ORIGINAL RESEARCH

Entropy in Education System: Transformation of an Individual Through Meaningful Interactions in a Community of Inquiry

Muhammad Imran Ahmad[1] ⬤ · Irfan Ahmed Khan[2] · Masuda Ahmad[3] ·
Abbas Husain[4] · Rozinah Jamaludin[5]

Abstract
Every individual is unique and may serve a unique purpose in this life. Education is widely accepted to be the means of transformation of individuals so that they may achieve their unique success or create their own lives. However, not every individual seems to be realizing their true potential. This paper explores the concept of entropy in education system as a force that is usually imagined to oppose realization of potential of an individual during life in this phenomenal world. Alternatively, the same may provide an impetus that is necessary to bring in organization in oneself to realize the hidden potential. A one group Pretest-Posttest quasi-experimental design was used to draw the conclusions on data obtained from participants of workshops in three different modes, viz. face-to-face Pre COVID-19, face-to-face in COVID-19 with SOPs, and online in COVID-19. Realization of an individual's potential was represented as a dependent variable, i.e. transformation in cognition, skills, and attitude while the independent variables taken into account were the meaningful interactions of an individual with peers and advanced learners in a designed environment. It was inferred from the results that transformation in learners' cognition (6-30 %), skills (0-20 %), and attitude (5-32 %) occurred through human discourse, in a community of inquiry.

Keywords Entropy · Education · Systems thinking · Community of inquiry

✉ Muhammad Imran Ahmad
    imran.ahmad@uetpeshawar.edu.pk

1   Department of Chemical Engineering, University of Engineering and Technology, Peshawar, Pakistan

2   National Institute of Urban Infrastructure Planning, University of Engineering and Technology, Peshawar, Pakistan

3   Qadir Nagar High School, Buner, Pakistan

4   Teachers' Development Centre, Karachi, Pakistan

5   Universiti Sains Malaysia, George Town, Malaysia

Introduction

A community of inquiry is a spontaneous form of human discourse in which a group of individuals construct knowledge together as proposed by Matthew Lipman in 1970's (Kennedy and Kennedy 2010). It has been observed that the community of inquiry framework, borrowed from Lipman (1991), is based on John Dewey's exposition (Dewey 1933) of inquiry as a social activity (Kilis and Yildirim 2018). Mohapatra looked into the influence of social media interaction and technology on online writing communities, and how massive open online courses (MOOCs) on the internet have changed over the years presenting a framework as a guidance for such ventures (Mohapatra and Mohanty 2017; Mohapatra and Mohanty 2018). Holmberg (2005) recommended teachers to develop relationships and empathy with students for creating a feeling of belonging in the learning community. This feeling of belonging could become a condition for success of distance education. Yates et al. (2020) evaluated Kearney et al's (2012) framework for learning using mobile devices in the context of online learning in COVID-19, particularly how the constructs of collaboration, personalization and authenticity were experienced by high school students in New Zealand. The impact of COVID-19 on schooling in 31 countries was synthesized by Bozkurt et al. (2020) with the conclusion that 'pedagogy of care, affection and empathy' may become foundation of education in crisis. Thus social nature of learning lends itself as a fundamental basis of various modes of learning including distance and online learning in the form of communities of inquiry. In view of the new world order rolled out due to COVID-19 there is a need to look into meaningful interactions of learners and their transformation in face-to-face, blended, and online communities of inquiry. Moreover, education system may be treated as a complex system of communities of inquiry with complexity and dynamics arising through interactions between large number of individuals and elements.

Entropy in Education System

Robert Fritz says, in Schools That Learn, 'the most profound purpose of education may be helping young people learn how to create the lives they truly want to create.' (Senge et al. 2012, pp. 209-215). In light of this purpose of education, an education system may be defined as 'The experiences of individuals due to interaction with each other and with materials through well defined processes within a dedicated space and time that may lead them to realizing their potential in life'. This definition is supported by the concept of 'learning' defined as "a change in an individual caused by experience" (Slavin 2012, pp. 204). Schuitema (2014) explored growth of an individual through transactional correctness on the basis of two differing intentions of being here to take or being here to give. Transactional correctness may be defined as "seeing things as they are and giving everything it's due". According to this model "it is transactional correctness or courtesy to the moment, which enables growth and maturity".

The key to realization of potential by an individual may be 'structural tension' as proposed by Robert Fritz, i.e. 'difference between current reality and our desired state creates a tension that drives us to strive to resolve it' (Senge et al. 2012). This desired state could be our aspirations, goals in the context of our potential at any moment that may or may not be realized. Resolution of structural tension is through accomplishment

of goals or realization of potential by an individual. It may be worthwhile to reflect upon some questions that arise here such as what can be the role of an 'expert facilitator' in this pursuit of realizing one's own potential? What is the role of a 'collective thought'? Can it be pursued in the presence of individual ones?

This concept of structural tension as a driving force that makes individuals strive to achieve their goals and aspirations may be viewed in the context of transactional correctness and level of maturity. An individual may strive to achieve personal goals and aspirations centered towards self. This effort certainly deserves recognition, however, in view of transactional correctness and degree of maturity there lies a possibility of realizing an even higher potential when our intent directs our efforts from self to the other, at any moment, rather than towards self, i.e. 'objectivise yourself'. A few verses of The Holy Quran are presented here (*Asr*):

"1. By (the Token of) Time (through the Ages), 2. Verily Man Is in loss, 3. Except such as have Faith, And do righteous deeds, And (join together) In the mutual teaching Of Truth, and of Patience and Constancy." Abdullah Yousuf Ali presents its introduction and summary as "This early Meccan Sura refers to the testimony of Time through the Ages. All history shows that Evil came to an evil end But time is always in favour of those who have Faith, live clean and pure lives, and know how to wait, in patience and constancy." (Ali 1977).

