Are STEM skills incorporated in the developed standards of Philippine TVET?

The changing reality of today's technology has heavily influenced education by injecting its demands for STEM knowledge and skills to the needed workforce. The World Economic Forum predicts that the future workforce need to have "strong cognitive skills in mathematics and literacy, as well as soft skills such as problem-solving and creative thinking, to enable them to adapt to a quickly changing environment".[1]

DISCUSSING THE NEED FOR STEM

STEM is an acronym for Science, Technology, Engineering and Mathematics, commonly used in relation to education and skills. STEM is also seen as an approach to a pedagogical strategy that emphasizes application of knowledge, skills and values from the disciplines of Science, Technology, Engineering and Mathematics, in an integrated manner to help students solve problems encountered in the real world. [2]

The Council of Canadian Academies (2014) hypothesized that the STEM literacy and skills evolves in the education system in three ways:

1) "Fundamental skills for STEM, including reasoning, mathematics, and computational facility (numeracy) as well as capacity for critical thinking and problem solving, and the ability to apply these skills in technology-rich environments;

2) Practical STEM skills include knowledge of established scientific principles and how to apply them to specific tasks or occupational roles, through the understanding and adoption of new technologies, or combining available technologies in ways that meet industry needs; and

3) Advanced STEM skills include familiarity with scientific methods, conceptual design, as well as specialized STEM discipline-specific training and knowledge of disciplinary concepts in order to develop new innovations, perform specialized analyses and research, and understand and adopt new production technologies in ways that meet industry needs".[3]

The STEM literacy and skills can either be taught or applied "either through traditional or discipline-specific manner, or through multidisciplinary, interconnected and integrative approach, which are both outcome-focused and aim to solve real-world challenges".[4] Traditional or discipline-specific just means that STEM literacies or skills are taught as subjects such as mathematics, science, coding or technology, while the multidisciplinary, interconnected and integrative approach is where two or more disciplines are integrated to enhance people's competencies through problem solving or working on complex scientific and technical work or projects.

From a strategic perspective, STEM is framed as an educational equality initiative that will enable students to gain the knowledge and skills they need to compete in the global marketplace. Above this, STEM is argued to be the most indicative educational reform discourse of our time and has become one of the primary foci of educational policy, in part due to its easy linkage to a wide variety of today's industries: from information and communication technology to the medical fields; to sustainable innovations. [5]

As a matter of fact, numerous pronouncements, reports and studies have emphasized the importance of STEM in all kinds of jobs- that there is a sizeable number of jobs in industries such as manufacturing, construction, health and information technology requiring high level of knowledge and skills in any one or more of the STEM fields, and that the higher-paying jobs demand advanced levels of STEM education. Some experts predict that the demand for workers with STEM-related skills will increase over time.[6]

The immense purpose of STEM in education and labor cannot be discounted particularly in the recent developments such as the Fourth Industrial Revolution and the transition to Green Economy.

It is through STEM that governments will be able to equip the people with the knowledge and skills needed. Siekmann and Korbel (2016) suggest that countries should invest in STEM education and training to expand people's abilities specifically on critical and creative-thinking skills, specifically for producing "technologically-proficient workers who are able to create, design, support and operate complex and evolving technological innovations".[7]

GAUGING THE IMPORTANCE OF STEM IN TVET

The strength of Technical-Vocational Education and Training (TVET) in advancing STEM lies on its practical thrust in learning. Many students may have difficulty grasping mathematical concepts and scientific theories if they are presented in an abstract manner devoid of clear application.[8] Highlighted as well was the contextual, situated, concrete way in which TVET courses deliver STEM which facilitates easier learning of students than in academic courses. TVET teaches STEM matters directly to be used in the workplace and this puts TVET in a crucial and transitory role from school to work.

While it is believed that TVET by nature offers an ideal platform for the integration of STEM, it can also be argued that integrative STEM is an ideal vehicle to facilitate TVET because of its focus on innovation and problem solving[9]. Whatever perspective is adapted, the mutually beneficial relationship of TVET and STEM is ascertained and there is no better way to move forward but to incorporate and/or enrich STEM in the education system.

IMPLICATIONS TO TVET

Training Regulations

STEM-related knowledge and skills are found in the units of competencies under Basic, Common and Core of the TRs. An attempt to map some of these STEM-related knowledge and skills is found in Annex A.

