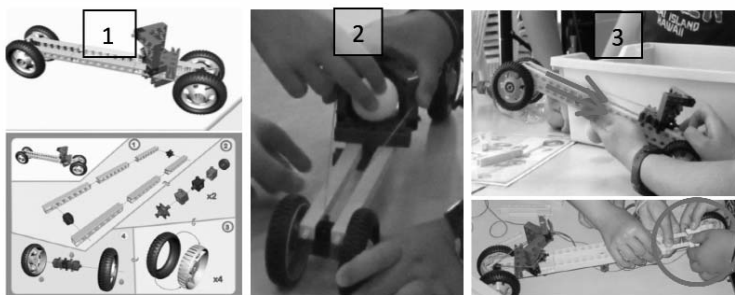


Figure 4 Getting to know the Engino set

Students were then asked to design their own models meeting a detailed specification, and building on the skills and knowledge gained through these tasks. The specification asked for the following: create a machine to sling a ball in a set basket, the distance and height of which will be adjustable. All groups proved to be

# Action Research to Develop and Validate a Scheme of Work to Promote Creativity and Designerly Thinking Through Play

capable of creating their own model, resulting in 9 different models from the 9 groups at the end of the day. Students did not have time to research the task in advance and were therefore required to work *spontaneously*. They had to explore *different possibilities* and *continuous reflection* (part of *flexibility*) in order to get a *functional and appropriate* result. An *understanding of the problem* was required, and some groups worked *seeking perfection*. The student were given a limited time to build their model, so *intuitive decisions* (related to *insightfulness*) were required by some groups closer to the deadline. All models were different, and some were *unique/uncommon, original* and used features in an *unexpected* way to achieve their goal (related to *novelty*).

Once it was established from case study 3 that when following a structured set of tasks, students can design and make their own working model using the Engino products, a complete Design and Technology Scheme of Work (SoW) was designed, following the basic steps of the design process. Two further studies took place during 2 phases, as part of a 6 weeks summer school for secondary school students, aged 12-15.

Written tasks were designed to be mostly completed on the computers where possible, assuming that today's learners would find that more interesting and appealing. The lessons were designed in a way so as to involve a range of different types of tasks (Figures 5 & 6) to allow inclusion for all types of learners.

At the end of each lesson and of the overall course, there was a questionnaire handed to all students to assess the quality of the lesson, tasks, and tools provided that was followed by a discussion. Seeing the students' reactions and actions during the class made it clear that even though they were not fond of the old-fashioned teaching style (i.e. look through a set of materials to find the answer), they did not know how to proceed or were not sufficiently motivated to become more pro-active in order to research and bring together information to answer a question. They enjoyed the class conversation as they could take an active role in the discussion, without the responsibility of taking on a leadership role. This illustrated a lack of *motivation* including all three aspects of it: *enthusiasm, determination* and *risk-taking*. Students enjoyed the freedom and creativity of designing symbolic

