Developing Human Character through STEM Planning and Design Learning (PaDL) Framework

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Summary

RECSAM as the lead SEAMEO Centre pursued on the development and publication of Common Core Regional Learning Standards (CCRLS) in Mathematics and Science in 2017 which presents standards for what every learner should know, be able to do and value in mathematics and science and in support to the goal of regional integration for an ASEAN Community. The CCRLS in Mathematics and Science envisions to developing basic human characters, creative human capital and well qualified citizens for a harmonious ASEAN society. SEAMEO RECSAM has long recognized and taken cognizance of the impact of STEM education in the national curriculum of SEAMEO Member Countries. Thus RECSAM attempted to develop a model or framework from which STEM educators could refer as they plan and implement STEM lessons. This paper describes the STEM Planning and Design Learning (PaDL) framework which highlights the development of the human empathy as one of the important stages in the Design Learning Process for students in addition to other stages of developing design ideas, prototyping/modeling and proposing solution.

Keywords: human character, values, empathy, learning standards, STEM, lesson planning

Introduction

In this era of automated world, majority of the countries are adopting Industrial Revolution (IR) 4.0 with the usage of innovations (i.e. IoT, big data, robotics and AI) to facilitate human tasks. This 'new' culture sometimes makes people strictly depend on smart gadgets and applications that seem to make humans as 'slaves' or followers. Therefore, challenges faced by IR 4.0 should be balanced with Society 5.0 that asserts that society should be the centre that "… balances economic advancement with the resolution of social problems by a system that highly integrates cyberspace and physical space" (Cabinet Office, 2020). Society 5.0 originated from Japan is the country's way forward in overcoming future challenges created by IR 4.0. Nevertheless, this policy can be applicable to other countries in achieving economic development as well in solving social problems. One of the main concerns with rapid industrial and economic development is the eroding of the values of human characters. One of the solutions is through education and apparently in STEM related subjects. The challenge is in developing a learning framework that would involve students to develop human character values in learning science and mathematics and STEM in general.

Character Education Overview

"Great learning and superior abilities will be of little value . . . unless virtue, truth and integrity are added to them."

- *Abigail Adams*

The above quote captures the essence and true meaning and value of human character. Character means different things to different people. The English work 'character' is derived from the Greek *character*, which originally refereed to a mark impressed upon a coin. Generally 'character' mean a distinctive mark by which one thing is distinguished with others and primarily mean the assemblage of qualities that distinguish one individual from another (Homiak, 2007). Kevin Ryan and Karen Bohlin (1999) define people of good character as individuals who know the good, love the good and do the good. A person's 'character' refers to the disposition and habits that determine the way that a person normally responds to desires, fears, challenges, opportunities, failures and success (Pala, 2011). A person's character is the sum of all the qualities that make who you are. It is your values, your thoughts, your words, your actions (Singla, 2009).

The Benefits of Character Education

Character education includes a broad range of concepts such as positive school culture, moral education, just communities, caring school communities, social-emotional learning, positive youth development, civic education and service learning. All of these approaches promote the intellectual, social, emotional, and ethical development of young people and share a commitment to help young people become responsible, caring, and contributing citizens. Educating the mind and promoting ethical values that lead to success for both individuals and society (Pala, 2011).

In the US, the Character Education Partnership (2010) describes character education as a *"national movement creating schools that foster ethical, responsible and caring young people by modelling and teaching good character through emphasis on universal values. It is the intentional, proactive effort by schools, districts and states to instill in their students important core ethical values such as caring, honesty, fairness, responsibility and respect for self and others. It provides long-term solutions that address moral, ethical and academic issues of growing concern to our society and key safety of our schools."*

The 11 Principles of Effective Character Education (2010) has listed the benefits of quality character education as follows:

- Helps students to develop important human qualities such as justice, diligence, compassion, respect, and courage, and to understand why it is important to live by them;
- Promotes character development through the exploration of ethical issues across the curriculum;
- Teaches how to solve conflicts fairly, creating safer schools that are freer of intimidation, hear and violence , and are more conducive to learning;
- It not only cultivates minds, it nurtures hearts;

- Teaches adults and students to understand, engage in, care about, and act on core ethical values such as respect, justice, citizenship, fairness, and responsibility for self and others in school and as part of a larger community; and
- Develops a positive and moral climate by engaging the participation of students, teachers and staff, parents and communities.