Wilson (1970) presented four views of the concept of entropy, viz. uncertainty about the micro-states of a system, in terms of probability distributions, Bayesian inference, and as a measurable system property which always increases. In this work, however, the concept of entropy is being explored in a social system, education, with the aim of modeling dynamics of an education system. The notion of entropy in classrooms as complex adaptive systems has been referred to previously as social interactive entropy (Vetromille-Castro 2013). If Entropy, is considered as one way of formalizing irreversible phenomenon, such as 'Population in a given country is expected to progress towards a higher macro state - more educated level because this result is consistent with our notion of the direction of time.' (Guevara and Posch 2015). Then the development of a child through education may be imagined as a set of interlinked processes within a complex system. The development of an individual has been a focus of much research and various theories have been proposed including but not limiting to Piaget's theory of cognitive development, Erik Erickson's stages of psychosocial development that in each stage an individual must deal with particular crises or critical issues and resolve them (Slavin 2012). Similarly, Maria Montessori also viewed the development of a child based on sensitive periods and stages of physical, intellectual, and emotional development (Montessori 1936).

A significant contributor to the development of a child is the genetic pattern which unfolds from birth to up to maturity and even up to forty years of life as believed by some scholars. If this genetic pattern may be considered as a child's potential that may be realized through interaction with the environment, i.e. nature and nurture paradigm. Then an ideal state for every child would be the realized potential, i.e. transformation of personality with time (life). However, not every child may realize their potential primarily due to a lesser degree of engagement with environment resulting in a transformation of personality different to the ideal state as a function of time. This sort of unintended trend in child's life may be attributed towards the gap due to the opportunities the child gets, however such gaps can be reduced through actions, which can restore the intended trend through corrective actions in an enabling environment and presence of a facilitator. This is to say that an 'Imbalance provides the needed organization' (Penrose 2010).

Education System as a Complex System of Communities of Inquiry

In this work physical representation of education system is accounted for in terms of state of infrastructure (learning space), human resource (learners and facilitators), and material resource (designed resources) while the quality of education system is measured in terms of the condition of these state variables as well as the transformation in students through learning (Also the three states refer to 'social, teacher and cognitive presences' in an education system). Thus, education system may be treated as a set of communities of inquiry. Kennedy and Kennedy (2010) define 'community of inquiry' as a variety of pedagogies and curricula, i.e. a spontaneous form of human discourse in which a group of individuals construct knowledge together. The discourse model of community of inquiry (CI) is based on 'building on each other's ideas' in classroom setting wherein teacher plays the role of a facilitator. This model was initiated by Matthew Lipman in 1970's for critical discussion of 'purely' philosophical concepts (Lipman et al. 1980; Sharp 1992; Splitter and Sharp 1995; Lipman 2003) as cited in Kennedy and Kennedy (2010). The discourse model of CI may be traced to Socratic dialogue and the 'dialogue' is to be taken under the notion of deriving a meaning collectively or through reflection in contrast to 'discussion', which takes the notion of fragmentation and competition (Bohm 2004). Education systems are considered as complex and dynamics systems consisting of interactions between large number of individuals and elements (Durlauf 1998; Mason 2008) as cited in Guevara and Posch (2015). From a systems viewpoint education system may be treated as a complex system of CIs with numerous feedbacks arising through interactions of learners, within the school infrastructure, with material resource, human resource (school's personnel including teachers), and amongst themselves. Grades or classes may be treated as communities of inquiry. The progression of a learner from one grade to another is presented in Fig. 1.

It may be observed from Fig. 1 that when a learner enters a community of inquiry, say CI-1 i.e. admitted to a grade or class. This community of inquiry consists of interactions

Fig. 1 A spiral representation of progression from one community of inquiry to another
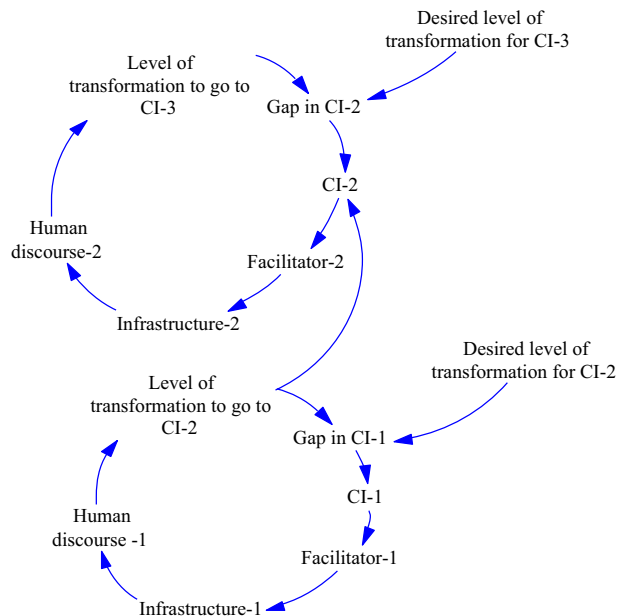
between peers and with teachers who serve as facilitators. As this community of inquiry is housed in a classroom or online, therefore, the quantitative aspect of state of education system is represented through infrastructure and the human discourse, i.e. ability of teachers as facilitators and the availability of appropriate material resources. The quality of learning depends on the condition of infrastructure, human and material resources, and is measured in terms of level of transformation.