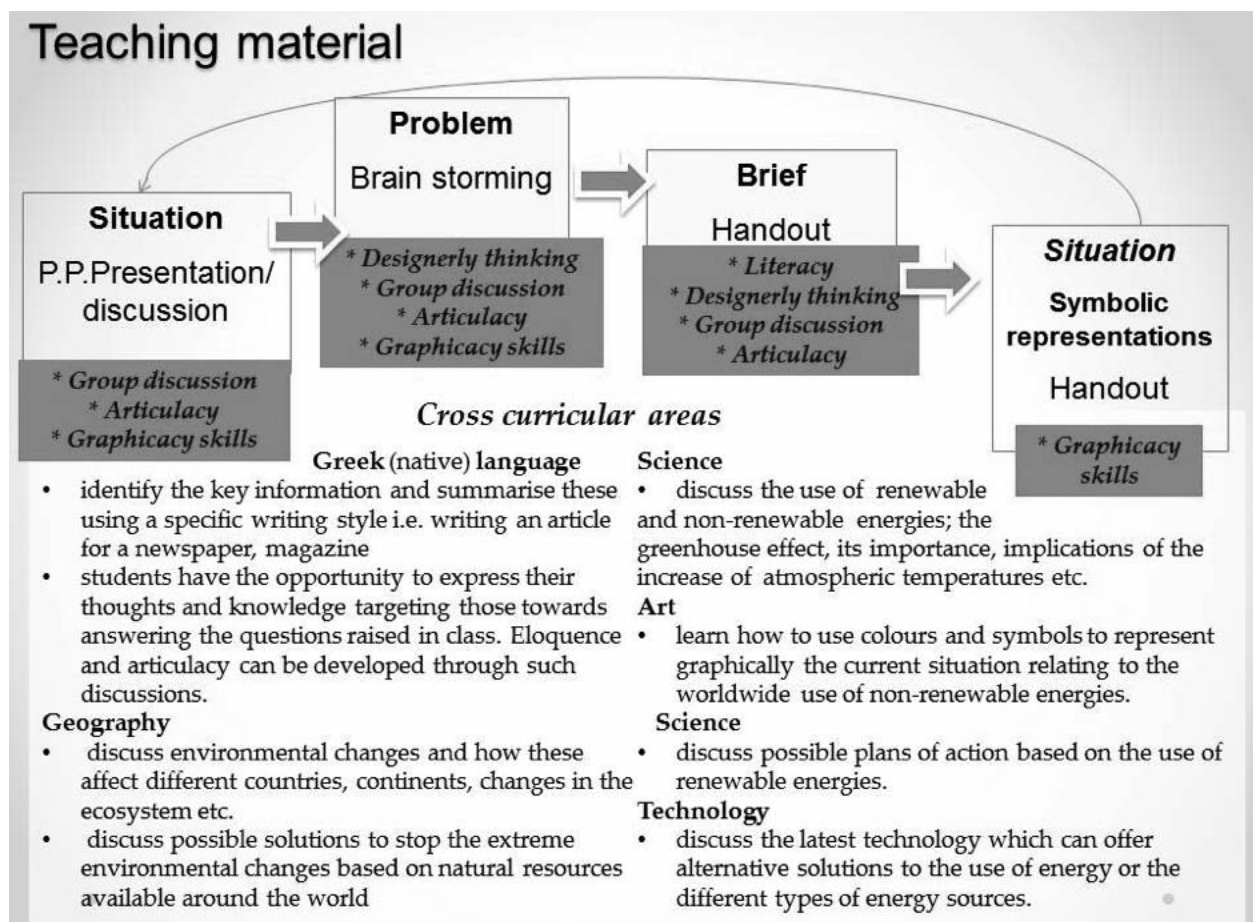


Figure 5 The structure of lesson 1

# Action Research to Develop and Validate a Scheme of Work to Promote Creativity and Designerly Thinking Through Play

**Lesson 1 Situation; problem, design brief, specification**

**Handout 1**

**The questions**

1. Γιατί είναι η παρούσα κατάσταση σε σχέση με την κατανάλωση αγκαλιωμένων πηγών ενέργειας;
2. Ποια είναι οι επιπτώσεις για το περιβάλλον από την υπερβολική χρήση αναλώσιμων πηγών ενέργειας;
3. Τι μας προσφέρει το περιβάλλον που να μπορούμε να χρησιμοποιήσουμε για να δημιουργήσουμε ενέργεια;
4. Ποια είναι τα πλεονεκτήματα της χρήσης ηλιακών συλλεκτών;
5. Ποια είναι τα μειονεκτήματα της χρήσης ηλιακών συλλεκτών;
6. Γράψτε 3 παραδείγματα προϊόντων που δουλεύουν με ηλιακούς συλλεκτές.

**Written answers**

**Αγροτικό όχημα**

**Κατάσταση**

Σήμερα, μόνο το 8% της παγκόσμιας ενέργειας αποτινάται από αναλώσιμες πηγές. Η αυξανόμενη κατανάλωση αναλώσιμων πηγών ενέργειας είναι η κύρια αίτια για την παγκόσμια κλιματική αλλαγή. Το περιβάλλον μας προσφέρει αέρα, νερό, ήλιο και θερμότητα με τα οποία μπορούμε να δημιουργήσουμε ενέργεια. Τα πλεονεκτήματα της χρήσης ηλιακών συλλεκτών είναι ότι είναι εύκολα στη χρήση τους και μπορούν να χρησιμοποιηθούν σε ολόκληρο τον κόσμο. Επίσης δεν παράγουν κίνηση. Είναι όμως ακριβά και χρειάζονται συντήρηση. Μπορούμε να τα χρησιμοποιήσουμε για να δημιουργήσουμε με ηλιακούς συλλεκτές: θηροτροφικές, λαμπές, τηλεφωνικός δίαυλος, ψυγείο, τηλεόραση, υπολογιστική, ανεμοστρόβιλος, ρολόι.

