From STEM to STEAM:
LED Light-Adjusting and Paper-Curved Pop Up Card Hands-On Curriculum Module Design

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***Abstract*—Pass researches on STEM education emphasized the rational problem solving among applied engineering and technology, while the nurture of the imagination and creativity in the students' art field was overlooked. Hence, this research aims to develop a STEAM curriculum module, with basic electronic technology and skill as the foundation, combining scientific RGB colour theory and the artistic concept of drawing and modelling design, with application of the Adobe Illustrator and SketchUp softwares, developing into a hands-on module "LED light-adjusting and paper-curved pop up card" STEAM curriculum. This research combined expert teachers from electrical engineering, physics and art fields to collaboratively develop the curriculum module, through reflective dialogues of three instructing teachers and two team teachers, experiencing three years of curriculum module revision. The first year developed the integrated curriculum of the mini DIY LED light-adjusting board that combined technology, engineering and mathematics, the second year combined with science concept and developed the STEM curriculum for LED light-adjusting board experiments, the third year combined with the artistic paper-curved pop up card and developed the STEAM curriculum module. This module can be applied in the living technology curriculum of the grade 8, which based on student-centred learning, with application of 6E Learning byDeSIGN™ Model for teaching, and this STEAM curriculum module can provide and be applied in 24 lessons of the secondary school's living technology curriculum.**

Keywords—STEAM curriculum; art; modelling; concepts learning process; creativity

I. INTRODUCTION

STEAM is a teaching method that trans-disciplinarily combined science, technology, engineering, arts and mathematics, having students with mathematical logic foundation, they get to learn the connotation of science and technology, through the presentation of engineering and arts. However, according to the research report of The International Technology and Engineering Educators Association (ITEEA), more than 2000 teachers of various expertise from nearly 15 countries who took part in the STEAM curriculum module training, there are only 7.6% of teachers who are practically teaching and truly developed STEAM curriculum with combination of art knowledge and hands-on learning activities (Yakman, 2017). The primary cause for most of the STEAM curriculum remained undeveloped as none of the art teachers was involved, and most of the expert teachers who developed the STEM curriculum are not in the art field, which made the integration of art knowledge and hands-on learning activity difficult for the curriculum.

With comparison to the STEM curriculum, the biggest distinction of STEAM curriculum that integrate art knowledge and hands-on learning activity, is firstly to have the professional connotation of the art field, i.e., drawing, modelling design, architectural art, etc. from designing field, and music theory and rhythm from musical field. Moreover, STEM curriculum's hands-on activity emphasized on the "practicality" of problem solving, while STEAM's encourages the "imagination" and "creativity" of the problem solving that the students' freedom to explore should be encouraged even if the performance might not be desirable (Connor, Komokar & Whittington, 2015). Researchers do stress that STEAM curriculum cannot be separated with "imagination" and "creativity", while art combines both (Connor et al., 2015; Boy, 2013; 陳怡倩, 2017). Hence, developing STEAM from STEM, participation of teachers with art expertise is firstly needed, collaborating with their art knowledge, together with the hands-on activity, the teaching strategy is integrated with the irrationality of artistic imagination and curriculum creation, to make up for the STEM's one-sided emphasis on the practical problem solving.

This research combined expert teachers from electrical engineering, physics and arts fields to collaboratively develop the curriculum module, through reflective dialogues of instructing teachers and team teachers, experiencing years of module revision, which truly implement the developing process from STEM to STEAM. This research is taking this opportunity to share the developing process of the STEAM curriculum, in order to stimulate the interest in more educational researcher in this area, making art to be truly integrated into the STEAM curriculum.

II. LITERATURE REVIEW

A. *Integration of Teaching Methods of Art Knowledge and Hands-on Learning Activity in the STEAM Curriculum*

Since 2006 ITEEA extended STEM's curriculum framework by integrating the artistic sensual elements with the rational STEM curriculum, and STEAM curriculum is defined as mathematical based, learning and using the ability in science, technology, engineering and arts, and arts application that covered social, language, physics, music and fine arts (ITEEA, 2016). Indeed, curriculum paradigms with integration of art and STEM emerge, for example, technology curriculums like three-dimensional printing, AR, VR, software design, etc., with all kinds of trendy curriculum contexts, however with uneven quality (陳怡倩, 2017). Although many STEAM curriculum researchers attempted to include art directly into the original STEM curriculum, the concept of integration is lacking. For examples, through "inquiry teaching method" with the original STEM curriculum, allowing students to have "questioning", to use "thinking method" with art-related topics (Harrison & Parks, 2017), or having added into the cooperative learning curriculum strategy (Gettings, 2016), making it the so-called STEAM curriculum, or topping it up with the term "STEAM", while the curriculum context did not truly integrate the art knowledge and hands-on learning activity together.