It is interesting to note here that the gap in CI as shown in Fig. 1 is the difference in current level of transformation of an individual and the desired level of transformation for progression to next state of community of inquiry. Progression from one community of inquiry to a more advanced or mature community of inquiry depends on the degree of transformation that may be measured in terms of learning outcomes in knowledge (cognitive), skills (psychomotor), and affective domains. A conceptual framework representing the realization of potential by an individual through structural tension based on human discourse in a community of inquiry is presented, as shown in Fig. 2.

As emphasized by Adom et al. (2016), the relationship of all elements within this research have been depicted in the conceptual framework in Fig. 2. It may be observed from the framework that learners build on each other's ideas in a classroom setting with teacher facilitating this community of inquiry. Human discourse in such communities of inquiry takes place in the form of learners interacting with designed resources (environment), other peers and teachers leading to growth and maturity, i.e. structural tension and transactional correctness providing the impetus to direct the efforts of individuals from personal aspirations to collective goals. The arrow pointing towards the 'Realization of potential' in Fig. 2 represents growth and maturity in an individual due to structural tension while the arrow pointing downwards and away from learning represents entropy in the context of education systems which results in a 'Gap in CIs' shown in Fig. 1. A careful
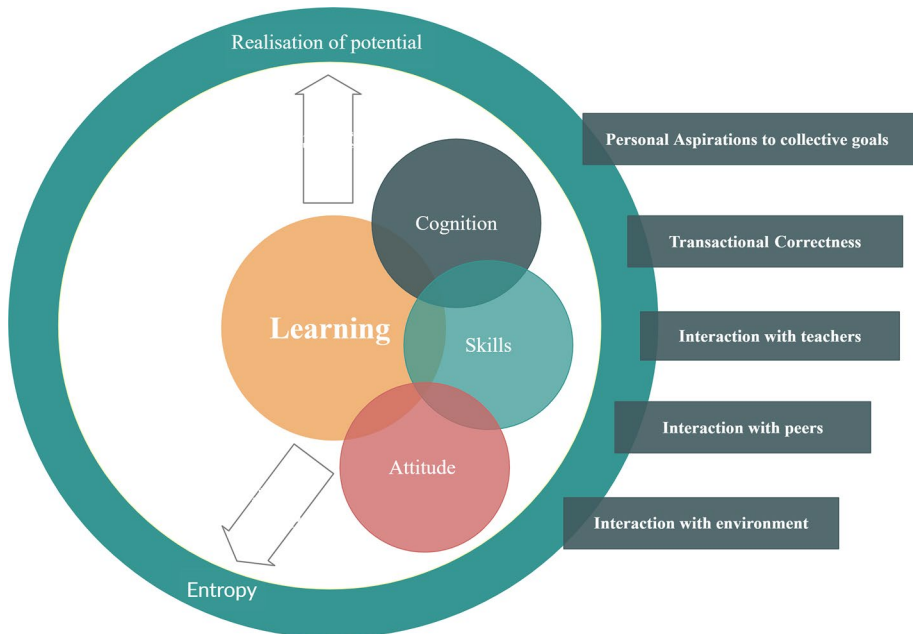

Fig. 2 A conceptual framework for learning through human discourse in a community of inquiry

introspection of this conceptual framework reveals the need for incorporating reflection at individual and collective level to render interactions meaningful in a community of inquiry. Reflection being an integral part of meaningful interaction is in accordance with the philosophy of John Dewey, i.e. 'meaningful experiences are not possible without some element of reflection' (Dewey 1923, 1933) as cited in Cloude et al. (2021). In this context, while the proposed conceptual framework models growth and maturity in an individual, based on meaningful interactions leading to transactional correctness, in a community of inquiry, the concept of entropy in education system needs further exploration.

Vetromille-Castro (2013) presented social interactive entropy in a similar manner seeing the interactional flow of messages in a classroom metaphorically as the energy of such complex systems. 'When interactional flows decrease or cease, participants disperse and the system succumbs', i.e. manifestation of disorder. Looking at social interactive entropy in a community of inquiry, metaphorically, in education, throw of love is the answer.

Systems Thinking in the Context of Education

Senge (1990) describes systems thinking as fifth discipline, which emphasizes on observing variations both in natural and manmade systems with the lens of system dynamics providing the observer a 'structure' of system on which the behavior patterns of the system depend. This type of enquiry not only develops the understanding of a system but also provides the leverages to effectively maneuver it. Here in this work the focus is on the fifth discipline that is Systems Thinking rather than Forrester's 'System Dynamics' because the fifth discipline with other four, viz. *mental models, team learning, shared vision* and *personal mastery* are very much compatible with the Lipman's concept of 'community of inquiry' where he is 'Thinking in Education'. Is there a Sixth discipline? If there is, what this sixth one has to do with 'Entropy' and it's allied 'Arrow of Time'? Weiner (1989) provides the roots of 'cybernetics' in life finding home in such enclaves that have limited and temporary tendency for the 'Organization' to increase. It is precisely the work of Wiener that brought the notion from 'Arrow of Time' to 'The Arrow that constructs the World'. The Control discipline the roots of which lie in cybernetics is named by Mella (2006) as Sixth discipline. "This quite obvious consideration represents a cardinal principle of cybernetics known as the law of necessary variety, formulated by Ross Ashby (1957), according to which the "variety" of a control system's admissible states must be greater than or equal to the 'variety' of the disturbances of the reality. This law of necessary variety also allows us to determine a rule to specify the system's boundary, which is described by the Causal Loop Diagrams: we must extend the system's area until it includes all the variables that provide sufficient variety to the model to describe the real system that must be controlled." (Ashby 1957; Mella 2006).