Teaching and Learning Human Characters in Science and Mathematics

At present, science teachers or educators are experiencing huge challenges with education reforms, accelerated technological advancement and globalization which contributes to the complexities in emphasizing moral values through teaching and learning (Chowdurhy, 2016).

According to Siahaan (2019), mathematics teachers did not inculcate human character values during teaching and learning process but focusing delivering the lesson materials and on problem solving. Nevertheless, he found that mathematics learning and character learning were taught in a separate manner. In this case, mathematics is taught directly as a subject while human character values are instilled indirectly based on the teacher's treatment to students' different ability levels

Despite the challenges stated, Huda, Ekowati and Husamah (2014) claimed that students' values can be developed through learning mathematics and natural sciences because of the subjects' closely related to facts and nature.

In general perception, science and mathematics are considered as cognitive dimension rarely integrated with affective dimension. Bishop in Seah (2008) states that most mathematics teachers did not consider teaching mathematics were incorporated in teaching values. This "value-free" teaching and learning mathematics perception is quite worrisome. If mathematics are treated as cold hard facts and figures subject, the impact will be on students' impression on the subject per se. This is again the irony of teachers to be a role model on values (Seah, 2008) but it does not seem to appear in mathematics classroom.

The SEAMEO Basic Education Standards Common Core Regional Learning Standards

SEAMEO education priority areas include development and enhancement of 21st century skills comprising of character education, entrepreneurship education, information and communications technology, language and literacy, numeracy, and scientific and technological literacy in all learners. Thus, SEAMEO RECSAM, with its mandate to promote science and mathematics education in the Southeast Asian region, led one of the 12 initiatives under the Golden SEAMEO and reflected in the SEAMEO Strategic Plan 2011-2020, known as SEAMEO Basic Education Standards (SEA-BES).

Under the new SEAMEO Education Agenda (2015-2035), SEA-BES project is re-aligned into Priority Area #7 "Adopting a 21st Century Curriculum" which states "*to pursue a radical reform through systematic analysis of knowledge, skills, and values needed to effectively respond to changing global contexts, particularly to the ever-increasing complexity of the Southeast Asian* *economic, socio-cultural and political environment, developing teacher imbued with ASEAN ideals in building ASEAN Community within 20 years.*"

The SEAMEO Basic Education Standards Common Core Regional Learning Standards (SEA-BES CCRLS) is a regional curriculum project which present common, shared and agreed upon standards for what every learner should know, be able to do and value in mathematics and science. Basically, the aim of the SEA-BES CCRLS in Mathematics and Science is "to provide world-class learning standards in Science and Mathematics, including 21st century skills that can be used as benchmarks in SEAMEO Member Countries to ensure all students have access to fundamental knowledge, skills and values in order to be socially responsible, globally competitive and sustainable." The SEA-BES CCRLS in Mathematics and Science was finally published in 2017.

Development of Human Character as Reflected in the Frameworks for CCRLS in Mathematics and Science

The aims of Mathematics in CCRLS are to: (a) develop mathematical values, attitudes and habits of mind for human character; (b) develop mathematical thinking and enable to produce appropriate process; and (c) acquire proficiency in mathematics content and apply mathematics in appropriate situations. Eventually, the aims would lead to the development of basic human characters, creative human capital, and well qualified citizens in Southeast Asia for a harmonious society through mathematics (Mangao, D.D., Ahmad, N.J. & Isoda, M. , 2017)

Mathematical Values, Attitude and Habits for Human Character

The mathematical values, attitudes and habits for human character component of the framework for CCRLS in Mathematics together mathematical thinking and processes and contents are shown in Figure 1. These are further categorised into mathematical values (seeking), mathematical attitude (attempting to), and mathematical habits of mind (for of mind are developed and inculcated through the learning of the content knowledge as seen in Figure 1.