Hence, focusing on the development of the STEAM curriculum integration, art knowledge connotation should firstly be included in the STEAM curriculum (drawing and modelling design applied in this research), secondly, subjects are combined in a systematic way to integrate art-teaching strategy with the original teaching strategy (that is 6E Learning byDeSIGN™ Model integrated with imagination and creative thinking), thirdly, STEAM curriculum should nurture the imagination and creativity, as well as problem solving in engineering (students are encouraged to explore and achieve different masterpieces and learning outcomes). To conclude, this research aimed at the essentiality and theory foundation of the art, with systematic integration of art and better planning and design of the curriculum activities which help the learners to explore with their learning outcome, progressively developing STEM into STEAM curriculum module.

B. *Teaching Strategy of STEAM Curriculum*

In the past, STEM curriculum discussed teaching mainly from the "engineering's" perspective, i.e., ITEEA's 6E Learning byDeSIGN™ Model process which includes engage, explore, explain, engineer, enrich and evaluate (Burke, 2014). This curriculum module is a "problem solving" process that is recognizing the systems context, reasoning about uncertainty, making estimates and performing experiments (Dym, Agogino, Eris, Frey & Leifer, 2005).

Boy (2013) considered that the curriculum design developed from STEM to STEAM is not only to nurture the ability for problem solving, it should be emphasized more on the students' creativity, its "human-centred design", "problem-based", "inquiry-based". Besides, "discovery learning" provides students with autonomous decision ability for project solution. At the same time, researchers also stressed that the way of learning in the 21st century is the "non-linear design of complex system" through the use of technological tools. STEAM educators should not remain applying with the traditional divisional teaching method as before, while they need new trans-disciplinary teaching methods, new concept principle and teaching tools (Boy, 2013). We can conclude the STEAM curriculum's teaching strategy is not only design based with problem solving, preserving explore and learn to a certain extend, it is also helpful to inspire students' imagination and creativity, which exactly matches the teaching strategy's intention for the art.

Yet, engineering teaching strategies like the 6E are not entirely lack with nurturing the ability for imagination and creativity, as the engineering's creativity producing stage emphasizes to "enrich" and to "evaluate", which in tuned with the "elaborate" suggested by the STEM educators (Bybee, 2013), or the "redesign" process (Hynes, Postsmore, Dare, Rogers, Hammer & Carberry, 2011). Hence, this research considered the teaching strategy of the STEAM curriculum with art integration, should has specifically in the stages of "enrich" and "evaluate" providing the students with enough flexibility, that helps them to have enough creativity and mental space in a fixed progress, creating their own distinctive "masterpiece" instead of a repetitive product.

Therefore, the curriculum strategy of STEAM in this research has not only follows the 6E problem solving of the engineering teaching strategy, i.e., engage, explore, explain and engineer, stages that provides students to learn science, technology, engineering and mathematics, integration with art at the "enrich" and "evaluate" stages, students are allowed to have enough space for imagination and creativity to create masterpiece.

III. METHODOLOGY

A. *McKernan's (2013) Reflective Method*

The curriculum module developed by this research has particularly integrated art creation with techniques beyond the steps and techniques taught, which the frontline instructing teachers and team teachers are able to control the teaching progress, and the students' imagination and creativity of their performance are also taken care of. Instructing teachers and team teachers are not only the curriculum executors, they also take part in the research as their teaching feedback during the research process is important for the research outcome. Hence, this research adapts the McKernan's (2013) "reflective method" in the curriculum development, relying on the instructing teachers and team teachers with consistent attitude and skill, making their feedback as part of the research. During the reflective dialogue process with the instructing teachers and team teachers, experts from the STEAM curriculum are invited. At the end of curriculum implementation, feedback from the instructing teachers and team teachers are integrated into the research outcome, and to revise the curriculum module of the research, as shown in "Fig. 1".