It may be observed from Fig. 3 that a generic structure for control system for any system must contain a goal, which is a desired state of a system whereas present situation is gauged against the desired state for which action is required to either achieve objectives or restore to a desired state. To strive for objective or restoration action both come under the domain 'control and communication' together. Based on Ashby's theory in a system the number of control or corrective action variables must be greater than or equal to the disturbing or perturbing variables to keep the system in order or say to prevent to move towards 'chaos'. Now 'communities of inquiry' when assessed against some desired level of transformation are checked on the basis of infrastructure, teacher,
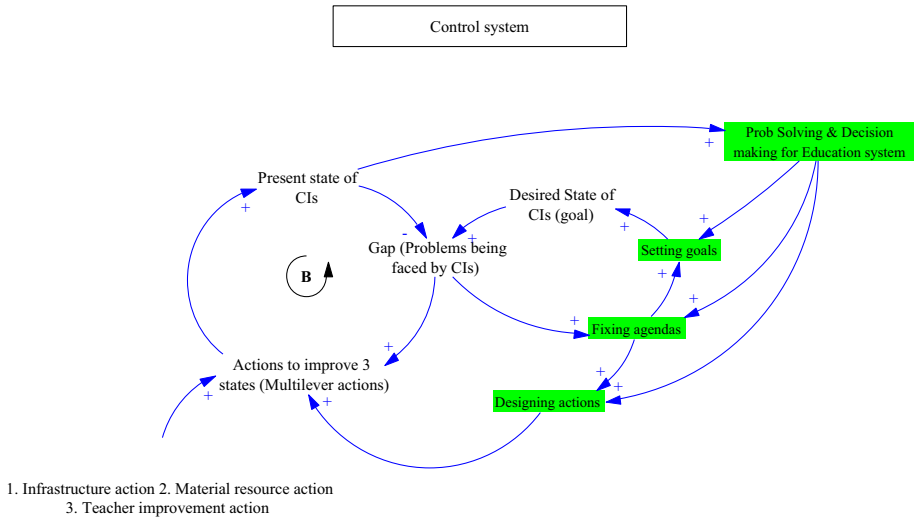
Fig. 3 A Causal loop diagram showing the structure of an epistemological system over community of inquiries

and material resources. Problem solving against the gap is to suggest design actions, setting agendas and introducing different interventions.

This control system (Fig. 3) and the conceptual framework of learning through human discourse in a community of inquiry (Fig. 2) together constitute our proposed model to represent transformation of individuals through meaningful interactions in a community of inquiry. Moreover, this proposed model envisions education system as a complex system of communities of inquiry wherein realization of potential by individual learners depends not only on human discourse within a community of inquiry but also on how interventions reduce gap between the current and desired state of education system. A systems behavior is governed mainly by the structure of the system and the purpose of the system. Vision provides the purpose to a system and defines the desired state. The gap is then measured with reference to the desired state and system is thereby directed towards the goal i.e., realization of the potential. An interesting extension of this study could be exploring how each intervention, designed to reduce gap between the current and desired state of education system, affects the human discourse taking place within a community of inquiry. Furthermore, it may be worthwhile to investigate dynamic behaviour of various communities of inquiry within an education system changing with various interventions and contributing towards the overall purpose of the system, modeled only qualitatively in this work.

Methodology

This section presents the methodology followed to implement and test the conceptual framework proposed in this research. The focus research question to be addressed in this work is:

Research Question and Objectives

> How can the probability of a learner to realize their potential in life be increased?

This research question led to our research objectives:

- To model the transformation of a learner due to meaningful interactions, i.e. human discourse in a community of inquiry.
- To assess the degree of transformation through learning outcomes achieved through interventions in community of inquiry.

In order to quantify the extent or degree of transformation in a learner through human discourse in a community of inquiry the following hypothesis was made which was tested through statistical analysis of feedback from one workshop on 'Systems Thinking in Problem Solving' Pre COVID-19, and two workshops on 'Learning Styles and Preferences' one being face-to-face under standard operating procedures for COVID-19 and other online using Zoom.

Hypothesis

If learners get to interact with peers and advanced learners in meaningful ways in designed environments then they will attain a transformation within their cognition, skills and attitude (resulting increased probability of realization of their potentials in life). The dependent variable, learning, i.e. transformation in a learner's cognition, skills, and attitude may be defined as a function of the following quasi-independent variables:

- Interactions with peers.
- Interactions with facilitators.
- Interactions with environment.