**Answers illustrated**

**Problem**

**Specifications**

- Κατασκευή με πακέτα Engino
- Χρήση 1 ή 2 Engino ηλιακούς συλλεκτές
- Χρήση 1 μοτοράκι Engino
- Να έχει καινοτομικό σχήμα
- Να είναι πρωτότυπη ιδέα
- Να λειτουργεί
- Να ολοκληρωθεί μέσα σε 6 μαθήματα
- Να προκαλεί ενδιαφέρον
- Θα έχει 2 κύριες κινήσεις: κυκλική 360 μοίρες και μπρος πίσω (ταλάντευση).
- Θα έχει σχήμα ανθρώπου γλειφιτζουριού
- Να είναι ασφαλές
- Να ισορροπεί

Figure 6 Sample students' work from Lesson 1

representations once they got over their fear of not being able to draw. Many elements of the SoW were familiar to the students; they could see how one stage was leading them to the next as a natural progression of their thinking process, which acted as a motivating agent for the students to complete each task to the best of their abilities once into the design related stages. Some students reported that this class was the most interesting and fun class of the entire summer school because they were given the time to create and make something by themselves and they were very proud of their final model, as they started the course not thinking they would be able to design and create a working prototype of their own (Figure 7). The methodology used and the outcome of the students work support the findings of literature in regards to using games (rather than play) for learning. Children learned through experience and experimentation, building new knowledge on prior understanding towards completing the given task; an idea also supported by social constructivism.

## Case study 6; dissemination of the SoW

Once the SoW was refined and finalised after taking under consideration the results from case studies 4 and 5 in the form of observations, students' end results, students' questionnaire responses and opinions shared during discussions, a seminar for primary and secondary school teachers was organised. The aim of the seminar was to

disseminate the new material by informing teachers of the new innovations designed and developed, and then experience a sample of that by participating in workshops which would guide them towards creating their own working models using the Engino products. During the discussion and according to the questionnaire responses provided at the end of the workshop, teachers enjoyed the tasks; they felt they gained new, useful teaching knowledge and were eager to attend the next Engino Teaching Material seminar and workshop.

## Requirements fulfilled by the SoW

The complete SoW fulfils numerous requirements from the Cypriot National Curriculum, covering areas such as mechanisms; structures, forces and levers; as well as the development of creativity, innovation, graphicacy skills and designerly thinking, amongst others.



