DESIGNING A TEACHING FRAMEWORK WITH A FOCUS ON FORMING MULTIPLE-NETS TO MAP STUDENT CREATIVITY PATTERNS

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Abstract *To inspire students' creativity for making science fair models and other science projects. A framework is provided with links to deep learning and multiple-nets. Making connections between ideas, subjects and material objects is mapped in a framework to develop some creativity patterns. Teachers are provided with a rubric to possibly apply this framework in the classrooms. The pathway of multiple-nets can be applied effectively in a vast range of activities and this approach is also supported by some theoretical grounds. Further studies will be needed to analyze and expand this approach for specific parameters at various levels.*

Keywords: Deep learning, science fair models, cognitive-nets, social-nets, concept maps, creativity, student portfolios

1. INTRODUCTION

The history of many inventions also reveals the ways in which pioneer approaches were the result of joining various ideas or material objects in an innovative way. This notion is also a hallmark of the new cognitive waves of paradigm shifts. According to The Brain- The Ultimate Guide: "If you want to be smart like Einstein, it's all about having the proper connections" (pg.69). The search for paths which can lead to the conceptual unification is also a way of forming connections between the ideas, a world of making nets/links of ideas, cognitive-nets, social-nets and material-nets.

Abdus Salam, a Nobel laureate in physics remarks: "The history of science is the history of search for unifying concepts." (Close, 2009). Kip Thorne the Nobel laureate in physics emphasized: "Huge discoveries are really the result of giant collaborations" (Thorne 2017).

The pathway of connecting ideas, thoughts, numbers, and material objects can lead to an intriguing discovery or invention (Derry, Schunn & Gernsbacher, 2005). Knowingly or unknowingly our concept formation processes, learning plans and daily work weaves through the frameworks of connecting various ideas and material objects (cf. Kalb, 2017). Thinking of multiple net links in innumerable fields and situations to explore many new creative pathways, from everyday answers to big equations, from student made traditional science models to creativity based models, a multitudinous power of creativity can be analyzed in our inner and outer surroundings (cf. Kalb, 2017; Shapiro, 2013). There is a growing need and interest to explore and apply this approach in our theory, research and practice. Perhaps the application of this framework in teaching can open doors for many possibilities to inspire creativity (cf. Derry, Schunn & Gernsbacher, 2005).

The analogy of 'trading zones' is used by Galison (1997), to show how different groups with different ways of trading can also use common grounds for trading certain items. This analogy is also used to explain the interactions between theory and experiment to develop physics (Derry, Schunn & Gernsbacher, 2005). Moreover, it can be applied in the world of school science pedagogy. Despite some differences, certain common grounds or trading zones can be explored to form interdisciplinary or multidisciplinary collaboration pathways (Figure 1). With the current trends of research in the field of neuroscience, the field of making connections is gaining momentum in a variety of forms (cf. Derry, Schunn & Gernsbacher, 2005).

