Received: 11 March 2021 | Revised: 15 June 2021 | Accepted: 23 July 2021

DOI: 10.1002/kpm.1684

RESEARCH ARTICLE

WILEY

Online machine drawing pedagogy—A knowledge management perspective through maker education in the COVID-19 pandemic era

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Abstract

Drawing is a visual mode of communication. Teaching drawing requires one-to-one personal interaction among the tutor and the learner. The technical drawing is no exception, and it requires a considerable amount of imagination skills. On-line mode of pedagogy shall be occupying a substantial portion of the mode of delivery in teaching and learning during, as well as, after the coronavirus disease 2019 (COVID-19) pandemic era. This work focuses on the training and knowledge sharing of machine drawing skills through online mode, which is the requirement of the present era. A knowledge management perspective for machine drawing pedagogy is involved in this work. Challenges in the online pedagogy of machine drawing are deliberated through Ishikawa diagram and service Failure Modes and Effects Analysis. A maker education perspective of online machine drawing pedagogy is delineated. An approach toward knowledge workforce, knowledge transfer, and tacit knowledge is adopted for online teaching of machine drawing. Finally, conclusions are drawn in context of online pedagogy for a spatial visualization–based course like machine drawing.

1 | INTRODUCTION

Coronavirus disease 2019 (COVID-19) brings more uncertainty and insecurity along with it. In the period of social lockdown, going outside the residence is a pretty risky activity where one can have a higher risk of COVID-19 infection. Moreover, a lot of monotony creeps in the daily life; thereby, under such situation, a maximum usage of available resources within home must be done in order to reduce the frequency of going outside the safer geographical zone for purchase of drawing instruments and other drawing resources related to machine drawing course work.

Online pedagogy is the most pragmatic solution for this pandemic situation. Restructuring of the education model is the demand of the time where the online and personalized learning is given due attention and focused upon. During online learning, the teacher is more of a facilitator rather than an instructor. Online pedagogy involves pre-recorded videos and live streaming of the course instructions through an online platform. Online pedagogy brings with it a plethora of opportunities. The faculty can easily reach a larger audience base directly through their personalized online studios either at home or residence. The main challenge in online teaching is that the physical contact is missing, and the faculty–student interaction relies heavily on the technological gadgets. Any interruption in the streaming internet hinders the continuity and flow of the learning. Smart boards with camera can be a supplement for the chalk-and-talk classroom teaching.

Explanation for the students in online classes must be such that they really feel, learn, and experience the course. Faculty must be able to grab the attention of the student during the online session. The concentration levels of the students are low in the online session, as, they are subjected to many distractions. In such a situation, the method to make students focused is by keeping them engaged through posing questions so that they find their own answers thereby leading to an explorative experience. In machine drawing course, this

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is possible by making the students to draw the dimensioned orthographic projections and sectional views of engineering components and assemblies. This shall enable them to visualize, imagine, and start thinking on their own and develop these capabilities within them.

There are predominantly two dimensions of knowledge namely, explicit dimension and tacit dimension of knowledge. The metaphor of an iceberg is used to represent them. The small outer visible portion of the iceberg depicts the explicit form of knowledge, and the major hidden portion of the iceberg represents the tacit form of knowledge. This is due to the reason that, "we know much more than we can express using language" (Bratianu & Bejinaru, 2019). There is an old adage saying that "A picture is worth a thousand words." The technical drawing subject like "machine drawing" conveys the tacit information, which otherwise takes volumes of written instruction to convey the same meaning. This tacit characteristic of machine drawing makes it a special course, which requires nurturing of visualization and imagination skills of students. During this pandemic trying times of COVID-19, online pedagogy is the suitable mode of teaching and learning. Online machine drawing pedagogy retains this tacit characteristic of the course and trains the student to decipher the information from complex machine drawings and also to construct and draw new drawings independently.

The structure of the paper is as follows. Firstly, online machine drawing pedagogy is introduced in context to COVID-19 pandemic era. This is followed by the background literature support in Section 2. In Section 3, the research tools namely, the Ishikawa diagram and failure modes and effects analysis (FMEA) are introduced. This is followed by statement of the research objective and comprehensive analysis of online machine drawing pedagogy in context of maker education, knowledge workforce, tacit and online knowledge transfer in the Sections 4–7, respectively. Section 8 focuses on the impediments faced in online machine drawing pedagogy. Section 9 plants a discussion on spatial visualization in context of machine drawing online pedagogy. Section 10 focuses on discussion and way forward. Section 11 discusses about the limitation and the future scope. Conclusions are drawn in Section 12 followed by the comprehensive list of references.

2 | BACKGROUND STUDY

2.1 | Knowledge and process management

Knowledge management is a discipline, which is under a constant change, and its future depends on the development of automation mechanisms for knowledge flow, based on advanced cognitive capabilities, machine learning, and artificial intelligence (Nakash & Bouhnik, 2021). For unstructured and complex business and knowledge processes, methodologies like process mining can be adopted for analysis of the process (Stefanini et al., 2020). Emerging opportunities must be explored for better management of business as well as knowledge processes (Van Looy, 2021). In the trying times of COVID-19, both the emergent knowledge strategies based on knowledge exploration and deliberate knowledge strategies based on knowledge exploitation must be integrated to face the uncertainty posed by such challenging situations (Bratianu & Bejinaru, 2021). Measures must be taken for retaining the best practices and alternatives experienced during COVID-19 even after the pandemic. Smart knowledge management systems with enhanced connectivity and interaction among objects and people are the key for development of the online pedagogy. This connectivity is now possible through IoT, which serves as a foundation for a better connected world (Ikeda et al., 2021).