Figure 7 Sample of students' work; case studies 4 and 5

# Action Research to Develop and Validate a Scheme of Work to Promote Creativity and Designerly Thinking Through Play

General skills and abilities		Making/ construction <i>Through appropriate means student will:</i>		
	scales 1&2 √	Scale 1 & Scale 2	√	
Scale 3	1. Submit appropriate questions and through brainstorming they suggest ideas for various structures and processes.	Scale 1	6. Are knowledgeable about the properties of materials to be used (folding the paper to make it more resistant).	
	2. Discuss existing technology products, referring to the form, function and safety of their use.		7. Learn about various assemblies of different components to provide simple mechanisms (levers and links, wheel axle).	
	5. Conduct research and evaluate information sources for a specific product or process.	Scale 2	2. Make recommendations for changes in their ideas and their construction according to the assessment they have completed.	
	6. Evaluate products and processes based on pre-set criteria.		5. They do various checks on their construction before they make improvements.	
	7. Apply the steps of the design process.		6. Understand how the physical properties of materials affect how they are used.	
	Scale 4	3. Establish an action plan and implement the steps of the design process.	Scale 4	2. Recommend and implement alternatives solutions to implement their ideas.
		4. Assess products based on specifications and requirements which have been set and propose amendments.		
5. Report and document modifications and variations made during the design and making stages and explain the necessity of these distinctions.				
<b>Communication <i>Through appropriate means student will:</i></b>		<b>B. Mechanism</b>		
Scale 2	1. Discuss and describe technological products and natural objects.	Objectives	1. Recognize mechanisms applications through examples of constructions.	
	2. Describe verbally and / or through drawings the design process for ideas which will be implemented.		2. Explain the role of mechanisms through various examples.	
	3. They use lines, shapes to represent their ideas.		3. To simulate and model mechanical systems.	
	4. Communicate using sketches.		4. To apply examples of mechanisms in their own constructions.	
	5. Communicate using recognized symbols.			
		<b>C. Energy</b>		
Scale 3	1. Describe verbally and / or through drawings the design process for ideas that will be implemented.	Objectives	1. To recognize the importance of energy awareness, by saving energy and using renewable energy sources (RES).	
	2. They use lines, shapes and simple design methods to present their ideas.		3. To report environmental problems and suggest ways to mitigate them.	
	3. Recognize and use symbols in diagrams, circuits and designs.			
	4. Communicate using sketches, three-dimensional drawings and orthographic projections.	<b>D. Electricity</b>		
	5. Communicate using recognized symbols.	Objectives	1. To illustrate the role of electricity in our lives.	
		<b>E. Design</b>		
Scale 4	1. Enrich their designs by adding information through detailed dimensional drawings and enlargements.	Objectives	1. Mention the importance of design as an integral part of the manufacturing process of technology products and construction.	
	2. Present ideas and methods of construction through three-dimensional drawings and orthographic projections.		2. Explain and apply the basic stages of design and assess	

Table 3 Cypriot National Curriculum Skills and abilities covered by the SoW

Table 3 lists the possibilities offered from the National Curriculum for primary and secondary education by the complete SoW. There are 101 targets to be covered throughout Primary education. Sixty five out of the 101 targets are covered fully by the SoW. An extensive Table providing the areas covered partially (24/101) or to some or no extent (12/101) can be provided upon request.

## Samples of work

Figure 8 provides examples of some of the work completed during case study 3, with Primary school students. Some of the key research questions were to test the sequence of tasks developed (illustrated on the top half of each image) and to identify if the Engino products allow creative behaviours.

Having the platform on wheels as their starting point (seen in slide 1 of Figure 8), a diverse range of models can be seen in slide 4 as a result of all the tasks. All

models kept the design for the platform with the moving crate for the ball. However, the adjustable free standing base on which that was attached is different in all models. One group incorporated stationary material in a similar manner as during the completion of the initial exercises. These results is the beginning towards demonstrating the potential the Engino products can offer towards **fluency, flexibility, novelty appropriateness** and at part **motivation**.

Figure 9 provides a sample of students' work collected as part of case studies 4 and 5, during the process of refinement and validation of the SoW



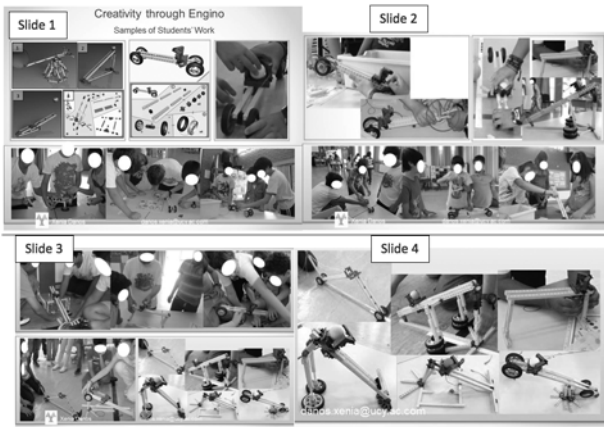
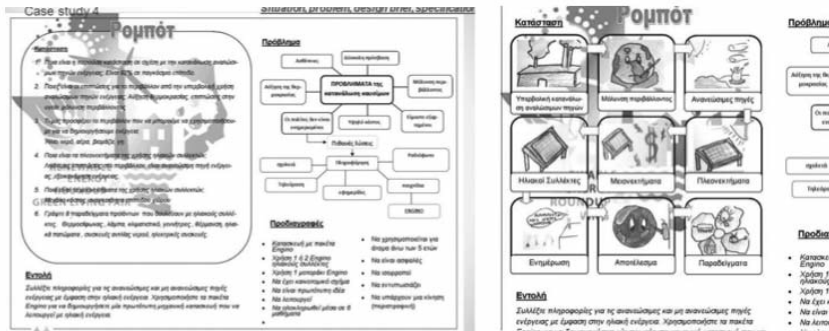