Mathematics values include generality and expandability, reasonableness and harmony, usefulness and efficiency, simplicity and beauty. Mathematical attitude includes seeing and thinking mathematically, posing questions and developing explanations, generalization and extension, and appreciation of others' ideas. Finally, mathematical habits of mind includes reasonable and critical while respecting and appreciating other's ideas, autonomous and social, creative, innovative and harmonious to develop citizenship, judicious in using tools, and empowerment in predicting the future. Mathematics as a subject fosters challenge and competitiveness, appreciation for others, develop mindset for lifelong learning, personal development and social mobility.

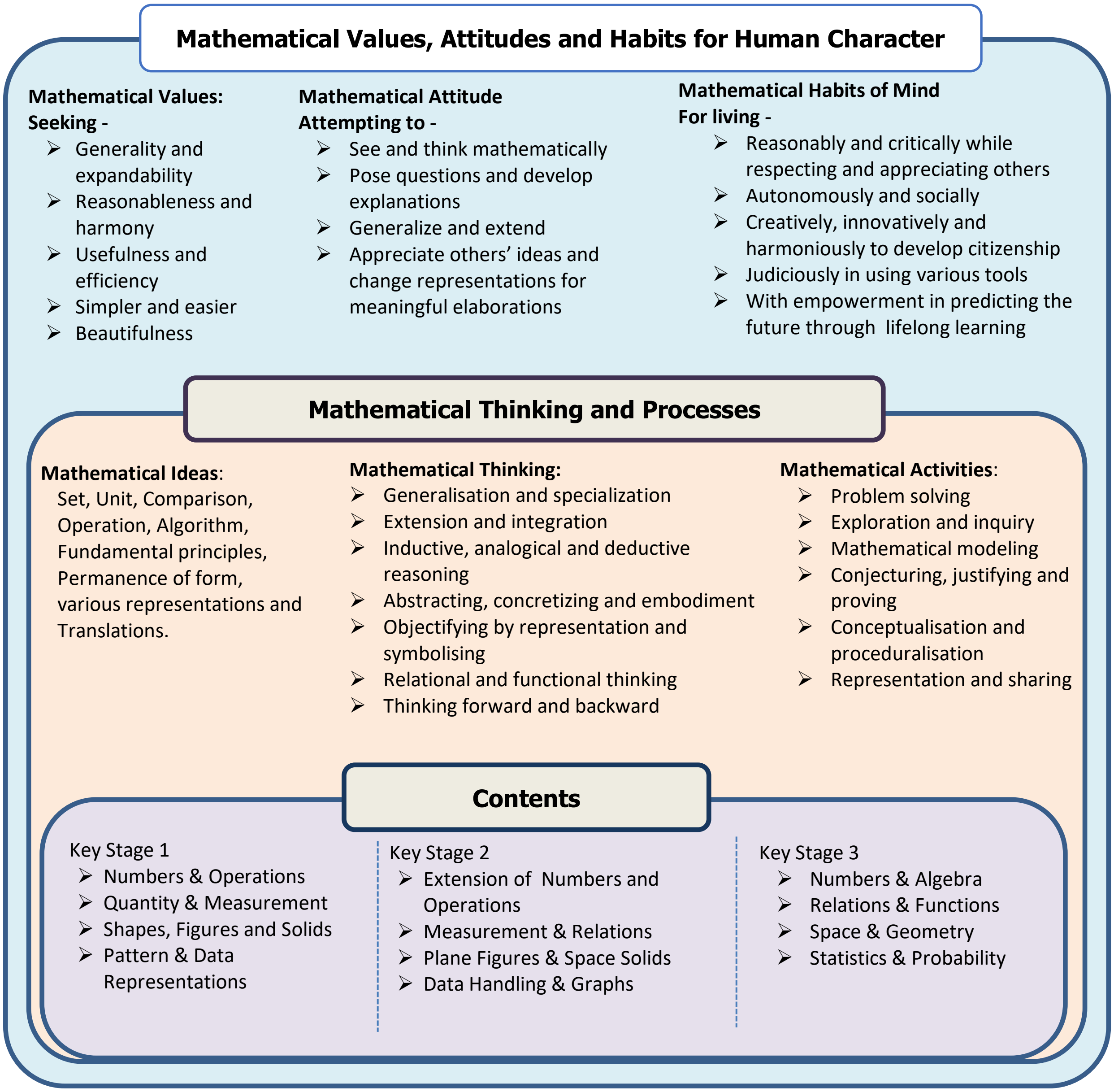

Figure 1. CCRLS Framework for Mathematics

Correspondingly, the aims of Science in CCRLS are to: (a) develop scientific literacy whereby scientific knowledge acquired through the processes of science with technology as an enabler is applied in daily lives and used to acquire new knowledge; (b) instill the ability to carry out scientific inquiry to understand the world around us; (c) demonstrate the understanding of the nature of science in the process of carrying out scientific investigation; (d) develop scientific skills through hands-on and minds-on experiences; (e) develop understanding of the interrelationship of science with society, environment, technology, engineering and mathematics; (f) demonstrate ethical behaviour, scientific attitudes and values when undertaking scientific thinking and processes; and (g) demonstrate the ability to use the acquired scientific thinking and processes in making informed decision, and debating scientific and social-cultural issues.