2.2 | Online pedagogy

Active online learning creates new knowledge and skills (Wang & Hitch, 2017). Online STEM pedagogy must include collaboration and interactivity through transformational strategies where the students get completely involved and immersed into the learning process (Keebler & Huffman, 2020). Faculty on the other hand must not resist change as it is inevitable, and faculty must be provided with sufficient time to prepare and present before the online audience (Gratz & Looney, 2020). Student satisfaction is the central idea for the success of any online e-learning program (Leong, 2011) and minimizing the attrition rate for online education depends on self-determination and motivation (Chen & Jang, 2010). Evaluation of online teaching must also be designed to address the "Higher Order Thinking" skills of Bloom's Taxonomy. The questions must include multidimensional responses for allowing students to gain mastery over the subject (Todd et al., 2021).

Online mode of pedagogy is the medium of instruction adopted for imparting machine drawing skills in the COVID-19 pandemic time. The knowledge flow involves one-to-one mapping where the flow of knowledge is from one tutor to one student. In the online education, there is a very less scope for counter-knowledge (Cegarra-Sanchez & Cegarra-Navarro, 2017). This is because during the online session, the peer interaction is very limited. Thus, in the online environment, gossips, lies, exaggeration, and partial truths have limited space, and hence students may not express their feelings and emotions if the faculty's style of teaching and delivery is authoritative. Care must be taken by the faculty to nurture the student's emotional well-being and set up a collaborative culture where the student may be motivated to set goals for oneself.

2.3 | COVID-19 pandemic and teaching and learning

Promotion of online teaching during COVID-19 outbreak in China is one of the key steps taken by Chinese Government (Zhang et al., 2020). Transition from traditional method of pedagogy (i.e., face-to-face) to online mode of instruction requires overcoming of inertia to accept the change by the teachers (Chang & Fang, 2020). Principles of high-impact on-line teaching includes appropriate relevance, effective delivery, sufficient support, high-quality participation, and preparation of a contingency plan (Bao, 2020). Learning should be effective, efficient, and enjoyable through updated effective pedagogical methods in this postdigital era (Rapanta et al., 2020).

SWOC analysis of e-learning modes in the time of COVID-19 crisis gives the major conclusion that IT infrastructure, which is a prerequisite for online learning, must be robust and strong, in order to provide unhindered services during and after the COVID-19 crisis (Dhawan, 2020). The IT infrastructure here refers to three types of ICT (Interactive Communication Tools) namely, Internet systems, Groupware, and Collective systems (Cegarra-Navarro & Rodríguez, 2012). Internet when integrated with Groupware and Collective systems paves way for new opportunities of collaboration among the faculty and students. The online delivery of course like machine drawing must be supplemented with the video animations, prerecorded video lectures, and live session recordings, uploaded in groupware and collective systems for better assimilation of the concepts by the students. Thus, a seamless IT infrastructure promotes an online learning among students with special care and attention toward each individual student.

2.4 | Drawing education

Drawing retains its own cross-disciplinary importance in every field ranging from fine arts to the study of medicine and technology. Drawing leaves a very intense impact on the students' learning and is offered as a separate course in the study of medicine (Lyon et al., 2018). Drawing is an effective medium to articulate thoughts and is a cognitive tool for enhancing creativity (Mayo, 2012). The value of drawing and visualization in teaching sociology is prominent for conveying the thoughts and perceptions through a meaningful analysis of the social world (Odhiambo, 2020). In learning technology, CAD tools and video training combined with traditional paper-and-pencil-based teaching, offers a good platform for effective learning (Pando Cerra et al., 2020). Study is focused on STEM subjects and technical drawing in particular for achieving Sustainable Development Goals (SDG) valuing the cognitive, socio-emotional, and behavioral learning (Del Cerro Velazquez & Lozano Rivas, 2020). Study through STEAM education supports transdisciplinary study for a better society (Liao, 2016). Here, it is appropriate to discuss about "spatial visualization" skills, which refer to imagining the views of an object in different directions without actually rotating the object in those directions. It requires considerable amount of imagination of the different angular and directional orientations of the object under study. STEAM education includes "Arts" in STEM education, which promotes spatial visualization and imagination skills in engineering education. Spatial visualization skills are classified as Mental Rotation Test, Purdue Spatial Visualization Test, Visualization of Rotations, Development of part, and 2D to 3D transformations. These spatial visualization skills are learnable and can be improved upon constant practice. These skills once mastered can boost the learning capabilities of technical drawing courses like engineering drawing, machine drawing, and production drawing. Thus, machine drawing is basically a course wherein these visualization and imagination skills play a prominent role. A single drawing conveys volumes of information, which is difficult to convey in writing. Higher Order Thinking (HOT) skills can be addressed through spatial visualization skills and perspective drawings in the course work of engineering drawing (Sharma et al., 2020). Apart from spatial visualization, learning spaces and maker education constitute a new way to embrace a different view of future learning (Miller et al., 2008). The next section discusses about this concept of maker education and its prominence in machine drawing learning.