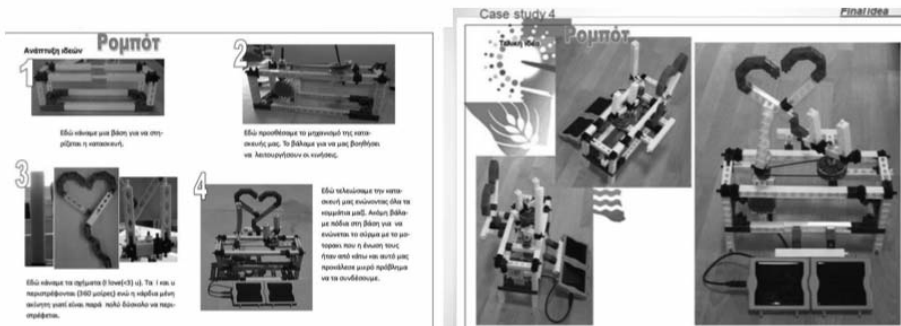
Figure 8 Sample work from case study 3



Identify the situation (using literacy and then graphicacy), problem, state the design brief and draw a specification list



Students conducted research on existing products for inspiration related to form, design, materials, mechanisms and movement. Two Engino models were created using a step-by-step guide for the students to experience building models using the Engino parts. Each model chosen for the groups offered some features which could potentially inspire the students' in their own design i.e. the use of gears in the bike design and the use of levers in the mechanical toy design.

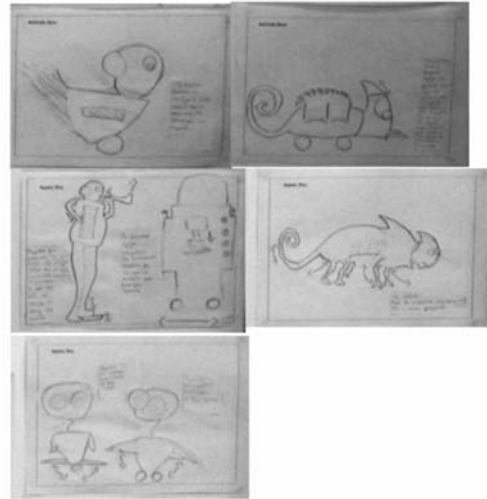
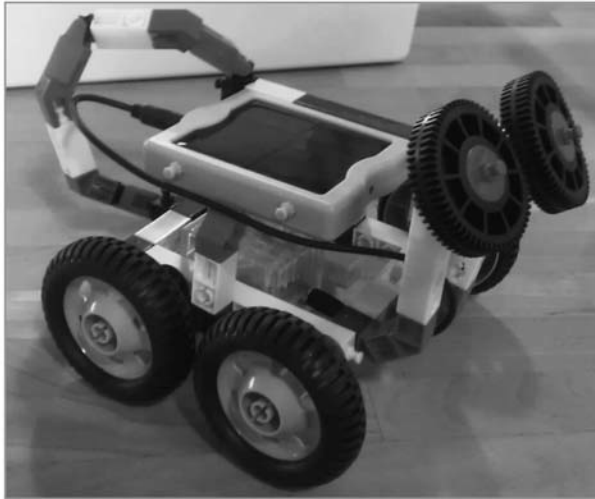


Having studied the different features the kit was offering, this group decided to use pulleys to transfer the movement from the motor to two moving parts in their design. The outcome is *original (novelty)* as it is a design created completely by the team. It is spontaneous (fluency) as it was created on the spot, without any 'on paper' design work. The students illustrated