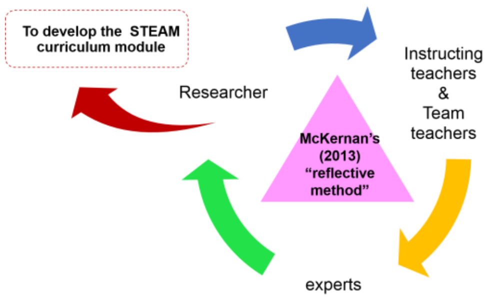

Fig. 1. Reflective method (McKernan, 2013)

B. Curriculum module from STEM to STEAM

This research has gone through three years of development from STEM to STEAM module, having first year developed the integration curriculum that combined technology, engineering and mathematics, with 18 lessons implemented for grade 7, second year integrated science concept and developed the mini DIY LED light-adjusting board with 22 lessons implemented for grade 8, third year integrated the artistic paper-curved pop up card and developed the STEAM curriculum module, with 24 lessons implemented for grade 8. The three years' development of curriculum module names, from STEM to STEAM and the teaching tools are shown in Table I.

C. Concept of Subjects' Integration

This curriculum module is mainly applied for the living technology curriculum of the grade 8, while the first year exploited subjects' concepts integration from technology, engineering and mathematics; scientific RBG colour theory was added in the second year; artistic concept of drawing and modelling design exploration were added in the third year. As shown in Table II.

TABLE I. CURRICULUM MODULE FROM STEM TO STEAM

Time	Curriculum name	Curriculum figure
first year	mini DIY LED light-adjusting board	
second year	LED light-adjusting board experiments curriculum module	
third year	LED light-adjusting and paper-curved pop up card hands-on curriculum module	

D. Curriculum materials and tools

This research collaborated with expert teachers from the electrical engineering, physics and art to develop the teaching materials and tools. The materials adapt printouts (Fig. 2) and eBook APP (Fig. 3) as usage for teaching the subject concept and hands-on learning activity. The tools planned to have the mini DIY LED light-adjusting board (Fig. 4), and applications with the Adobe Illustrator drawing software and Google SketchUp for designing paper-curved pop up card (Fig. 5), providing the learners to produce the pop up card with carving knife, and lastly, combining with the LED light-adjusting board and the creative masterpiece is completed.

E. Hands-on Learning Activity Design

The STEAM curriculum hands-on learning activity is designed based on the STEAM's student-centred concept, focusing on the "STEAM concept modelling" and "situational approach" to guide students. In the area of "STEAM concept modelling", lessons are started with the STEAM's scientific concept teaching, which facilitates the students' hands-on learning activity for the mini DIY LED light-adjusting board with the RGB colour concept, while in "situational approach", topics related with everyday life are adopted, i.e., wildlife conservations from the Taiwan ecosystem like Formosan black bear, Formosan sika deer and Formosan rock macaque, are assimilated into artistic hands-on learning activity, leading the students to have more imaginative connections with their living environment. The process of the students' hands-on learning activity is shown in "Fig. 6".

TABLE II. CONCEPT OF SUBJECTS' INTEGRATION FOR THE CURRICULUMS

Subjects	First Year	Second Year	Third Year
	Mini DIY LED light-adjusting board	***LED light-adjusting board experiments curriculum module***	***LED light-adjusting and paper-curved pop up card hands-on curriculum module***
science	non	RGB colour theory experiment	RGB colour theory experiment
technology	welding tools used	welding tools used	welding tools used
engineer	knowing circuit board & electronic components	knowing circuit board & electronic components	knowing circuit board & electronic components
math	electronic colour code calculation	electronic colour code calculation	electronic colour code calculation
art	non	non	Drawing & 3D modelling exploration
learning performance	knowing circuit board, measuring battery voltage with tri-functional electric meter, electronic colour code calculation, welding circuit board components	foam tube used for RGB colour theory experiment, students get to learn to adjust light change (RGB colour theory)	creating table lamp with collaboration of 3D pop up card, students were inspired for modelling art aesthetic, with effects of LED light transmission through 3D pop up card.

F. Curriculum learners, Instructing Teachers and Team Teachers and Curriculum location

The curriculum learners are from three secondary schools (two located in Taipei, one in Penghu). The first year is implemented in grade 7; second year is modified and implemented in grade 8 with integration of the scientific RGB colour theory experiment; third year is similarly for grade 8 too. Besides having the instructing teachers, this research has also further recruited two team teachers to take part in the curriculum, with one of them as electrical engineering expert, another with physics expertise. The two secondary schools from Taipei had their lessons in the living technology curriculum and were carried out in the exclusive classrooms (Fig. 7 and 8), the secondary school in Penghu had their lessons with their extracurricular activity and classroom (Fig. 9), all the above mentioned students were each provided with the curriculum materials and tools needed for their hands-on learning activity.