2.5 | Maker education

Maker pedagogy is relatively a new improvement concerning with the principles of maker movement, which involves people to design, create, and develop things of value. Anderson is the pioneer in the maker movement involving development of small-scale production of technological devices (Anderson, 2012). This Maker approach can be broadly classified into the category of Higher-Order-Thinking (HOT) skills, which involves kinesthetic learning by "do-it-yourself (DIY)" culture (Bullock & Sator, 2015). Kim et al. (2020) traced ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model for developing and applying a maker education course for preservice teachers with various majors based on novel engineering (NE). "Making" can enhance STEM learning (Bevan, 2017) through maker spaces as environments enabled to distributed expertise and as an open configuration of learning (Halverson & Sheridan, 2014). As a part of maker education, tinkering is defined as to "build something, first, and then figure out what it is or what it can be useful afterward." Tinkering triggers creativity among students through the medium of machine drawing, which is by-and-large visualization-based subject.

3 | ISHIKAWA DIAGRAM AND FMEA AS A RESEARCH TOOLS ADOPTED IN THIS WORK

Ishikawa diagram, or cause and effect relationship, or the fish bone diagram, is the scientific concept adopted from the manufacturing process capability studies of Industrial Engineering branch of study. As the name suggests, diagram is derived from the fish bone geometry where all the branches of the bones (causal factors) are directed toward the central head of the fish (central effect being examined). The fish bone structure is shown in the Figure 1 below.

In this research of online machine drawing pedagogy, the concepts of Ishikawa diagram is implemented in addressing the central effect of "Ineffective machine drawing online pedagogy." This is achieved by brainstorming the potential causes under the four categories of, students; Faculty and Governance; Course delivery mode and method; and Machines (equipment and gadgets).

Apart from the Ishikawa diagram, another research tool adopted in this work from the Industrial Engineering principles is, the FMEA. The format of FMEA work sheet is shown in Table 1 below. FMEA is widely used in manufacturing environment for analyzing and prioritizing the corrective actions for the process deviations. The potential failure modes are identified followed by identification of effects of failure, causes of failure, and current controls for causes not to occur. Then, the severity ranking is given for the potential effects, followed by occurrence ranking for the identified causes of failure. Next, the detection ranking is given for the current controls that how easily the

controls can detect the failure. The rankings for severity, occurrence, and detection are given on a 10-point scale from 1 to 10 where 1 is the lowest rank and 10 is the highest rank. Finally, the risk priority number (RPN) is obtained as the product of the rankings of severity, occurrence, and detection. The failure mode with highest RPN is addressed first followed by the next lower RPN. In this way, the corrective actions for the process deviations are prioritized depending on the RPN value of FMEA. This work has successfully performed the manufacturing FMEA in the service-based educational environment.

4 | RESEARCH OBJECTIVE

Objective of this work is to propose a maker education-oriented knowledge process for online teaching of machine drawing and deliberate the impediments faced in this scenario during the wake of COVID-19 pandemic era. Machine drawing faculty are viewed as the knowledge workforce possessing the valuable tacit knowledge and are viewed as an asset to the institute. It is proposed to adopt Ishikawa diagram for brainstorming the causal factors for the effect of ineffective machine drawing pedagogy. FMEA is used in service-oriented knowledge domain for prioritizing the corrective actions for eliminating the causes and establishing controls for the potential failure modes for ineffective machine drawing pedagogy. It is also envisioned to propose the way forward for the online teaching of machine drawing in a pandemic situation like COVID-19 and similar natural disasters where face-to-face teaching of the spatial visualization–based technical drawing skills is not possible.

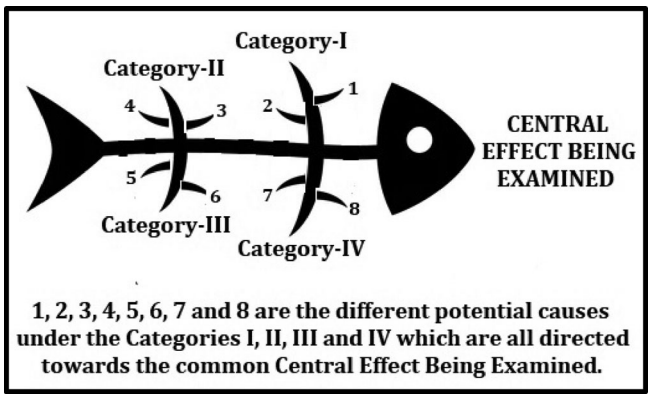

FIGURE 1 Structure of fish bone diagram/Ishikawa diagram/cause-and-effect diagram

5 | "MAKER" MECHANISM FOR ONLINE MACHINE DRAWING PEDAGOGY

Maker pedagogy is relatively new improvement concerning with the principles of maker movement, which involves people to design, create, and develop things of value. This approach can be broadly classified into the category of HOT skills, which involve kinesthetic learning by "DIY" culture. To be more precise, the maker culture includes physicality, participatory action, collaboration and ethos of sharing using networked approaches (Bullock & Sator, 2015). Anderson is the pioneer in the maker movement involving development of small-scale production of technological devices (Anderson, 2012). The maker education perspective can be applied for online pedagogy.