One-Group PreTest-Posttest Quasi-Experimental Design

A one-group pretest-posttest quasi-experimental design was selected for this research as shown in Fig. 4, wherein the same dependent variable is measured in one group of
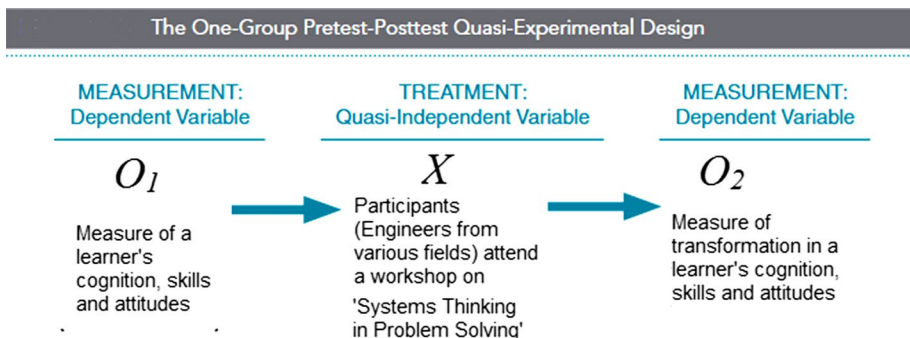

Fig. 4 Research design

participants before (pretest) and after (posttest) a treatment is administered. According to Cohen et al. (2007), this design is represented as $O_1\ X\ O_2$ where O_1 is the pretest, X is the treatment and O_2 is the posttest. In this research, the treatment (X) was the workshop on 'Systems thinking in Problem Solving', and then two more workshops on 'Learning Styles and Preferences', these were attended by participants which were Engineers from various fields. A survey was conducted before each workshop (Pretest) and another conducted after each workshop (Posttest).

Treatment (X)

For the purpose of this research, an experiment was conducted on a Community of Inquiry; a group of Engineers that participated in a Workshop on 'Systems Thinking in Problem Solving'. In a similar manner two more workshops were conducted in which teachers and researchers (all Engineers) from three different disciplines participated. Within each workshop, lectures were followed by group activities involving sharing ideas, creating collective meaning to concepts by applying them on problems and case studies. Finally, presentations were given by the participants and the workshop concluded with an overall discussion session.

Participants

There were a total of 18 participants in the first workshop, including Civil Engineers, Electrical Engineers and Chemical Engineers working in industry, government departments, and academia. The second workshop was attended by 16 participants, including Agricultural and Mining Engineers working in Academia, under the standard operating procedures in COVID-19 scenario while the third workshop was attended by 10 participants, Chemical Engineers engaged in teaching and research, online using Zoom.

Data Collection

Quantitative data collection was done via surveys, both before and after each workshop. The survey consisted of questionnaires with 5-point Likert scale questions, in which participants had to rate their own knowledge and skills. Questions were designed based on the objectives set for the workshop. All participants were given questionnaires with sufficient time to answer three questions. Non-probability sampling was used which involves non-random selection based on the participation of Engineers from various fields.

The response rate in each of the workshop for the Pretest and the posttest was following:

- Systems Thinking in Problem Solving (face-to-face Pre COVID-19): 12 out of 15 for the Pretest and 14 out of 18 for the Posttest.
- Learning Styles and Preferences (face-to-face in COVID-19 with SOPs): 15 out of 16 for the Pretest and 16 out of 16 for the Posttest.
- Learning Styles and Preferences (online in COVID-19): 8 out of 10 for the Pretest and 6 out of 10 for the Posttest.

Analysis

Before analysis, the gathered data was prepared. The dataset was checked for missing data; however, outliers were not removed and variables were not transformed. All responses were considered to be valid. The data was analyzed using statistical software SPSS, taking descriptive statistics looking into mean, standard deviation and histogram.

Results and Discussion

This section presents a discussion of the insights gained through feedback from participants of three different workshops, each planned and conducted to provide meaningful interactions in a community of inquiry. The first workshop on 'Systems thinking in Problem Solving' was conducted in 2019 and is referred to as 'face-to-face Pre-COVID-19'. The second and third workshops were on 'Learning Styles and Preferences' one being conducted physically with adherence to standard operating procedures for COVID-19 and other being online on Zoom, referred to as 'face-to-face in COVID-19 with SOPs' and 'online in COVID-19' in 2021.

The first workshop on 'Systems thinking in Problem Solving' was planned to attain the following objectives:

- To develop in-depth comprehension of complexity and dynamic nature of complex problems.
- To develop skills in representing feedback loops within complex systems.
- To develop appreciation of utility of systems thinking in formulating complex problems.

The workshop consisted of lectures followed by group activities such that the participants along with the resource persons discussed various aspects of the complexity and dynamic nature of complex problems and also performed activities in groups. Thus, the whole workshop was designed on the concept of community of inquiry providing an opportunity for Engineers from various disciplines to develop collective meaning of utility of systems thinking in formulating complex problems. A survey was conducted at the beginning and end of the workshop to get feedback and assess the degree to which objectives were achieved. Statistical analysis of the feedback surveys is shown in Figs. 5, 6 and 7.

It may be observed from Fig. 5 that the mean score, representing the ability to comprehend complex and dynamic nature of complex problems, increased from 3.08 to 4 (+29.87 %). Participants were required to gauge their own ability on a scale of 1-10. Here we analyze that the treatment, which can also be considered as design-oriented learning, as defined by Seitamaa et al. (2010) as having emphasis on interaction within and between peers and teams, students, teachers, experts and the community, has caused change in the attitudes of participants. This change can be gauged as an increase in the participant's self-assessment towards their ability to comprehend complex problems.