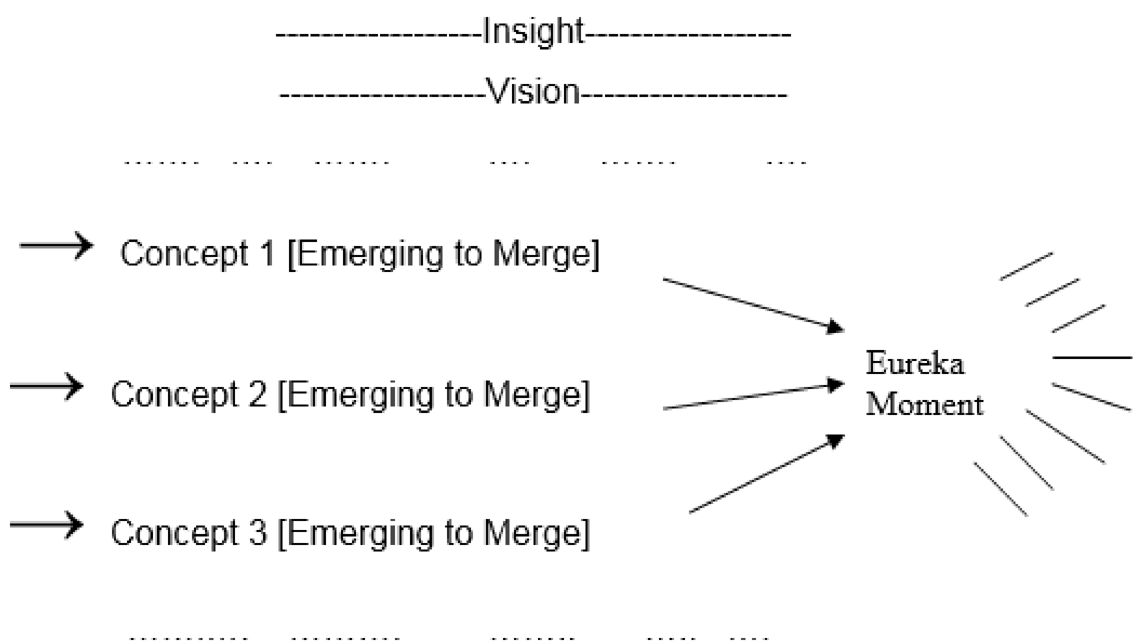

Figure 1. Making nets of ideas leading to a creative solution

Certain theories emphasize about the links between how knowledge is provided from the outside surroundings, social environment, and how it is internally processed in the psychological form by the learners. According to Vygotsky (1997) "every function in the cultural development of the child appears on the stage twice, in two planes, first, the social, then the psychological, first between people as an interpsychological category, then within the child as an intrapsychological category." In the light of this notion, a social and psychological environment can facilitate certain concepts and it is linked with how a learner will be presented the information and then how a learner will process that information (cf. Vygotsky, 1997). It is also a possibility if the starting point will be from the inner to outer framework or the other way.

To evolve ideas for science fair projects, students are also given the analogy of a plant growth; starting from seeds, then giving them favourable environments, growing plant, flowers, and fruits– then from individuals to others for cross pollination. Using these analogical ideas for deep learning, the science fair projects can also be gradually developed. At the middle school level, science teaching has many challenges and one of them is to inspire students' creativity and make some new forms of designs and models. The following framework and outline shows some pathways to address this problem within given parameters.

1.1. Creativity dimension in the curriculum

Although the descriptions of creativity are varied, it includes forming novel ideas with new possibilities, reaching new levels of originality and to explore new results (cf. Craft 2008). The emphasis on creativity related activities is increasing in the curriculum and other fields.

The Curriculum of Ontario, Canada is going under review and among other parameters the focus on creativity is also mentioned, according to the news release from the office of the Premier of Ontario (2017):

"Ontario's updated school curriculum will be developed through the public consultations with the goal of improving student achievement in core skills such as math and increasing emphasis on transferable life skills that can help students of all ages meet the changing demands of today and tomorrow. Communication, problem-solving, critical thinking, creativity and global citizenship are skills that will help Ontario students thrive as they grow up in a changing, interconnected world. Beginning next school year, new report cards will better track a young person's development of these essential and transferable life skills."

1.2. Educational connectivity, forming links and creative work

The approach leading to deep learning is supported by various studies (Sawyer 2014). In comparing the notions of deep learning and traditional learning some important factors are distinguished in the following ways. Deep learning focuses on connecting new ideas with previous experiences and knowledge, integrating knowledge relevant conceptual frames, exploring patterns and looking for beyond apparent level interactions, evaluating new ideas, relate them to meaningful conclusions and apply metacognitive reflections. In contrast, the traditional learning practices include: syllabus as not related to previous knowledge, learning not well connected to experiences, memorization of facts, lack of making connections between new concepts and the previous knowledge, knowledge as a piece of information to remember and memorizing with a lack of purpose (cf. Sawyer 2014). The extended application of deep learning is a multi-fold process. Making connections to design an innovative model or a project in science education is also highly useful.

The science fairs and other forms of school based science education, relates to various projects that are designed by students. In general practices, when students are given opportunity to design projects for the science fairs or classroom projects, they commonly look for ideas from the already published science experiment books, written for science fairs or internet based science experiments and try to repeat them, except some innovative models made by a smaller number of students. By classifying projects in terms of students' creativity versus traditional types, data can be collected to observe the trends (Figure 2). The need to inspire students in science learning is being elaborated through various approaches, including the pathways of STEM and STEAM. This need indicates possibilities to include nets of various subjects. The approach with integrating deep learning and making multiple-nets can inspire students to make creative models for science fairs or other paths of learning.