TABLE 2 Maker-based online machine drawing pedagogy

S.No.	Phase No.	Description
1	Phase 1	Understanding concepts, working, applications of components, and assemblages
2	Phase 2	Manual drawing practice at the student end on paper and pencil
3	Phase 3	Practice in a 2D software through live demonstration of software in online platforms like Microsoft Teams or any other online platform
4	Phase 4	Construction of CAD geometric models of components and assemblages in 3D geometric modeling software package
5	Phase 5	Performing analysis on the CAD geometric models in an analysis-based software such as ANSYS
6	Phase 6	Generation of solid models through additive manufacturing techniques like 3D printing and sharing the knowledge among the peer group
7	Phase 7	Performing testing on the models generated through 3D printing and scaling up the results to the real-time equipment

TABLE 1 Structure of FMEA worksheet

Process	Potential failure	Potential effects	Severity (Sev.)	Potential causes	Occurrence (Occ.)	Current controls	Detection (Det.)	Risk priority number (RPN)
Process description	Failure mode 1	Effect 1	S1	Cause – 1 for Failure mode 1	C11	Control for cause-1 for Failure mode 1	D11	S1 × C11 × D11
	Failure mode 2	Effect 2	S2	Cause-1 for Failure mode 2	C21	Control for cause-1 for Failure mode 2	D21	S2 × C21 × D21
		Effect 3	S3	Cause-2 for Failure mode 3	C22	Control for cause-1 for Failure mode 2	D22	S3 × C22 × D22

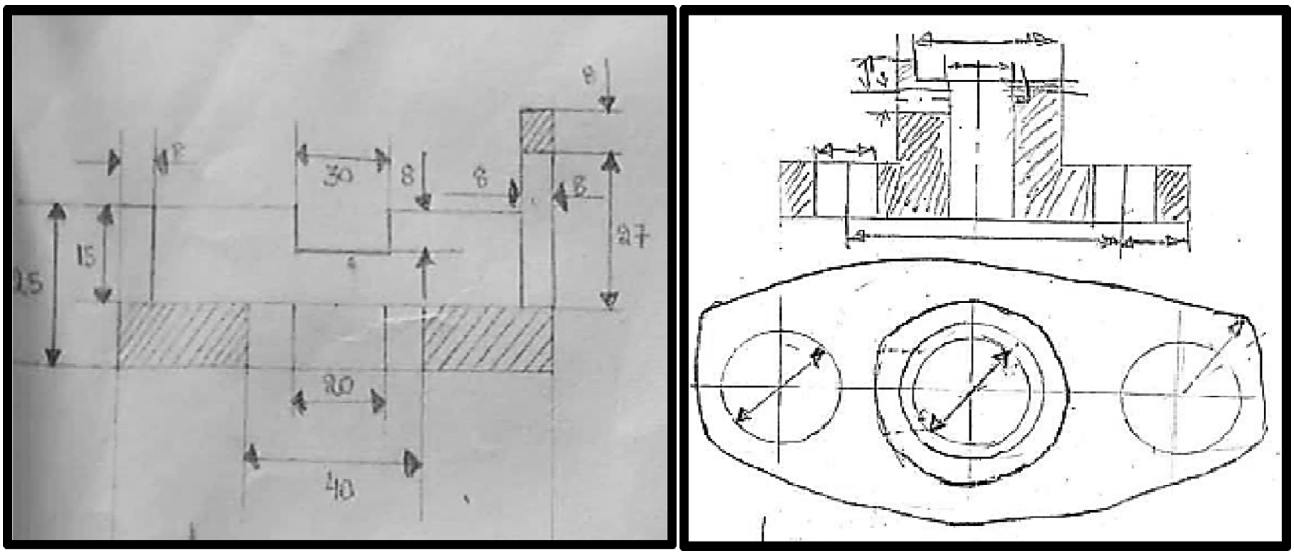

FIGURE 2 A novice student's effort toward sectional view representation

Table 2 traces the phases proposed in maker-based online pedagogy with reference to machine drawing course.

In the Table 2, Phase 1 to Phase 5 can be carried out on on-line mode and whereas the last two phases, Phase 6 and Phase 7 are based on an off-line approach for generating solid models through 3D printing and testing and characterization of the models developed.

Day-to-day machine drawing sheet work of the student can be transferred on-line by capturing the sheet work soft copy in a **.pdf* format and then evaluating the respective soft copy. This enhances the speed of the correction thereby giving instant feedback to the student.

It is important for the faculty to assess whether the student has visualized the concepts and working of the assemblages, apart from the drafting skills. Understanding, application, evaluation, and creation levels of RBT must be given due to weightage rather than confining the students merely to drafting skills. One of the instances of a student's work is captured in Figure 2. It can be seen here that the student performed the given task of orthographic projection of a sectional view on a background rough sheet. The point to be focused here is that the student performed the given task within the resources available at the disposal. Also a free-hand sketch of the student depicts the commitment toward the given work and that the student did not refrain from performing the task in the trying times of COVID-19 pandemic era.

There are instances where the student economically sound and affording a laptop, displayed extra efforts in learning the geometric modeling software and go an extra-mile further in geometrically modeling the textual exercise in a CAD software package. One such student's effort is captured in the Figure 3 below. This is an instance of maker education wherein the student makes the geometric model by himself and shares it on-line with the class.

The response is captured to assess and understand the learners' abilities on graphical communication. A primary Program Outcomes (PO) emphasizes on "communication" with the aim to communicate effectively on complex engineering activities with the engineering community and with society at large. This includes the ability to comprehend

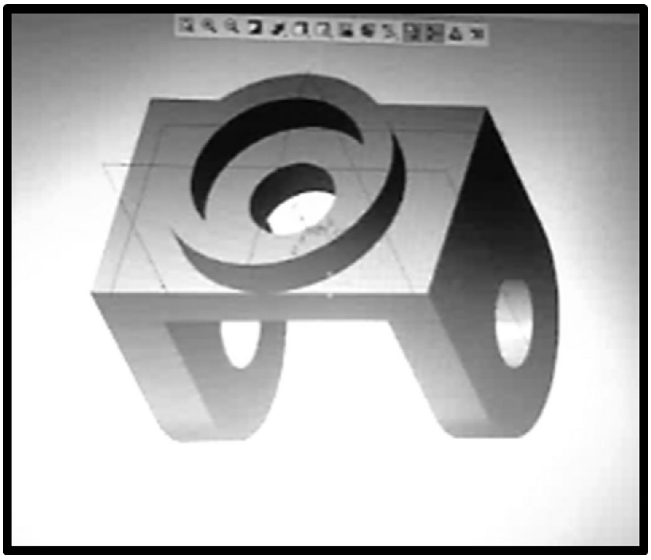

FIGURE 3 Student's effort in CAD geometric modeling of a textual exercise based on on-line learning sessions

and write effective reports and design documentation, make effective presentations, and give as well as receive clear instructions. In engineering learning, communication is not only limited to oral and written but is extended for graphical, that is, drawing mode of communication.