Thus, mean score of 4 indicates that a majority of participants gauged themselves with a score of 6-8.
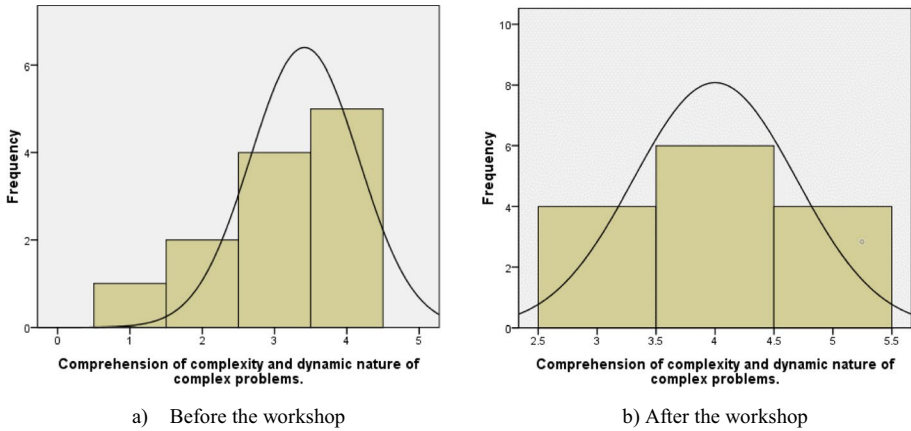
| | |
| a)   Before the workshop | b) After the workshop |

Fig. 5 Assessment of ability to comprehend complex and dynamic nature of complex problems. **a**) Before the workshop. **b**) After the workshop

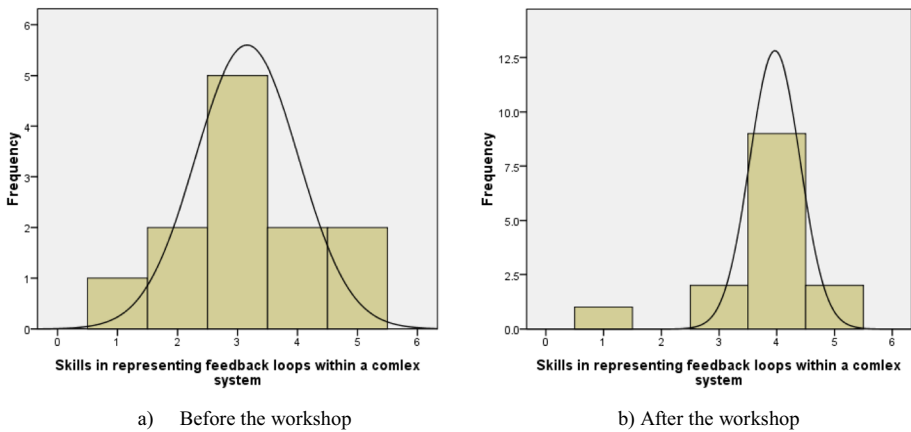| | |
| a)   Before the workshop | b) After the workshop |

Fig. 6 Assessment of skills of representing feedback loops within a complex system. **a**) Before the workshop. **b**) After the workshop

It may be observed from Fig. 6 that the mean score, representing skills of the participants to represent feedback loops within a complex system, increased from 3.17 to 3.79 (+19.55 %).

Similarly, the third objective of the workshop was assessed by the participants as shown in Fig. 7.

It may be observed from Fig. 7 that the mean score, representing the appreciation of utility of systems thinking in formulation of complex problems, increased from 3.08 to 4.07 (+32.14 %).

The second and third workshop on 'Learning Styles and Preferences' was planned to attain the following objectives:

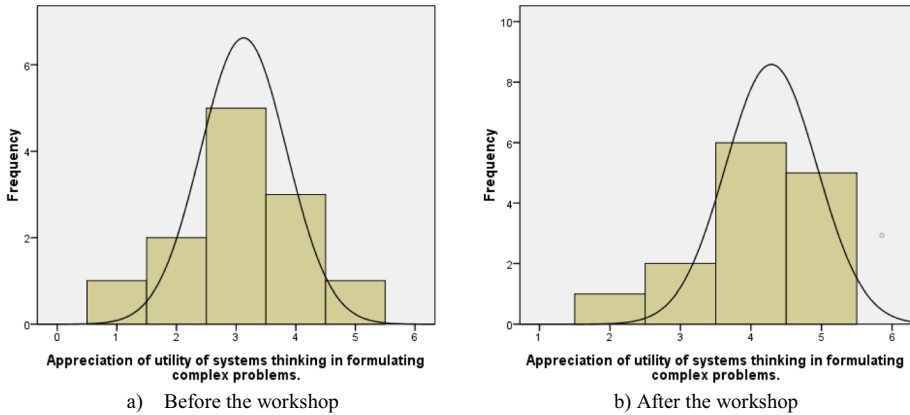• To develop comprehension of different learning styles and preferences.

| a)   Before the workshop | b) After the workshop |

Fig. 7 Assessment of appreciation of utility of systems thinking in formulating complex problems. **a**) Before the workshop. **b**) After the workshop

- To develop skills to address needs of different learners in teaching and learning.
- To develop appreciation of diverse styles, preferences, and needs of learners.

A time sequence of tasks and activities in both the workshops is shown in Table 1.

It may be observed from Table 1 that both the workshops consisted of direct instruction using PowerPoint presentations, discussions, and group or individual activities such that the participants along with the facilitators discussed different learning styles, preferences and needs to be addressed in teaching and learning. One major difference between the second and third workshop was that the second one, i.e. 'face-to-face in COVID-19 with SOPs' offered one additional session for supervised group work before participants could extend their learning in individual tasks.

Survey was conducted at the beginning and end of these workshops to get feedback and assess the degree to which objectives were achieved. Statistical analysis of the feedback surveys is shown in Table 2.