The framework of CCLRS in Science as shown in Figure 2 covers the major aspects of science, as well as the social and technological implications of science while Table 1 shows the components of the framework.

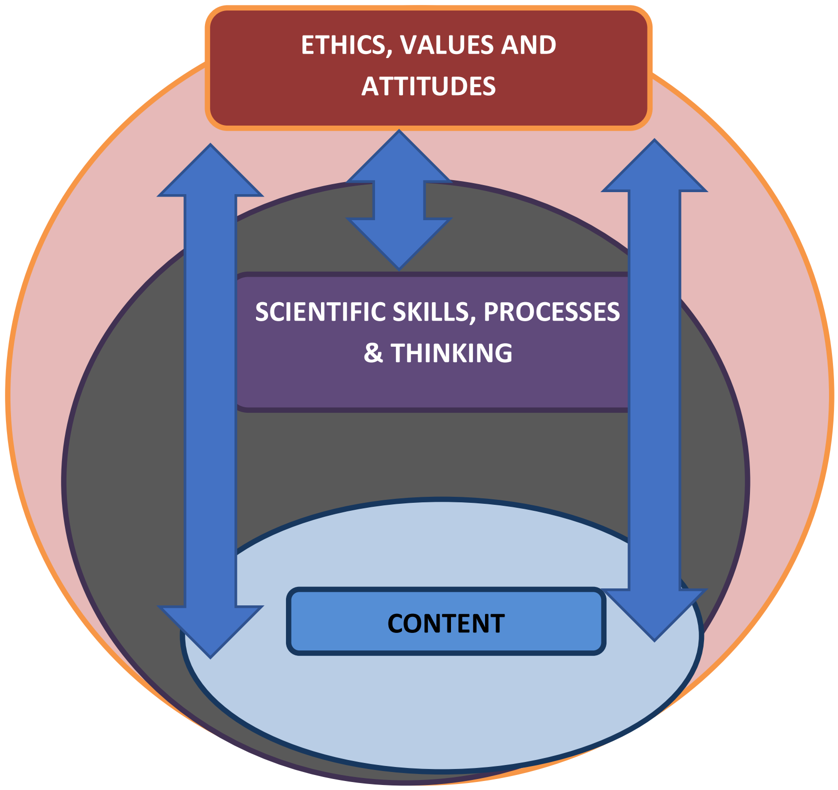

Figure 2. *CCRLS in Science Framework*

Table 1
Components of CCRLS Science Framework

Content	Scientific Skills, Processes and Thinking	Values and Attitudes
	Science Skills and Process	

• Scientific Inquiry • Life and the Living World • Material World • Energy and Change • Earth and Space • Science, Engineering, and Technology for Sustainable Society	• Questioning • Observing • Classifying • Measuring • Hypothesizing • Predicting • Inferring • Explaining • Communicating • Evaluating • Identifying and controlling variables • Formulating and testing hypothesis • Defining operationally • Interpreting data • Planning and carrying investigations **Thinking** • critical and creative thinking • reasoning • problem solving • decision making • applying and creating • generating solutions • safe use of equipment • ICT skills • Collaboration skills	• Caring for the living and non-living environment • Social awareness • Sustainability • Responsibility • Truth • Interdependence • Integrity • Perseverance • Self-discipline • Self-esteem • Empathy • Appreciation • Trust • Critical reflection • Inventiveness • Tolerance • Uncertainty • Belief and interest • Curiosity • Honesty • Objectivity • Open-mindedness • Respect for evidence

Context as the Link to the Three Components of the Framework

The three components of the framework for CCRLS in Mathematics and CCRLS in Science shown in Figures 1 and 2 and Table 1 are embedded in every key stage (i.e. Key Stage 1 – Grades 1 to Grade 3; Key Stage 2 – Grades 4 to Grade 6; and Key Stage 3 – Grades 7 to Grade 9) as standards for the content of teaching.