6 | KNOWLEDGE WORKER—THE NEW ERA WORKFORCE

Knowledge worker of the new era workforce is the person who designs, implements and oversees the organization's knowledge infrastructure (Cegarra-Navarro et al., 2020). Life-long learning, uninterrupted teaching, continuous innovation, quality of work and freedom to manage

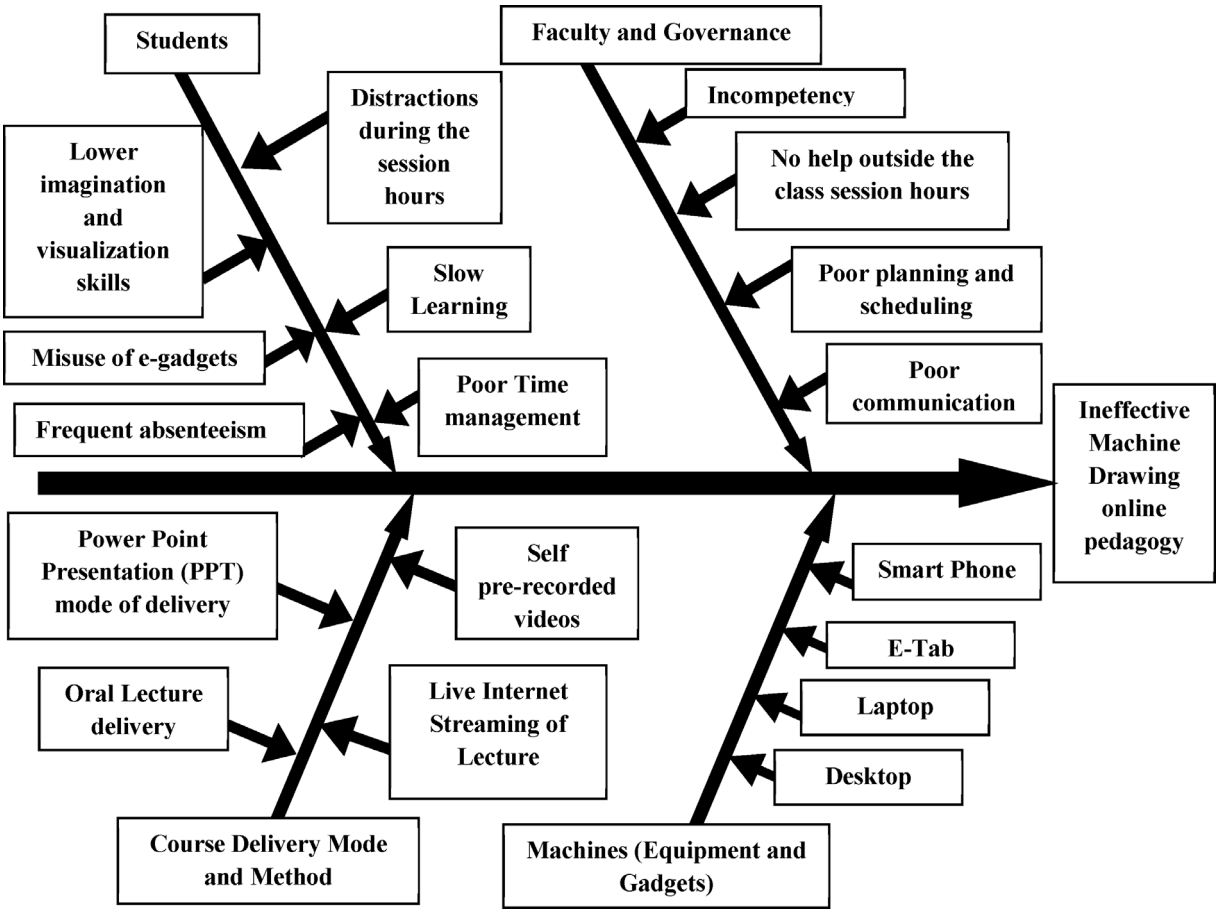

FIGURE 4 Ishikawa diagram for ineffective machine drawing online pedagogy

themselves are some of the measures of productivity of the knowledge worker (Drucker, 1999).Unlike the manual worker, the knowledge workers "own" the means of production and are mobile. Thus, today's knowledge worker is seen and treated as an "asset" rather than a "cost." They are neither an insider nor an outsider to an organization. They in fact work in-between spaces (Fenwick, 2007) where they are treated as someone possessing "special" knowledge which others do not have.

Being basically a knowledge worker, the machine drawing faculty works on enhancing the 3 Cs (capacity, competency, and capability) among the students. The faculty must build in all the 3 Cs at all levels of knowledge. Firstly, at the technical level, next at the mid-level, to build the wisdom judging between the right and wrong, and finally at the senior level, requiring building consensus among all the stake-holders for achieving the Institute's vision.