Fig. 2. Printouts material-LED control programming

Fig. 3. Digital material-eBook APP

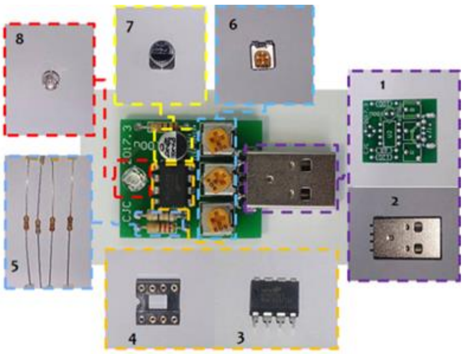

Fig. 4. mini DIY LED light-adjusting board

Fig. 5. Paper-curved pop up card

Fig. 6. Hands-on learning activities

Fig. 7. The living technology exclusive classrooms of A school in Taipei

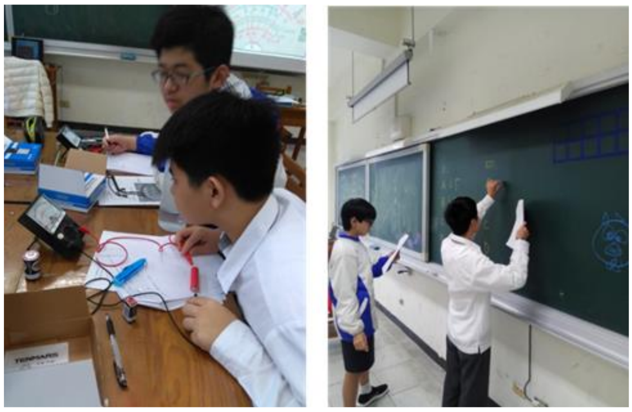

Fig. 8. The living technology exclusive classrooms of B school in Taipei

Fig. 9. The extracurricular activity classroom of C school in Penghu

G. Curriculum Objective and Progress Chart

The curriculum was started with the STEAM concept modelling, followed by the engineering 6E Learning byDeSIGN™ Model procedures, and lastly the creative masterpiece was completed by integrating the three-dimensional pop up card with the LED light-adjusting board. As shown in Table III.

IV. RESEARCH FINDING

A. First Year's Curriculum Module, Teaching Implementation and Teachers' Feedback

The first year in this research we had the mini DIY LED light-adjusting board developed by the electrical engineering expert teachers, aiming for students to learn to create a light-adjusting board with welding tools, with 18 weeks of lessons implemented for the grade 7 students of a secondary school in Taipei, having one living technology instructing teacher as A1, and one team teacher for physics guidance as B1.

TABLE III. CURRICULUM AIM AND PROGRESS

Week	Aim	Progress	Learning concept					Ability		
			S	***T***	***E***	***A***	***M***	***problem solving***	***imagination***	***creativity***
1	modelling-T	knowing tri-functional electric meter		•						
2	6E(engage)	measuring battery voltage with tri-functional electric meter		•				V		
3	modelling -M	knowing electronic colour code resistance calculation and learn to calculate resistance					•			
4	6E(explore)	resistance calculation combination					•	V		
5	modelling -S	knowing RGB colour theory	•							
6	6E(explain)	LED light-adjusting board control	•					V		
7	modelling -E	knowing circuit board			•					
8-10	6E(engineer)	welding exercise、welding circuit board、production of LED light-adjusting board			•			V		
11	6E(enrich)	create 3D pop up card				•			V	
12	6E(evaluate)	combining 3D pop up card with LED light-adjusting board model to complete creative masterpiece				•				V

The electronic colour code calculation is a rather complicated task for the grade 7 students, forasmuch it is suggested to modify and shift this curriculum to the grade 8. Besides, with too many students involved, the circuit board and welding demonstration by the teacher was not visible to all students. By having all of them to fully understand every single step, repetition of demonstration is needed and hence affecting the teaching efficiency. It is suggested to have utilities from digital teaching material and videos, helping the students to individually repeat learning any step that one might need. (A1)

Most of the time after the teachers had completed guiding the students for the hands-on activity, the students were only amazed with the multi colours shown by the mini DIY LED light-adjusting board but not realizing the scientific RGB colour theory, which defeat the purpose of exploration in the curriculum objective. It is suggested that the curriculum context should be added-in with the scientific concept modelling and exploration course, integrating with lampshade tools that will help students to apply the idea of LED light-adjusting board. (B1)