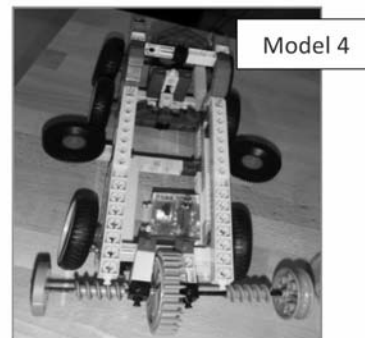
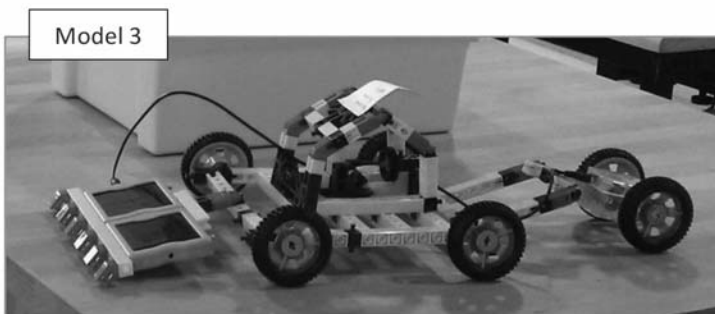
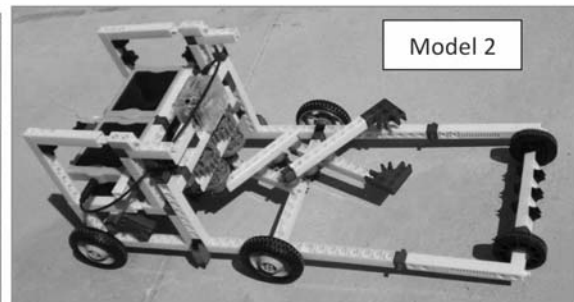
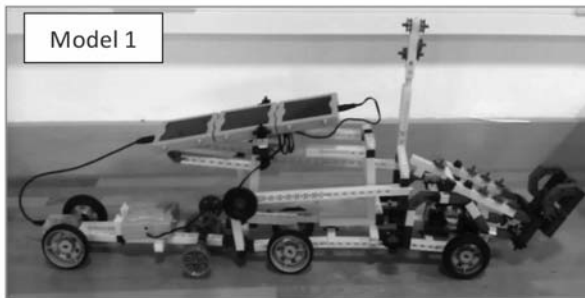
Figure 9 Students work completed during Case studies 4 & 5, part 1

# Action Research to Develop and Validate a Scheme of Work to Promote Creativity and Designerly Thinking Through Play

**flexibility** in their thinking and **determination (motivation)** as they had to *explore different possibilities* through *continuous reflection* in order to achieve a **functional (appropriateness)** product.



The model seen above is the result of the design work illustrated on the right hand side. The student wanted to create a 'cute animal looking' robot. To achieve that, the students constructed a simple base after getting to know the Engino products through experimentation and step-by-step constructing guides. They then used some pieces in a **novel** way to achieve the desirable outcome i.e. used wheels as big round eyes.



The four images above demonstrate the creative behaviour of **novelty** between the outcome models of four different groups. Even though the students worked together in the same class, the outcome of each group was featuring different agricultural vehicles, and each model was constructed using the Engino pieces in a different and unique manner i.e. the Archimedes screws were used as rotating blades in model 4, the solar panels were used as part of the vehicle tool in model 3 etc.

Figure 9 Students work completed during Case studies 4 & 5, part 2

## Action Research to Develop and Validate a Scheme of Work to Promote Creativity and Designerly Thinking Through Play

Type of study	Event	Ages	Research aims
Case study 1	First contact with the Engino products	6, 12 & 16 years old	Observe how children of various ages deal with the Engino products
Case study 2	Introduction to Engino products	Student's Helpers	Appropriate task sequence Creativity through Engino products
Case study 3	Competition day	10-12 students	Age appropriate Creativity through Engino products
Case study 4	Summer school phase 1	12-15 students	Test of SoW Age appropriate Creativity through Engino products
Case study 5	Summer school phase 1	12-15 students	Test of modified SoW Creativity through Engino products
Case study 6	Educational seminar	Primary & secondary school teachers	Dissemination of SoW Test of SoW Observe how teachers' perception of the new material Creativity through Engino products

Table 4 Summary of the studies completed with their research aims

### Discussion

The progression achieved through the studies (Table 4) completed allowed for the 'key' questions to be answered as well as the successful development of the SoW.