To elaborate on the STEM-related knowledge and skills in the TRs:

- The practice of occupational health and safety requires the knowledge and use of science behind injury prevention and ensuring safety at work.

- Solving problems related to work activities relates to the concept of scientific method as solving problems warrant the determination of the causes of the problem, their corresponding correct / preventive action, and the stipulation of recommendation to the manager in a workplace situation.

- The use of mathematical concepts and techniques requires the identification and application of mathematical concepts, tools and techniques in order to solve workplace problems.

- The use of relevant technologies relates to the selection and application of appropriate and relevant technologies in the workplace in accordance with industry standard.

- Collection, analysis and organization of information is likewise a part of the general scientific inquiry relative to problem solving. This unit of competency requires knowledge on data processing, information analysis and interpretation, research methods (qualitative, quantitative, statistical), report writing and use of relevant software.

- The promotion of environmental protection does not only require the knowledge of environmental protection principles, strategies and guidelines, but more so the conduct of research, analysis and interpretation data and information, as well as problem solving.

It is important to note that while the STEM competencies are present in the basic, common and core competencies in the TRs, the basic and core competencies should be taught in the context of the core competencies, and not as abstract concepts or subjects.

By looking at the 3 types of STEM literacy and skills, the fundamental skills may serve either as part of the basic competencies in the TVET competency standards/qualifications, or as prerequisite skills for the higher level TVET competency standards/qualifications. The practical STEM skills seem to be the ones that are covered in most of the current TVET competency standards/qualifications, specifically in the common and core competencies, as they relate to the application of STEM skills in occupational roles.

As to the advanced STEM skills, research and analysis are articulated in the NC IV qualifications. In addition, Learning and Innovation is one of the competencies specified in the 21st Century Skills Framework, which has been adopted and have been incorporated in the expanded Basic Competencies in the TVET Training Regulations (TRs). The units of competency have also been defined per NC level.

Competency	Learning and Innovation
NC I	Support innovation in the workplace
NC II	Contribute to workplace innovation
NC III	Discuss problems in the use of innovation in a constructive way
NC IV	Manage innovation and continuous improvement
Diploma	Lead and present ideas and practical suggestion to appropriate people on how improvements could be made

Table 1. Learning and Innovation Competencies per NC Level

STEERING STEM SKILLS DEVELOPMENT IN TVET

More than being a challenge, TVET can view advancing STEM as an opportunity. The emphasis on the importance of STEM education has caused many to revisit the role of TVET is preparing future technicians, technologists, and engineers. In addition, TVET has always used applied sciences and mathematics in its framework for instruction, and many of the instructional paradigms that are being championed as part of STEM education have been used exemplarily in TVET for many decades.[10]

While STEM knowledge and skills are already articulated in TRs, there is need to revisit STEM knowledge and skills during the review of TRs in order to ensure that they are responsive to societal changes and in the jobs of the future. There should be more emphasis in enabling learners to learn the advanced STEM skills such as development of new innovations, research, analysis, and adoption of new production technologies by providing the facilities and adequate instruction to gain the competencies.

The curriculum of TVET training programs should be able to elaborate the STEM knowledge and skills in the TRs. It has to articulate what STEM concepts will be taught and how, and where STEM knowledge and skills from the disciplines are applied. There is also a need to ensure that the STEM competencies are not taught in the abstract but in the context of the core competencies of TVET training programs. One of the critical factors in ensuring that trainees learn about STEM competencies are the trainers and how they are able to facilitate learning of STEM knowledge and skills. While there is a dearth of literature about teaching STEM in TVET, the literature about innovative strategies in Science teaching may be looked into and see what can be adopted in the TVET context. Assessment of learning STEM in TVET should also look into various strategies that are aligned with the standards that truly defines what constitutes competent performance in STEM skills.

TESDA also needs to look into how it can support trainers as to how they can teach STEM skills in TVET training programs by providing professional development, coaching and mentoring opportunities.

In summary, this is to say that STEM skills development in TVET is important, and TESDA needs to ensure that the TVET competency standards, curriculum, trainers and facilities are prepared to teach STEM in TVET in the context of a changing workforce training and development requirements.