7 | TACIT KNOWLEDGE AND ONLINE KNOWLEDGE TRANSFER

Drawing faculty are the creative practitioners who can teach art and design, which is more of an unarticulated aspect of teaching. Making, reading, and comprehending the engineering drawings, which comprise of the parts and assemblages of machinery and their corresponding geometric dimensioning and tolerances, prominently requires the inherent embodied knowledge of the observer (Latilla et al., 2018). This embodied knowledge, which is tacit in nature (Budge, 2016), can be measured through an index known as the Tacit Knowledge Index (Harlow, 2008). Teaching machine drawing involves noncorporeal processes where the students need to grasp the embodiment and spatially visualize the product and assemblages.

Machine drawing teaching involves less of verbal and more of "action oriented" and "doing" mode of instructions. Hence while teaching online, either a touch screen/board for drawing, or pre-recorded video instructions embedded with intermittent questions, would be more suitable for communication rather than continuous verbal instructions. The live online session in an internet platform can be recorded and played any number of times by the student. This is an unique facility for a class through online platform. Ultimately, the cross-border knowledge transfer occurs effectively and efficiently when the student has the intent to learn and when the source of knowledge is attractive thereby holding the attention of the student throughout the session (Pérez-Nordtvedt et al., 2008).

8 | IMPEDIMENTS FACED IN ONLINE MACHINE DRAWING PEDAGOGY

Online classes bring a lot of mental pressure along with it. This is because sitting before the laptop or any other electronic gadget for

TABLE 3 Failure modes and effects analysis (FMEA) in a service environment

Process	Potential failure	Potential effects	Sev.	Potential causes	Occ.	Current controls	Det.	RPN
Online machine drawing pedagogical process	No direct physical interaction with the student	Cannot judge and feel the physical expressions and emotions of the student	10	Social distancing and lockdown situation due to COVID-19	10	Vaccination and cure of COVID-19 pandemic	10	1000
	Heavily dependent on the online software platform	Interruption in online streaming leads to discontinuous class	9	Online learning becomes mandatory because of social distancing and lockdown situation due to COVID-19	10	Vaccination and cure of COVID-19 pandemic	10	900
				Student relying only on electronic gadgets and equipment and not studying from hard copy textbooks	7	Supplementing on-line study with self study from hard copy text book	2	126
	Doubts clarification not fully carried out	Students become perplexed	9	Improper communication of the faculty with the student	5	Improvement of communication soft skills of the faculty	3	135
				Time-lag due to discontinuous online streaming of the class	8	Strengthening of the transmission signal by opting for a better bandwidth	3	216
				Online software not having optimum interactive features	7	Switching over to a better software with superior features	2	126
	Student unable to assimilate the concept and working applications of components	Purpose and outcomes of the session not achieved	9	Student is a slow-learner	5	Improving the grasping capacity of the student through the various spatial visualization techniques	5	225
				Late joining of the student in the course work	4	Conducting bridge-course to the late-joiners	2	72
				Ineffective gadget used by the student	6	Switching over to a better gadget	2	108
				Discontinuous class because of signal problem	6	Switching over to a transmission consisting of a better signal strength	2	108
				Ineffective explanation by the faculty	5	Faculty to adopt a better teaching skill	3	135
	Easy distraction of the concentration of the student	Intermittent learning leading to difficulty in assimilation of the concepts	9	Student receiving the class in an open public place where distraction and noise are high	7	Self-isolation of the student to a calm and serene place during the period of class	1	63
				Inherent behavior pattern of student is that of a low concentration level	4	Student may be guided through a proper psychological support	2	72

continuous long hours brings in a lot of monotony and reduction in concentration levels (Bao, 2020). Hence, self-motivation is the key factor in online pedagogy. Hands-on practice in the course is strongly recommended. Addressing and clarifying the doubts are heavily dependent on the online platform. Moreover, students must not limit one-self only to the problems discussed in the online session. Instead,

the student must expand one's horizons and do the exercises outside the classwork and more number of unsolved examples given at the end of the each chapter of the text book. Here the concept of "tinkering" can be of some help. Tinkering is the concept where something is build first, and then it is figured out that what it is or what it can be useful afterward (Cipolla, 2019). Thus, students must be given the freedom to make mistakes and learn from those mistakes.

Mindset of students as well as faculty must be open to change, as change is inevitable. Teaching-learning methodologies are bound to undergo a sea change. Technological developments and recent scientific innovations must be adopted for generating excitement in the session. "Embrace change" must be the buzz word in this postdigital era.

Ineffective online pedagogy creeps in frustration among the students, which paves way for losing of interest in the course. Figure 4 depicts the cause and effect diagram for ineffective machine drawing online pedagogy. All the stakeholders including students, staff, administration, governance, as well as parents were plunged into the world of online pedagogy overnight because of the genuine reason of COVID-19 pandemic. All the stakeholders were inexperienced to the online mode of teaching and learning. This can be the root cause of poor performance of some faculty as pointed in the Ishikawa diagram in Figure 4. In such a situation, the Institute Governance is the driving force for developing emergent strategies and create favorable conditions for introducing or intensifying the use of Information Technology and related software packages dedicated to improve the machine drawing online pedagogy. Today's society demands and looks forward to the Universities and Institutes to be continuous learning organizations to solve the societal technical problems. The society today expects the universities to switch their role from a mere knowledge adaptation to knowledge generation and be the technical backbone of the society (Bratianu & Pinzaru, 2015).