2. METHODS

The main aim is to develop a framework that can be useful for applying a multiple-net model in the classroom learning at the middle school level, with a focus on science teaching. This framework can help in applying and developing new pathways for future science education pursuits. Furthermore, it provides an answer to this research question: what kind of framework can integrate deep learning strategies to inspire students' creativity for making innovative science models/ projects.

2.1. Analyzing the component of students' creativity in their designs and models

The problem analysis of this project led to the observation of fact that it was common among students, at the middle school level, to make science fair models or projects based on repetition of certain experiments or models. The level of student creativity was not clearly exhibited in the designs of their models. This data was derived based on the number of models made by students and categorizing them into two groups: students' based creativity or repetition of models from other books and resources (Figure 2).

2.2. Frameworks for applying multiple-net pathway

Students were provided with reasonable time and framework sheets to explore their own ideas to design a model which reflects their own creativity to prevent the activity from being limited to the science classes on the given timetable of a class. Students were keeping a record of how their ideas develop. A special focus was given on making connections on a range of frameworks (such as nets of numbers, nets of subjects, nets of social frames, nets of language, nets of material objects). Students first designed their individual outline of the project and then they brought their ideas to a small group of students for further interfaces of new frameworks. This process enriched the framework-oriented thinking, application by making multiple-nets and considers the role of deep learning with boundless possibilities to innovate. Students shared their views emerging from social experiences and challenges in making inventions to solve those problems. Students exhibited their interest to solve a problem and thereby came up with a creative model for science fairs or other projects. By creating an inspiring environment, students showed their creativity which was reflected in the models they designed. The framework designed gives broad options to create and record the development of ideas and models with an individual's map of creativity. The ongoing possibilities of developing the ideas and models remain open while it sustains a framework to reflect with other framework(s). This framework also incorporates the outline given in the rubric of the Ministry of Education, Ontario, Grade 8, science curriculum, the program in science and technology (Rubric indicating the stages: Beginning→ Exploring→ Emerging→ Competent→ Proficient). The current framework designed opens avenues beyond a typical rubric for assessment and guides in making extensive connections. By making new nets and links, the possibility of reaching a creative solution is inspired and some mapping is used to record the patterns. The mapping is not just a linear mapping framework but it unfolds multiple dimensions using arrow diagrams, Venn diagrams, graphic organizers and self generated diagrams.

Some studies indicate an overlap between the everyday explanations conveyed by the scientists and the non-scientists (cf. Keil and Wilson 2000). The notions of overlap can also be analyzed from the dimension of frameworks used to explain and categorize the nets of ideas and the nets of material objects. Although students and teachers frequently make connections in their learning and creativity interactions; the process of making it a well-defined process facilitates the exponential world of forming nets of multiple types and associational strategies (cf. Hargrove and Nietfeld 2015). The framework with a creativity focus and deep learning is at the early stage and needs more analysis from the lens of various domains and variables.

3. DATA AND FRAMEWORK OUTLINE

In order to compare the student designed science models to explore the pathway of scientific creativity the following comparisons are presented.

Examples of student made science fair models:

1 Without an encouragement to make connections

2 With an encouragement to make connections and use creativity

Without an encouragement to make connections		With an encouragement to make connections and use creativity
1	Volcano	Circular roof bumper
2	Car with a motor	Car with slim pillars for safety
3	Simple fan	Purse with an electronic system to avoid theft
4	Model of animal cells	Language learning machine
5	Model of plant cell	Machine to help English language learners
6	Elastic band car	Math soccer board game invented
7	Windmill (still model)	Car with a bike function

Figure 2. Students made models grouped for applying creative pathways and using conventional ways

The role of combining various material objects and ideas is emphasized at many forums to improve innovation and creativity. The comparison shown in Figure 2 is an example of some models which were made using effective collaboration, making connections and applying the deep learning model. Teacher’s observations about making connections can also facilitate the process of learning and working with creativity.