Annex A: Examples of STEM-related knowledge and skills in the Basic, Common and Core Competencies

Basic Competencies

NC I	NC II	NC III	NC IV	Diploma
• Support innovation • Follow occupational safety and health policies and procedures • Apply environmental work standards	• Solve/address general workplace problems • Contribute to workplace innovation • Practice occupational health and safety procedures • Exercise efficient and effective sustainable practices in the workplace	• Use mathematical concepts and techniques • Apply critical thinking and problem solving techniques in the workplace • Propose methods of applying learning and innovation in the organization • Evaluate occupational safety and health work practices • Evaluate environmental work practices	• Manage innovative work instructions • Lead in improvement of occupational safety and health program, policies and procedures • Lead towards improvement of environmental work programs, policies and procedures	• Evaluate higher order thinking skills and adjust problem solving techniques • Incorporate innovation into work procedures • Supervise Implementation of OSH programs in the workplace • Supervise implementation of environmental programs in the workplace

Common Competencies (other than Perform Mensuration and Calculations)

SECTOR	UNIT OF COMPETENCY
Automotive and Land Transportation	Perform job estimates
	Interpret/Draw Technical Drawing
	Practice health, safety and environment procedures
	Inspect technical quality of work
	Maintain quality systems
Chemicals / Plastics / Petrochemicals	Observe safe working practices
	Comply with emergency procedures
	Use hand and measuring tools
Construction	Maintain tools and equipment
Decorative Crafts	Apply basic first aid
Electrical & Electronics	Prepare and Interpret Technical Drawing
	Terminate and Connect Electrical Wiring and Electronic Circuits
	Test Electronic Components
Footwear & Leather goods	Set-up and operate machines
	Perform basic maintenance
Furniture and Fixtures	Interpret technical drawings and plans
	Comply with occupational health and safety (OH & S) practices and 5S in the workplace
	Maintain tools and equipment
Garments	Set up and operate machine/s
	Perform basic maintenance
Human Health / Health Care	Implement and monitor infection control policies and procedures
	Apply basic first aid
	Maintain high standard of patient services
	Perform workplace security and safety practices

SECTOR	UNIT OF COMPETENCY
Heating, Ventilation, Air-conditioning and Refrigeration	Perform Basic Electrical Works
	Maintain Tools And Equipment
	Perform Housekeeping And Safety Practices
Information and Communication Technology	Prepare and Interpret Technical Drawing
	Apply critical thinking and thought organization
Logistics	Perform workplace security and safety
Maritime	Survive at sea in the event of ship abandonment
	Minimize the risk of fire and maintain a state of readiness to respond to emergency situations involving fire
	Prevent, fight and extinguish fires
	Take immediate action upon encountering an accident or other medical emergency
	Take precautions to prevent pollution of the marine environment
	Observe safe working practices
	Demonstrate security awareness practices
Metals and Engineering	Apply Safety Practices
	Interpret working drawings and sketches
	Perform preventive and corrective maintenance
Processed Food & Beverages	Apply Food Safety and Sanitation
	Use Standard Measuring Devices / Instruments
	Perform Mathematical Computation
	Implement Good Manufacturing Practice Procedure
	Implement Environmental Policies and Procedures
	Monitor the Implementation of Good Manufacturing Practice Procedures
	Monitor the Implementation of Environmental Management Policies
Pyrotechnics	Perform firefighting and fire prevention
	Apply first aid treatment
Social, Community Development and Other Services	Maintain a safe, clean and efficient work environment
Tourism (Hotel and Restaurant)	Manage finances within a budget
	Observe workplace hygiene procedures
	Perform workplace and safety practices
Utilities	Comply with environmental protection procedures
	Operate and maintain hand/line tools and equipment
Wholesale and Retail Trading	Perform workplace security and safety practices