B. Second Year's Curriculum Module, Teaching Implementation and Teachers' Feedback

The second year in this research we modified the curriculum module as the LED light-adjusting board experiment with the STEM curriculum module. In the fifth and sixth week's lesson of 6E's "explanation" stage, the teaching strategy was integrated with the scientific RGB colour theory experiments, and scientific concept modelling was implemented. Besides having printouts, digital teaching material like the eBook APP was developed. Teaching tools were equipped with not just the LED light-adjusting board, foam tube was purchased for the students to have colour theory experiment and lamp application. The curriculum module was co-developed by both the electrical engineering and physics expert teachers, lessons were implemented for 20 weeks in the grade 8 of two secondary schools in Taipei, conducted by two living technology instructing teachers as A1 and A2, and two team teachers each from the electrical engineering and physics expertise, as B1 and B2.

Digital teaching material like the eBook APP helps the students to individually repeat learning any step that one might need, increasing the teaching efficiency, while the interactive teaching for the electronic colour code in the APP has been also very helpful to them for the resistance calculation. But sometimes students will use the iPad for internet browsing while they need to be restrained appropriately. (A1)

It is indeed very interesting to guide the students for welding the LED light-adjusting board by themselves, and they were very excited when they saw the bulbs lighted up. However, it was a pity for just using the foam tube as it can be better with more creative applications like the cute lampshade. (A2)

The lessons were enhanced with scientific conceptual modelling, making the teaching process smoother. It is suggested to have a chapter in the eBook APP for colour theory explanation, for *example, interactive movement of RGB colour plates for colour change. (B1)*

Currently the usage of foam tube as application is indeed too simple, it will be better if lampshade can be developed by art expert teachers and be implemented for the students to have creative thinking. (B2)

C. Third Year's Curriculum Module, Teaching Implementation and Teachers' Feedback

The third year in this research, we adjusted the curriculum module as LED light-adjusting and paper-curved pop up card Hands-on Curriculum Module. The strategy remained with the scientific RGB colour theory experiment, added-in with 11 to 12 weeks of art hands-on learning activity as the 6E's "enrich" and "evaluate" stages that inspired students' imagination and creativity. Teaching materials were modified with printouts as main which the eBook APP as secondary support. Teaching tools include the mini DIY LED light-adjusting board material pack, three-dimensional paper-curved pop up card developed by art expert teachers that were further recruited, provided students to have creative masterpiece from integration of three-dimensional paper-curved pop up card with LED light-adjusting board. The curriculum module was co-developed by three expert teachers from the fields of electrical engineering, physics and art, having lessons conducted in two secondary school in Taipei and one secondary school in Penghu for the grade 8, for 24 weeks' lessons. It was conducted by three living technology instructing teachers as A1, A2 and A3, and two team teachers each from the electrical engineering and physics expertise, as B1 and B2.

There was basically not much problem with the third year's curriculum, many things were modified for the better, and the new three-dimensional pop up card for the lampshade application aroused more learning interest and motivation in students, especially the girls. Besides, students still like to use iPad for internet browsing, which was very distracting during the stage with eBook APP teaching. (A1)

The newly added 3D pop up card is very lovely, all the students liked it, but it can be better if students are allowed to colour their own pop up card. (A2)

Imperfection was observed when the iPads are not available for students to have one each, which is troublesome for sharing management too. (A3)

Good response was shown in both students and teachers. It is suggested to develop more types of pop up card as having just one type is a pity. (B1)

The LED light-adjusting board can be developed into diverse controls, for example: dip switch. (B2)

V. RESEARCH RESULT AND SUGGESTION

In the three years' process of development from STEM to STEAM, the feedback from reflective dialogues of instructing teachers and team teachers helped the module for its constant adjustments, and the teaching materials and tools were improved with more creativity too. However, in the phase of the curriculum module, teaching strategy and teaching evaluation need to be improved further. For the curriculum module, art hands-on learning activity was integrated, but still lack with the art knowledge teaching. Secondly, for the teaching strategy, although the three-dimensional paper-curved pop up card is used, it is still a modelling tool and the students' imagination and creativity can be more efficiently nurtured if they are allowed to create their own three-dimensional model. Furthermore, the development of performance assessment has yet been included in this research which the students' learning performance is not obviously shown, while this will be the future progress for this research to improve.

This research was limited to the usage of printouts and digital teaching materials, leaving the teachers to choose and adjust the usage with individual preference, which could not be deducted for which material is the better one. This research will still rely on the teachers' feedback from the reflective dialogues, with improved printouts and digital teaching materials, making both good learning and teaching aids for the students and teachers.

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