My pathways **My portfolio**

(Pathways of my discoveries and creativity- one example of student's gradual growth of making creative models)

Student Name: Date:	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
Creative approach				Designed sleeves or covers to protect my hands at the handle of my bicycle	Safety design by students' example	Circular roof bumper,
Which pathway led to this idea				Injuries of hands while riding a bicycle		News of car accident, sadness, analyzing reasons and making a new style protective shield
How it was refined				First made with construction paper, then with canvas		By many tests on toy cars
Future growth possibilities				May be design of protective covers for the handle of bicycle		Applying with robust design for cars
Links to deep learning				Looking for patterns of the repeated injuries, finding a solution		Social impact to science invention, in-depth reasoning

Figure 3. Record of students' creative work, a way to inspire creativity continuum (One example)

The framework of development of ideas shows the growth of creativity patterns, the converging and diverging waves of possibilities, with some parameters of students' work to indicate a few dimensions of progress for improving their designs and models.

Outline of the framework	**At an individual level**	**At a small group level**
First flash of a problem to solve	Car accident, news of death	Enriched discussions, developing ideas, from social and emotional level to science and technology
Refine question(s)	Why this car accident happened? How? What I can invent to save lives for this type of accident?	Reasoning, research, refining
Review of previous inventions in this field	Already in use, safety features of cars, impact bars, bumpers	Sharing research, exchanging ideas
Developing multiple nets to lead to a creativity driven project (activity occurs on various days)	Researching on the common reasons of accidents, rollovers, how it happens? Coming up with a new idea to make a circular roof bumper, providing an extra layer of safety in case of rollovers.	Group work to develop ideas, designing models, testing with a given weight,
Developing ideas and project within the small group (activity on various days)	Making circular roof bumper and testing it	Reframing ideas, re-examine links, revisit the possibilities, group work to design models, testing with a given weight
Links to curriculum	Systems in action, mechanics, levers	Systems in action, mechanics, levers
Assessment	Checking all aspects according to the rubric provided by the teacher, ministry outlines	Checking all aspects according to the rubric provided by the teacher, ministry

Figure 4. Framework for developing ideas, solving a problem and evaluation for creativity driven science projects at the middle school level (one example)

The rubrics and frameworks mentioned above are like a pedagogical connectome, to facilitate the growth of ideas and creativity patterns. Those patterns may indicate the

initial steps of thinking, next stages of development, and the maps of connections among various entities (Figures 3, 4, 5). The details may not include an exact route of the development of all dimensions, however some guidance is provided to develop the ideas. The problem-solving stage may encompass brainstorming, developing ideas with a focus, finding a solution, making a prototype, testing or retesting.

Problem brainstorm emerging new waves viewing various dimensions of the problem	Nets of ideas Nets of subjects Nets of numbers Nets of communication Nets of social frames Nets of inventions Nets of language Nets of material gadgets Nets of ………. {add any new links you develop} (making connections over a period of time)	Pathways for discoveries, making new models

Figure 5. A framework to make interactive journey for creativity and problem solving

This framework is to facilitate collaboration for finding creative solutions, observing the nets of multiple forms and expanding the conventional limits.

Table 1. The number of students that made creativity-based and conventional style models

Students' creativity based models	Students' conventional models
65 (74.71%)	22 (25.28%)

The students' performance on making models with creativity shows an increase in the comparison of their work. Out of a total of 87 models made by students, 65 (74.71%) models were based on students' creativity, while 22 (25.28%) designs were based on conventional models (Table 1). There is a possibility to compare the dimensions of making connections and the journey of students to collaborate to enhance their creativity. The classification and the rubrics in Figures 2, 3, 4 and 5 indicates the framework designs to facilitate the development of creative tasks.

4. DISCUSSION AND CONCLUSIONS

The results clearly indicate an increase in the students' applied creativity to design science models by making links and mapping as shown in the framework. Students' creative skills in science can be flourished by making connections, enhancing collaboration, encouraging making creative models, linking various subjects, making nets of material objects and forming nets of ideas. Multiple nets of various types, such as cognitive-nets, social-nets, number-nets, material-nets can be a fruitful way, if it is applied effectively. This framework facilitates a teacher to keep track of the way students develop ideas, facilitate innovative designing, make creative models and map the creativity patterns. In the student assessments, the role of their creativity portfolio can also be incorporated in some form. The use of a creativity portfolio for mapping students' framework from grade to grade (or through the yearly change of classes) can also provide useful data. The record of student's creativity patterns can also guide students in many ways to re-frame, re-examine and re-define their growing potential. The framework can also be used for other formats of students' work and mapping learning patterns. The next stage will be to design new frameworks to adjust the needs of various schools and their curriculum expectations. Further research on multiple-nets can be conducted with interdisciplinary frames to analyze various dimensions.

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