It must be observed that machine drawing course is better imbibed as a peer-learning methodical course. But, it is a real challenge for the faculty to convert this peer-learning based course into a personalized online learning methodical learning course. The solution for this is to perform a Service FMEA and address the concerns starting from the highest RPN and proceeding to the lowest RPN. Current control which is easily detectable is allocated lower rank, and control which is difficult in detecting is ranked a higher number. Table 3 shows the FMEA in a service environment.

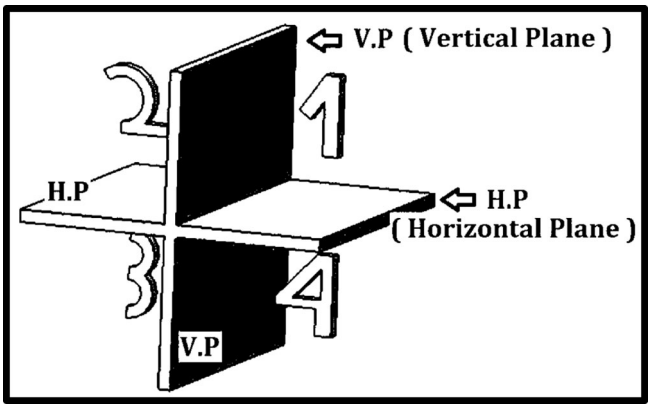

FIGURE 5 The four quadrants of technical drawing depicted through a geometric modeling software

9 | SPATIAL VISUALIZATION AND ONLINE MACHINE DRAWING PEDAGOGY

Drawing is a visualization-based course where the process of learning is more important, and the end result is good if the process is adhered to. Apart from the concepts of drafting, working of components, and assemblages, the student is simultaneously trained in the spatial visualization skills. Technical drawing courses consist of being creative with spatial visualization techniques. These are the techniques that can be mastered through practice (Sharma et al., 2020).

The first and the foremost visualization in technical drawing involve the concepts of the four quadrant visualization constituting the first-, second-, third-, and fourth-angle projections. The representation of these quadrants is visualized through geometric modeling software and is depicted in Figure 5. Also Figure 6 shows the different angular orientations of the same component. Such visualization through geometric modeling software clears the concepts and generates interest among the students by clearing the mental blockages.

Thus, the training can be effectively imparted in online mode of delivery during the social lockdown period of COVID-19 pandemic or in fact in any other natural calamities and disasters. The student

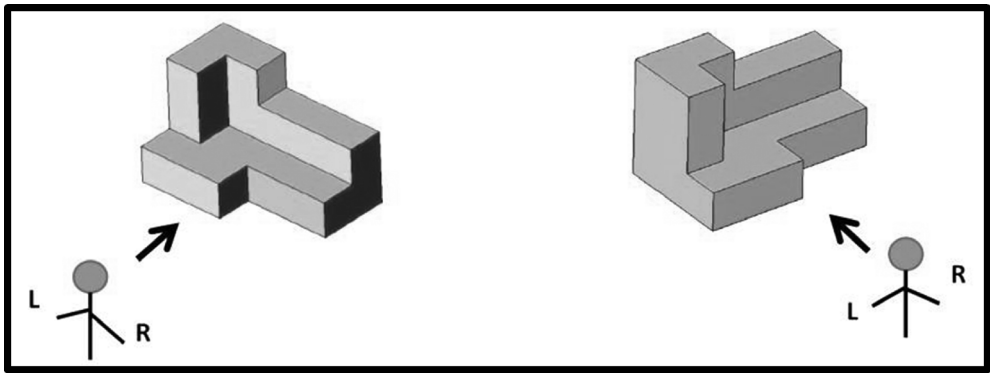

FIGURE 6 The different angular orientations of the same component when spatially visualized

TABLE 4 Students' feedback on online sessions

S.No.	Parameter	Rubric-1 Excellent	Rubric-2 Very good	Rubric-3 Good	Rubric-4 Adequate	Rubric-5 Barely adequate	Rubric-6 Poor	Number of students
1	**Preparedness for online classes**	23	13	10	2	1	1	50
2	**Handling of questions on-line**	21	15	13	0	0	1	50
3	**Level of interest and excitement generated in the on-line session**	18	18	11	2	1	0	50
4	**Extra help outside on-line class hours**	0	1	1	13	15	20	50
5	**Teaching aids used other than oral delivery like ppts, prerecorded videos during the online session**	22	16	10	2	0	0	50

feedback of a cross-section of 50 students after imparting training in machine drawing through online mode of delivery was collected for each of the following five important parameters with rubrics of six levels. This feedback of the same 50 students for each parameter is captured in Table 4. It reflects from the feedback on online sessions that the students voted positively toward online mode of teaching, which registers the success of the faculty in handling online sessions in spatial visualization-based course like machine drawing. The drawback observed is about "extra help outside on-line class hours." This is designated due to the reason that the extra help outside online class hours demands more personal time of the faculty, for which the faculty may not be in a position to extend.

10 | DISCUSSION AND WAY FORWARD

It is clear and evident that the way the world approaches toward teaching and learning does not remain the same in the post COVID-19 era. Online mode of pedagogy shall be occupying a substantial portion of the mode of delivery in teaching and learning. Focus shall shift from assessment- and output-oriented learning, to, outcome and higher order thinking learning, where application, analysis, evaluation, and creation shall have more emphasis.