Core Competencies

SECTOR	TR	Unit/s of Competency/ies
Agriculture Forestry and Fishery	Animal Health Care and Management NC III	• Restrain and handle animal • Apply bio-security measures • Administer drugs and biologics • Handle and store drugs and biologics • Collect and handle specimen
	Pest Management (Vegetables) NC II	• Conduct field assessment • Apply bio-control measures • Apply cultural management strategies • Apply physical control measures • Apply chemical control measures • Monitor results of pest management activities and provide feedback
Automotive and Land Transportation	Laboratory and Metrology / Calibration NC III	• Use Comparison and Basic Measuring Devices • Measure Components Using Coordinate Measuring Machines • Use Graphical Techniques and Perform Simple Statistical Computations
	Automotive Servicing NC IV	• Service Diesel Engine Management System • Service Electronic Body Management System • Service Diesel Fuel Injection System Components • Service Electronic Drive Management System • Service Emission Control System • Service and repair electronically controlled anti-lock braking system • Service and repair electronically operated traction control System • Service and repair electronically operated stability control System • Estimate complex jobs • Ensure a safe workplace • Plan and manage compliance with environmental regulations in a workplace or business
Construction	PV System Design NC III	• Calculate System Components Requirements (System Sizing) • Prepare Installation Drawing
	PV Systems Servicing NC III	• Perform PV System Diagnosis • Repair PV System • Monitor PV System Operation
Electrical & Electronics	Instrumentation and Control Servicing NC IV	• Calibrate Instrumentation and Control Devices • Configure Instrumentation and Control Devices • Loop Check Instrumentation and Control Devices • Maintain and Repair Instrumentation and Control Devices • Start-up and Commissioning Instrumentation & Control Systems • Diagnose and Troubleshoot Instrumentation & Control Systems
	Mechatronics Servicing NC IV	• Develop advanced Programmable Logic Controller (PLC) and human machine interface (HMI) application program • Commission advanced PLC- and HMI-based mechatronics and automation systems • Diagnose and troubleshoot advanced PLC- and HMI-based mechatronics and automation systems
Human Health / Health Care	Biomedical Equipment Servicing NC II	• Install biomedical equipment • Perform corrective maintenance on biomedical equipment • Perform preventive maintenance on biomedical equipment • Repair biomedical equipment • Assess and refer biomedical equipment

SECTOR	TR	Unit/s of Competency/ies
	Emergency Medical Services NC II	• Perform Cardiopulmonary Resuscitation with AED Operation • Implement safe access and extrication procedures in an emergency • Deliver basic ambulance communication skills • Deliver pre- hospital patient care • Contribute to ambulance operations management
Information and Communications Technology	Telecom OSP and Subscriber Line Installation (Copper Cable/POTS and DSL) NC II	• Perform basic troubleshooting and correction of cable fault and error
	Programming (Oracle Database) NC III	• Perform relational database management in Oracle database technology • Use and apply Procedural Language/Structured Query Language (PL/SQL) Programming Language • Design and tune PL/SQL Language
Metals and Engineering	Mechanical Drafting NC I	• Prepare basic engineering drafting • Perform basic engineering detail drafting
	CAD/CAM Operation NC III	• Create drawing using CAD software • Apply CAD/CAM program
Processed Food & Beverages	Food Processing NC III	• Apply product knowledge to complete work operations • Perform basic tests in raw materials, in process and finished products • Handle dangerous goods/ hazardous substances

REFERENCES

I https://www.weforum.org/agenda/2018/08/global-learning-crisis-millions-without-basic-skills-unesco

2 UNESCO - UNEVOC (n.d.). Retrieved from http://www.unevoc.unesco.org/go.php?q=TVETipedia+Glossary+A-Z&filt=all&id=640

3 Council of Canadian Academies, 2015. Some Assembly Required: STEM Skills and Canada's Economic Productivity. Ottawa (ON): The Expert Panel on STEM Skills for the Future, Council of Canadian Academies.

4 Siekmann, G & Korbel, P 2016, Defining 'STEM' skills: review and synthesis of the literature — support document 2, NCVER, Adelaide, p. 6.

5 Parawira, W. (n.d.) An overview of STEM Education and why it is important to everyone. Retrieved from https://www.buse.ac.zw/downloads/An%20overview%20of%20STEM%20Education%20and%20why%20it%20is%20important%20to%20%20%20everyone.pdf

6 TESDA Planning Office (2018)

7 Ibid., p. 7.

8 Association for Career and Technical Education [ACTE] (2009). STEM AND TVET IN THE CARIBBEAN A Framework for Integration at the Primary, Secondary, and Tertiary Levels. Retrieved from http://uwispace.sta.uwi.edu/dspace/bitstream/handle/2139/42602/Framework%20for%20Integrating%20STEM%20in%20TVET%20Dixon%20and%20Hutton.pdf?sequence=1

9 Ibid.

10 Parawira, W. (n.d.) An overview of STEM Education and why it is important to everyone. Retrieved from https://www.buse.ac.zw/downloads/An%20overview%20of%20STEM%20Education%20and%20why%20it%20is%20important%20to%20%20%20everyone.pdf