Taking an active role in leading the studies provided valuable information and knowledge on a number of areas. Assumptions and expectations were easy to investigate while working with the participants from the beginning until the end of the project. For example, during case studies 2 and 3, the assumption that students would prefer working on the computers whenever possible was disproven when most students clearly stated that in some stages they would rather hand write the answers rather than type them. In addition, the experience gained as an active teaching participant during the studies cultivated the ability to identify the participants' capabilities in the area set, which allowed for instant differentiation of the tasks to fulfil the needs and abilities of the group.

In particular, the way participants were involving themselves in the task of assembling a product following the Engino guides, offered a strong indication to a number of each participants' skills and abilities such as their: willingness to try something new (*fluency: open to new ideas*); persevere until the task was correctly completed (*motivation*); patience towards correct and careful observation of the guide to assemble the correct pieces to the corresponding spaces in the right orientation (*sensitivity*); dexterity when dealing with small pieces; simple symbol recognition, identifying when pieces had to be created multiple times with variations such as in

reflection to one another; team work skills by clearly assigning 'jobs' so stages on the step-by-step guide are not repeated; organisational skills by identifying the easiest and fastest way of working methodically as a team; and cognitive modelling for understanding how each piece constructed would fit together to make the 3 dimensional model.

Action research also provided evidence on areas which would be difficult to identify otherwise, as at times participants' comments and feedback did not reflect the sequence of events and outcomes of the tasks. For example, students and teachers started the group tasks believing that working in groups would not allow them to complete the tasks as they shared the belief that 'people in Cyprus schools do not know how to work together well'. Action research however clearly showed that through discussions and group work, all teams were able to find common interests and join their skills to produce a working prototype which everyone in the group was very proud of. Despite that being the outcome in all the studies completed for this project with participants of various ages, the majority of participants left the events thinking that it only worked because it was a designed event from the University, and it would not work in mainstream education. However, some teachers were prepared to try it in schools.

Having the opportunity to complete 2 case studies with participants of similar ages and backgrounds also offered the opportunity to amend parts of tasks and at times sharpen the details in the guidance offered towards

# Action Research to Develop and Validate a Scheme of Work to Promote Creativity and Designerly Thinking Through Play

creating a smoother succession of teaching and learning. An example of that was when resistance was clearly demonstrated, mostly by the students in case study 4, during the stages of research. Students could not see the 'long term' benefits of researching and learning more about the product appointed as their theme i.e. agricultural vehicles. They found the task boring and time consuming. This demonstrated a lack of **fluency** (*open to new ideas*) **flexibility** (*associate remote ideas*) and **insightfulness** (*influence by inspiration*). During case study 5, the benefits of each stage were clearly explained and examples were shown and analysed, to make the importance of each stage clear. This gave students the incentive to complete the tasks, even though they still did not enjoy doing it. Some teachers during the seminar did not feel comfortable following instructions which might have contained new ideas to the ones they were familiar with, which resulted in them failing to complete a working model. However, some were very willing to follow the 'new' way of working and instructions which they found very exciting and interesting. This provided a strong validation towards the success of the sequence of tasks designed for the SoW.

## Conclusions

The aim of the project was to design and develop a scheme of work suitable for the subject area of Design and Technology based on the Engino.net SolarPro products and, in particular to determine:

- the appropriateness of the age range of the Engino SolarPro products; and
- the potential for creative behaviours leading towards creativity through the Engino products.

Through a number of action-research studies, the material was successfully designed, created, tested, modified and tested again until satisfied with the results and these were then disseminated through a seminar for teachers. Through the studies, the following understandings were validated:

- the Engino products offers opportunities for creative behaviour to be used and developed, as illustrated by the different models created by each group in case studies 2 to 6 (novelty) and the creative behaviours which the products supported;
- a complete SoW for Design and Technology can be produced using the Engino products as the main teaching and learning tool;
- the Engino Design and Technology SoW developed is suitable for the recommended ages (10+);
- the SoW produced can guide the participants, if followed

correctly, into creating their own working model using the Engino SolarPro products;

- all students thoroughly enjoyed learning through the SoW developed based on the Engino.net SolarPro products; and
- action research was a good methodology for the testing, development and validation of the SoW developed.

All in all, action research allowed for thorough and complete participation of this researcher into the development of this material, by having a 'front seat' to the participants responses, actions, outcomes and learning.

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