In the trying times of COVID-19 where the social lockdown largely prevails, the educators have switched over to online mode teaching based on the internet connectivity. Delivering the concepts is just a part of the job. Apart from the technical and conceptual teaching, the faculty has to concentrate on the development of humane qualities like spiritual and emotional facet of the student personality. During the online classes, the physical touch between the student and the tutor is absent. This makes the tutor to be more cautious in addressing the emotional aspect of the student. Emotional facet of knowledge delivery is an important aspect of personality development of the student. Another domain which is gaining importance nowadays is the emotional knowledge itself. Knowledge management and decision-making sciences are largely dependent on the emotional knowledge, which can be transformed into another forms of rational and spiritual knowledge (Brătianu & Orzea, 2014). This interchange of one form of knowledge into another is the knowledge dynamics. Machine drawing can be an important tool in switching over from one form of knowledge into another. Reading the technical drawing and interpreting it correctly through various annotations of the drawing deciphers the rational form of technical information. This technical information when applied to the social needs like designing a bridge or styling of a car is governed by the social emotions of the people of the society. Thus, this aspect of the knowledge dynamics has to be taken into account during the pedagogy of the machine drawing course.

Due to COVID-19 pandemic, it seems that the "present" has accelerated at an unprecedented pace into the "future" where the online presence in every walk of life is more common. Due to this pandemic, all of the humanity was thrown into the online digital world overnight. There was no enough time for preparation, and almost all walks of life had to overcome the inertia of rest all of a sudden and had to come into the motion, of a world filled with a considerable degree of uncertainty.

Education is no exception. Students as well as faculty are undergoing an emotional and intellectual turmoil. It is in these trying times, the qualities of being humane like compassion and caring toward the student are direly required. The role of parents, guardians, and mentors is very crucial in these situations. It is through an optimistic approach filled with concern and care that we all can overcome this crisis together. If we look back and see, then we find the year 2020 as a nightmare, which is peeping in the years to come. As rightly said, "health is wealth." The first and the foremost action should be to take all the precautions, which ensure a good health. It would be not surprising to state that the next priority subsequent to health management is "knowledge management." Students are expected to equip themselves to be comfortable with online mode of learning, and institutions are expected to strengthen their IT infrastructure to provide a seamless online learning platform for the learners. After acquiring skills and knowledge, the students are expected to translate and share their learning with their peer group, which is also the main facet of maker education.

Since past one decade, maker education has gained momentum and is a feasible solution for situations that are pandemic like COVID-19. Thus, it is through the concepts like "tinkering" in maker education that the concept of going global through local facilities, that is, being "glocal" for fulfilling the needs of individual as well as society is possible. Helping each other by fulfilling the intellectual appetite of one another is the key to success. Hence, the maker movement is a

promising philosophy, which has a long way to go for building the future together.

11 | LIMITATIONS AND FUTURE SCOPE

The following are the limitations envisaged in this work:

1. The machine drawing online training imparted is limited to a single section of 50 number of students. The future scope of this work depends on the horizontal deployment of similar study on a larger section of students comprising of a broader size of research sample.
2. The time span of the study is one single semester. The feedback of the students from more number of different batches from different academic years would probably give a broader picture on the online machine drawing pedagogy. Since the online pedagogy has started evolving since the onset of COVID-19, hence, there is more future scope to achieve perfection in the years to come.
3. In order to streamline the pedagogy of machine drawing during and after the COVID-19 pandemic, a blended approach toward learning has to be proposed in the Board-of-Studies Senate meeting. This blended approach shall cover both on-line and off-line mode of course delivery depending on the requirement of the topic of the subject. In this aspect, the Government of India has recently released NEP-2020 (National Education Policy-2020), which gives a fair chance for blended learning pedagogy. If NEP-2020 would not have been formulated, it would take several years for the developing countries like India to adopt the blended learning approach involving the online mode of instruction delivery.

Thus, in an optimistic note, COVID-19 has indirectly been an enabler for implementing online pedagogy not only in the course of machine drawing but also in many other allied courses.

12 | CONCLUSIONS

Online pedagogical technique has been examined in the light of teaching and learning of course like machine drawing involving considerable amount of imagination and visualization skills in this era of COVID-19 pandemic. Impediments faced in the online machine drawing pedagogy in the COVID-19 pandemic era have been identified. Opportunities in the wake of COVID-19 pandemic era in context of machine drawing pedagogy have been discussed and consolidated. Approach for maker-based online pedagogy with reference to machine drawing course is delineated. Maker education model of online mode of delivery in the coursework of machine drawing is focused in this work.

Machine drawing has the tacit knowledge aspect largely associated with it. This work discusses the tacit knowledge aspect of machine drawing, while teaching the same in online mode of delivery. The faculty are thought to be a reservoir of "tacit" knowledge for imparting effective and efficient training in computer-aided machine drawing skills through online mode, which is by-and-large a non-corporeal method of tacit knowledge transfer. It is also emphasized that for a barrier-free knowledge transfer, in this COVID-19 pandemic era, the University Governance must take strong steps to strengthen the IT infrastructure for seamless learning.

Finally, the training in spatial visualization basics of technical drawing is imparted to the students through online mode and the feedback from the students is recorded. It is also observed that the feedback given from the students that online mode of machine drawing course delivery is skewed toward the positive face of learning. The limitations and future scope of this work are also envisaged. Thus online machine drawing pedagogy is there to remain for long even after the COVID-19 pandemic.

DATA AVAILABILITY STATEMENT

Data sharing not applicable - no new data generated.

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How to cite this article: Sharma, G. V. S. S., Prasad, C. L. V. R. S. V., & Rambabu, V. (2022). Online machine drawing pedagogy—A knowledge management perspective through maker education in the COVID-19 pandemic era. *Knowledge and Process Management*, *29*(3), 231–241. https://doi.org/10.1002/kpm.1684