Table 2 provides an interesting comparison between the second and third workshop, one being face-to-face and the other being online, that transformation in both cognition and skills of the participants regarding learning styles, preferences, and needs of different learners occurred to a greater extent in face-to-face in comparison with online mode. This

Table 1 Task and activities in workshops conducted during COVID-19

S.No	Face-to-face in COVID-19 with SOPs (2021)	Online in COVID-19 (2021)
1	Introduction to different learning styles and preferences. (90 min session)	Introduction to different learning styles and preferences. (90 min session)
2	Supervised practice of planning a unit/project to address needs of different learners in teaching and learning. (90 min session)	Individual task: Preparation of a unit/project plan to address needs of different learners in teaching and learning based on guidelines provided. (90 min session)
3	Discussion, revision of planners, and final presentations by participants. (90 min session)	-

Table 2 Statistical analysis of Pretest and Posttest feedback from participants

S. No	Intervention	Learning Outcomes	Pretest (Mean, Std. Dev)	Posttest (Mean, Std. Dev)	% Increase
1	Face-to-face Pre-COVID-19 (2019)	Cognition	3.08, 0.99	4.0, 0.78	29.87
		Skills	3.17, 1.19	3.79, 0.97	19.55
		Attitude	3.08, 1.08	4.07, 0.92	32.14
2	Face-to-face in COVID-19 with SOPs (2021)	Cognition	3.73, 0.79	4.38, 0.50	17.19
		Skills	4.13, 0.52	4.38, 0.62	5.85
		Attitude	4.53, 0.52	4.69, 0.60	3.4
3	Online in COVID-19 (2021)	Cognition	4.0, 0.53	4.25, 0.50	6.25
		Skills	4.50, 0.53	4.50, 0.58	0
		Attitude	4.13, 0.64	4.75, 0.50	15.15

may be attributed to discussions being conducted both in smaller groups and collectively, and an additional supervised group activity, in the face-to-face mode. The time sequence of tasks and activities as shown in Table 1 for the second workshop, i.e. 'Face-to-face in COVID-19 with SOPs' also implies that the element of reflection at individual and collective level by participants may have resulted in increased achievement and transformation in both cognition and skills as desired in the learning outcomes. This observation is similar to findings previously reported about importance of reflection for learning and problem solving in game-based learning environments, and the need for designing reflection prompts based on learning goals to guide instructional decision making in a classroom to support reflection, learning, and performance (Cloude et al. 2021).

Furthermore, it may be inferred from these results that the interactions amongst participants and facilitators through designed interventions created a community of inquiry in which collective meaning was constructed in terms of the learning outcomes. A similar perspective of looking into the learning in classrooms, schools, and training sessions having to be in the service of the learning that happens in the world, is communities of practice. Wenger-Trayner (2015) have defined communities of practice as 'groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly'. Communities of inquiry and communities of practice seem to be overlapping perspectives, however, this work aiming to probe into how interactions within a group of learners result into transformation in individuals in terms of learning outcomes, treats the three designed interventions, viz. three one time workshops, as communities of inquiry and the question of emergence of a community of practice is beyond the scope of this paper.

It may be worthwhile to note here that these workshops only served as a demonstration of how a community of inquiry could be assembled to undertake necessary human discourse that may lead to transformation in the way individuals perceive, interpret reality, and construct knowledge. The feedback from participants of three different workshops, as an example of human discourse in a community of inquiry, showed increase in cognition (6-30%), skills (0-20%), and attitude (5-32%) transformation of learners through meaningful interactions with peers and facilitators in a designed environment. Therefore, the proposed conceptual framework to model growth and maturity through meaningful interactions as well as the control system to address gap in the degree of transformation occurring in learners in a community of inquiry may serve as basis for further studies and research on how to maximize the probability of learners to realize their potential in life.

Conclusions

This paper explores the complexity of education system in terms of how an individual may realize potential, aspirations and goals, and contribute positively in society. Education system is treated as a set of communities of inquiry, wherein, each community of inquiry is a group of individuals that strive to construct knowledge together. A conceptual framework is proposed to represent the realization of potential by an individual through structural tension based on human discourse in a community of inquiry. The proposed conceptual framework models growth and maturity in an individual, based on meaningful interactions leading to transactional correctness, in a community of inquiry, incorporating the concept of entropy in education system. The concept of entropy in education system, similar to social interactive entropy as presented by Vetromille-Castro (2013), needs further exploration.

A control system, is proposed to address gaps in degree of transformation occurring in learners in a community of inquiry. This control system (Fig. 3) and the conceptual framework of learning through human discourse in a community of inquiry (Fig. 2) together constitute our proposed model to represent transformation of individuals through meaningful interactions in a community of inquiry. The model proposed in this work is qualitative only and it may be worthwhile to investigate dynamic behaviour of various communities of inquiry within an education system changing with various interventions and contributing towards the overall purpose of the system.

In order to quantify the extent or degree of transformation in a learner through human discourse in a community of inquiry, it was hypothesized that learners will attain transformation within their cognition, skills and attitude, if they get to interact with peers and advanced learners in meaningful ways in designed environments. This may result in increased probability of realization of their potential in life. This hypothesis was tested through statistical analysis of feedback from workshops in three different modes, viz. face-to-face Pre-COVID-19, face-to-face in COVID-19 with SOPs, and online in COVID-19 demonstrating how a community of inquiry could be assembled to undertake necessary human discourse, as well as evaluate the efficacy of the concept of community of inquiry wherein transformation in learners cognition (6-30 %), skills (0-20 %), and attitude (5-32 %) occurred, as perceived by the workshop participants.

Author Contributions Supervision and Writing: [Muhammad Imran Ahmad]; Conceptualization and Writing – original draft preparation: [Irfan Ahmed Khan]; Methodology, Formal analysis and investigation: [Masuda Ahmad], Writing – review and editing: [Abbas Husain]; Writing – review and editing: [Rozinah Jamaludin].