In summary, Human Character as an important component of the framework for CCRLS in Mathematics and CCRLS in Science are reflected as "Mathematical values, attitudes and habits for human character" and "Values, and attitudes", respectively. This Human character component together with Mathematical thinking and processes for Mathematics and Scientific skills, processes and thinking component for Science is interwoven by the content component. The two components cannot exist without "Content" component. The first two components can be taught through teaching with the content.

Empathy and STEM Education

According to Cambridge Dictionary (2020), empathy means " … the ability to share someone else's feelings or experiences by imagining what it would be like to be in that person's situation" while the New Oxford American Dictionary Online 2011 defines it as "understanding and sharing the feelings of another." By understanding others' feelings, one can respond aptly to the situation. This human character value is important in determining the decisions made based on many aspects of life situations.

Empathy is the first of the five phases in Design Thinking model proposed by Hasso-Plattner Institute of Design at Stanford, which is also known as d.school. By engaging empathy, students will learn the process of solving issues through observing and listening.

What is empathy and why is it important for STEM education?

Scientists and engineers are often perceived as lacking interpersonal skills, and these beliefs can alienate particular students from engaging in or identifying with STEM-related fields (Cheryan et al. 2013). Engaging students in empathy can make STEM learning more meaningful because students can see the impact of STEM in their lives and the lives of others. The content becomes relevant and important to students and their communities. By making STEM content relevant, students will be able to see themselves as potential contributing members of the STEM community. Taking a more interpersonal and empathy-based approach to STEM learning can also broaden our visions of what it means to be a "STEM person." Such work aligns with research that emphasizes the need for teachers to make instruction culturally relevant and accessible to all students (Ladson-Billings 1995).

STEM Curriculum Design: Planning and Design Learning (PaDL) Framework

SEAMEO RECSAM and Faculty of Education, Monash University are currently undertaking the development of curriculum design called the "Planning and Design Learning (PaDL)" Framework to illustrate the workings of STEM as a pedagogical approach. The PaDL is comprised of Design Planning Model for Teachers and Design Learning Process for Students (Kidman and Mangao, 2019).

The PaDL Framework was developed from the analysis of 14 commonly used Western planning models and learning design combined with the experiences, knowledge, skills and values of the ASEAN educators who attended the workshop. Among the teacher planning models reviewed and compared were: Teaching with technology; TPACK model; Polya's problem solving; Conceptual model for teaching arithmetic problem solving; Team initiated problem solving slide 5; Conceptual framework of the math problem-solving process; Science and Engineering practices; Science in Early Childhood Classrooms: Content and Process; The difference between Science and Engineering; and Writing Lab reports: Overview. For the Design Learning Process for Students, models reviewed and compared included: NGSS Engineering Design Process; What is design thinking?; Design Cycle; and Getting to grips with design Thinking. The participants were briefed to consider a number of principles in the development of the framework which include: focus on the student's, not the curriculum; teacher's vision, focus, objectives, students' needs; resources available and confidence in developing the learning tasks.

What is Planning for teaching and Design learning process for students?

In this step you incorporate your ideas about creating enthusiasm, a real-world problem or issue for students, connection to the curriculum, and plan the sequence of learning activities, scaffolding, resources, and assessment. The sequence of learning activities will lead students through the Design learning process (empathising, …, proposing solution). Get students to consider issues like ethical use of knowledge, implications and consequences of solutions, how to work cooperatively in groups, how to conduct inquiry and develop other 21st Century Skills.

Integrating Human Character of Empathy into the Design Learning Process for Students

The Design Learning Process for Students as shown in Figure 3 is comprised of four main stages, namely; (1) empathizing, (2) developing design ideas, (3) prototyping/modeling, and (4) proposing solution.

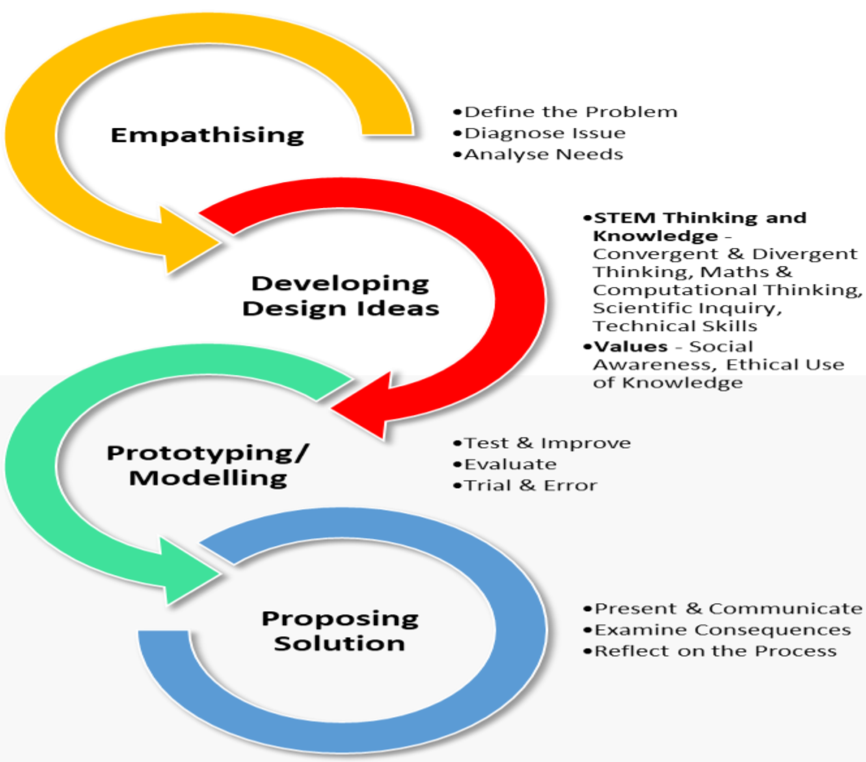

Figure 3. The Design learning process for students

Why students use the Design learning process

This Design learning process model for learning is a particular pedagogical approach which will develop students' collaborative, problem solving, 21st Century skills, while learning and applying their disciplinary knowledge and skills.

What is Empathising

"Empathy is seeing with the eyes of another, listening with the ears of another and feeling with the heart of another." – Alfred Adler

The empathy stage of the student design process is about you developing a human- centred view of problem solving. Observe other people, examining their context and listening to their needs and requirements. This will help the student become more deeply empathic and understanding. A great project demands a rich empathy experience.

Why include empathy

The empathy stage puts other people at the start and heart of any planning activity or research project. This human-centred approach ensures that the design and proposed solution is anchored in the real-world. It will help the students make the right decisions and avoid design failure when solving problems. Do not guess what other people need without first listening to them. A lack of empathy will contribute to design failure. Without empathy, there is no solution.

Humans and communities have various degrees of willingness to adopt particular solutions to problems, which can act as potential design constraints. Engaging in empathy encourages students to examine these constraints from multiple perspectives and to ask questions to refine ideas and solutions to better address these constraints. Insights gained from engaging in empathy can also support students to better identify and define a problem statement that addresses the needs of particular communities.

Transition: Empathising to Developing Design Ideas

In this step, you brainstorm many different ideas, based on the problem, issue and needs found in the previous step. Go wild with different ideas! Write or draw them out. Link different things together to create new ideas. Ideas will push you to the next step of prototyping and modelling. Use your social awareness and ethical use of knowledge. You need to think creatively and generate the widest possible range of ideas from which you can choose from (this is called divergent thinking). You will start to narrow down your options to find the best solution in the next step, through testing your prototypes or models (convergent thinking).

How to develop design ideas

Combine your understanding and knowledge in different subjects (Mathematics, Science, Technology) to new thinking about how to solve the problem or issue. Use your conscious and unconscious mind, logical thinking, computational thinking, and imagination. Building things (prototyping) can be a way to help you come up with new ideas. Other ways: Brainstorm, MindMap, Role-Play, Draw.