Declarations

References

Adom D, Adu-Gyamfi S, Agyekum K, Ayarkwa J, Dwumah P, Abass K, Obeng-Denteh W (2016) Theoretical and conceptual framework: Mandatory ingredients of a quality research. J Educ Hum Dev 5(3):158–172

Ali AY (1977) An Interpretation of The Holy Qur-an. Sh. Muhammad Ashraf Publisher, Lahore

Ashby WR (1957) An Introduction to CYBERNETICS. Chapman & Hall Ltd, London

Bohm D (2004) *On Dialogue*. (L. Nichol, Ed.) (Classics). Routeledge, Milton Park

Bozkurt A, Jung I, Xiao J, Vladimirschi V, Schuwer R, Egorov G, Lambert S, Al-Freih M, Pete J, Olcott D, Rodes V, Aranciaga I, Bali M, Alvarez A, Roberts J, Pazurek A, Raffaghelli J, Panagiotou N, Paskevicius M (2020) A global outlook to the interruption of education due to COVID-19 pandemic: Navigating in a time of uncertainty and crisis. Asian J Dist Educ 15(1):1–126

Cloude EB, Carpenter D, Dever DA, Azevedo R, Lester J (2021) Game-based learning analytics for supporting adolescents' reflection. J Learn Anal 8(2):51–72

Cohen L, Manion L, Morrison K (2007) Research methods in education. Routledge, Milton Park

Dewey J (1923) Democracy and education: an introduction to the philosophy of education. Macmillan, New York

Dewey J (1933) How we think: A restatement of the relation of reflective thinking to the educative process. Houghton Mifflin Company, Boston

Durlauf SN (1998) What should policymakers know about economic complexity? Washington Quarterly 21(1):157–165

Guevara P, Posch A (2015) Dynamic complexity, entropy, and coordination in educational systems: a simulation of strategic and exogenous interventions. Syst Pract Action Res 28:179–196. https://doi.org/10.1007/s11213-014-9327-y

Holmberg B (2005) The evolution, principles and practices of distance education. BIS-Verlag Carl von Ossietzky Universitat

Kearney M, Schuck S, Burden K, Aubusson P (2012) Viewing mobile learning from a pedagogical perspective. Res Learn Technol 20(1):14406

Kennedy NS, Kennedy D (2010) Between chaos and entropy: community of inquiry from a systems perspective. Complicity 7(2):1–15

Kilis S, Yildirim Z (2018) Investigation of community of inquiry framework in regard to Self-regulation, metacognition and motivation. Comput Educ 126:53–64

Lipman M (1991) Thinking in Education. Cambridge University Press, BIS-Verlag Carl von Ossietzky Universitat

Lipman M (2003) Thinking in Education, 2nd edn. Cambridge University Press, Cambridge

Lipman M, Sharp A, Oscanyan F (1980) Philosophy in the Classroom, 2nd edn. Temple University Press, Philadelphia

Mason M (2008) Complexity theory and the philosophy of education. Educ Philos Theory 40(1):4–18

Mella P (2006) Systems Thinking, vol 3. https://doi.org/10.1007/978-88-470-2510-3

Mohapatra S, Mohanty S (2017) Assessing the overall value of an online writing community. Educ Inf Technol 22:985–1003

Mohapatra S, Mohanty R (2018) Making online courses free for everyone – an empirical study to determine feasibility. Int J Bus Innov Res 15(4):403–430

Montessori M (1936) The secret of childhood. Orient Longmans, Hyderabad

Penrose R (2010) CYCLES OF TIME An extraordinary new view of the universe. The Bodley Head, London

Schuitema E (2014) Intent: exploring the core of human being, 2nd edn. Na'Layn Publications, Karachi

Senge PM (1990) The Fifth Descipline The art and practice of the learning organization. Currency Doubleday, New York City

Senge P, Cambron-McCabe N, Lucas T, Smith B, Dutton J, Kleiner A (2012) Schools that learn: a fifth discipline fieldbook for educators, parents, and everyone who cares about education. Crown Business, New York

Sharp A (1992) "What is a community of inquiry? In: Oxman W, Michelli N, Coia L (eds) Critical thinking and learning. Montclair State University, Montclair, pp 295–312

Seitamaa-Hakkarainen P, Viilo M, Hakkarainen K (2010) Learning by collaborative design: Technology-enhanced knowledge practices. Int J Technol Des Educ 20(2):109–136

Slavin R (2012) Educational psychology: Theory and practice, 10th edn. Pearson, London

Splitter LJ, Sharp AM (1995) Teaching for better thinking: the classroom community of inquiry. Australian Council for Educational Research, Melbourne

Vetromille-Castro R (2013) Social interactive entropy and interaction in the language teacher education classroom. RBLA, Belo Horizonte 13(2):625–641

Wenger-Trayner E, Wenger-Trayner B (2015) Communities of practice: A brief introduction. www.wenger-trayner.com. Accessed 18 May 2021

Wiener N (1989) The human use of human beings cybernetics and society. Free Association Books, London

Wilson AG (1970) The use of the concept of entropy in system modeling. Oper Res Q 21(2):247–265

Yates A, Starkey L, Egerton B, Flueggen F (2020) High school students' experience of online learning during Covid-19: the influence of technology and pedagogy. Technol Pedagog Educ. https://doi.org/10.1080/1475939X.2020.1854337