Transition: Developing Design Ideas; Prototyping / Modelling

The modelling stage of the student design process is about the construction of a unique model that solves a real-world problem. Your final model or prototype is a representation of a proposed solution. It should clearly illustrate what the solution could look like, how it works or how it could be used. A model does not need to be the same size or even made of the same materials as the proposed solution. There are many different tools and techniques for this stage; from ideation and testing to hands-on construction. They all require you to plan using your mind, look with your eyes, build with your hands and listen to everybody else's ideas and questions. The final model you design and build is a display of your imagination, creativity and playful tinkering.

A great project demands a curious disposition, a compelling modelling experience and an interesting prototype or final model that can be designed, built then shared with others. To do this, you all need to generate and build upon ideas from your imaginations and personal experiences. Your model can represent the behaviour of a solution, or test the solution in different ways. It is something that you can showcase and learn about. It is something to share and build from. The modelling process rapidly moves from an initial paper design towards a working solution, physical 3D model or prototype, with idea checking along the way.

Moving from idea generation to hands-on action and construction, requires mental activity that constructs new knowledge and objects. To do this, you must collaborate in groups and draw your plans, communicate with others to explore alternative ideas and build new knowledge.

Transition: Prototyping/ Modelling; Proposing Solution

In this step you get feedback, evaluate your prototype or model, consider the consequences, and come up with your groups' solution to solve the problem. You need to finalise your prototype or model into a model that is realistic and as good as possible given the time frame and resources. You must also decide how to present your solution to your audience, to convince them that your solution is the best possible.

To connect your model/ prototype back to the context or problem, and check if it is a good solution. To communicate your model/ prototype to other stakeholders. To reflect on the entire design process and make improvements.

In proposing a solution, think of the different components of your prototype/ model – how can you improve them based on the context?

Evaluate - Does your prototype/ model solve the problem? What are the consequences of the model when it is used?

Communicate – How can you use words, diagrams, graphs and other media to present your solution to convince others?

Iteration and making the process your own

This process can go in many cycles and sometimes you have to go back to the previous step or even back to the first step, in order to go forward. This process is only a suggestion and, in the end, you have to make the process your own and adapt it to your style and your work. It is about your way of thinking and working.

Summary

The SEA-BES CCRLS project is used as benchmarks in curriculum development among SEAMEO Member Countries to ensure all students have access to fundamental knowledge, skills and values, including 21st century skills in science and mathematics in order to be socially responsible, globally competitive and sustainable. The CCRLS in Mathematics and Science are utilised in the development of an integrated, interdisciplinary and multidisciplinary STEM lesson sequences which integrate human character development and global citizenship. Major problems and issues such as energy, climate change impacts, diseases, natural disasters, violence, pollution, environmental degradation and natural resource depletion become the centrepiece of these STEM lessons to realise human character development, SDGs and targets. Moreover, the concept of global thinking, global perspectives and global citizenship will be integrated in future curriculum development projects to ensure that the new Agenda for Sustainable Development is realized and the lives of all humanity will be improved and our world will be transformed for the better towards a more resilient and sustainable planet Earth.

Conclusion

In conclusion, since Education 4.0 is introduced to align with the progress in IR 4.0, now education has to keep up with achieving Society 5.0. Ideally, there should be a balance in technology and saving the human values as human who created the technology naturally would realize that actually human values help the society and the world work in harmony. Aligning with the rapid changes in industry, education should be the frontrunner in making the changes to suit the Society 5.0, in this particular case within the aspects of teaching mathematics and science or in STEM education. Therefore, a comprehensive framework for teaching STEM incorporating human character should be developed to assist teacher and educators alike in inculcating the human character such as empathy (in this case) in teaching and learning. According to Sun (2017), engaging empathy in students make STEM lessons more meaningful because it affects them and their surroundings. Furthermore, producing students with empathy will create a matured generation with the ability to resolve issues with practical solutions for various conditions. Hence, in achieving Society 5.0, this human-centred society also contributes to the attainment of Sustainable Development Goals (SDGs) established by the United Nations.

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