Gordon Pask's Conversation Theory and Interaction of Actors Theory: Research to Practice

Enacting Cybernetics

RESEARCH

CYBERNETICS SOCIETY

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ABSTRACT

This three-part paper presents Gordon Pask's conversation theory (CT) and interaction of actors theory (IA) and outlines ways to apply these cybernetic approaches to designing technologies and scenarios for both formal and informal learning. The first part of the paper covers concepts central to CT and IA, explaining the relationship between conceptual and mechanical operators, and machines mediating informal and formal learning. The second part of the paper applies visual representations of CT and IA to understanding the use of Pask's course assembly systems (CASE and THOUGHTSTICKER), created between the late 1960s and the 1980s, and the ThoughtShuffler search interface, created in the 2010s. The third part proposes two pathways for design based on CT and IA: firstly, the potential for designers and observers to reformulate the qualities of tools and learning scenarios to augment human thinking and collective action; and secondly, the possibility to create tools with malleable interfaces that allow users to become intermediaries rather than consumers of knowledge.

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The technologies used to navigate everyday life are evolving in open-ended ways, creating hopes and concerns for social realit(ies). Today's digital tools allow humans to change their actions and thinking, in turn producing a machine response (e.g., a search engine accumulates digital histories to fine-tune results to correlate with past searches, and, in turn, changes user perspectives gleaned from viewing presented sources) (Glassman et al., 2023). In this equation, the human part of the interaction must exercise greater agency to navigate information in ways that overcome the biases that may be inherent to algorithms (Glassman, 2016). Without agency, wicked problems (or issues that are hard to tame, requiring constant influence or change initiation) such as misinformation become a reality in a digitized world (Barzilai & Chinn, 2020). To combat the possible dangers with the widespread creation and dissemination of information in a digitized society, designing digital tools iteratively to meet the needs of users is a necessity for designers. Another pathway, one that can be exercised by psychologists and educators, is using tools to create scenarios to equip users to exercise critical thinking in navigating online realities (e.g., project based social media activities on the Reddit platform; Evans et al., 2023). All in all, tools and educational scenarios must be designed to tap into the emergent experiences of users as they adapt to their environments rather than to use previously existing data to fine-tune output and guide users towards biased information. A systems approach to decode the variables that guide human-computer interaction can employ well-defined analytic distinctions. These distinctions may better help designers, educators and psychologists adopt a unified theoretical language to understand how to create technology-mediated scenarios that serve the widest range of human needs in real-time.

Cybernetics is a transdiscipline that investigates how to construct complex systems (brains, organisms, societies and machines) and measure how they adapt to emergent changes in the environment. Derived from the Greek *kybernetes,* referring to the act of steering, the term "cybernetics" was coined by mathematician Norbert Wiener (1948/1961, p.12) in 1947. Wiener simulated adaptation through a feedback loop in anti-aircraft fire devices during World War II to shoot enemy airplanes. Cybernetics initially focused on creating machines to simulate the nervous system, as a detached observer/researcher (Tilak et al., 2022). Researchers could implicitly change the parameters within which machines functioned but recorded these as objective changes made to the system by virtue of its functions and features. An example to illustrate detached observation would be Ross Ashby's (1952/2016) homeostat. The device was constructed from military surplus parts and comprised four electromagnets with vanes, dipped in water troughs, and connected by a circuit. The researcher could displace any of the vanes, leading them all to move until each of them reached a stable position. The homeostat was a metaphor for an organism interacting with its environment (Tilak et al., 2022). The observer gauges the properties of the system as an external, objective agent. While such research can be effective in studying artificial systems; understanding the uses of these tools in highly distributed social systems sometimes requires observers to act from within the system and explore the needs of users as interactions unfold.

The humanistic shift in cybernetics was fueled by a critique of detached, external observation in social systems (Pias, 2016). This participatory turn involved following thinking/behavior iteratively as an active observer and becoming part of the system to alter it (Pask, 1961). The movement inspired the creation of several technologies finding real utility in daily lives, like the Internet, and decision-making software for industrial processes (Pickering, 2010).

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Educational psychologist and engineer Gordon Pask (1976) created technologies that could act as surrogate participants in conversations (see Pickering, 2010; Wilson & Scott, 2017), and fine-tune human thought and action on the fly. Pask entered the field of cybernetics in 1958 at the *Mechanization of Thought Processes* conference at London's National Physics Laboratory (Pask, 1959). Pask's paper, "Physical Analogues to the Growth of a Concept" explained how learning and concept development were dynamic processes (Scott, 2007) using the metaphor of a plexus or network of electrodes in solution with thermally sensitive resistance. Per Pask's (1959) demonstration, concept development spurring changes in mental models occurred in a networked fashion. Changes in one part of an assemblage or system create ripples, producing a change in other parts (of neurons/individuals). Supplying the electrolytic assemblage with varying currents produced changes distributed across the assemblage (Figure 1).

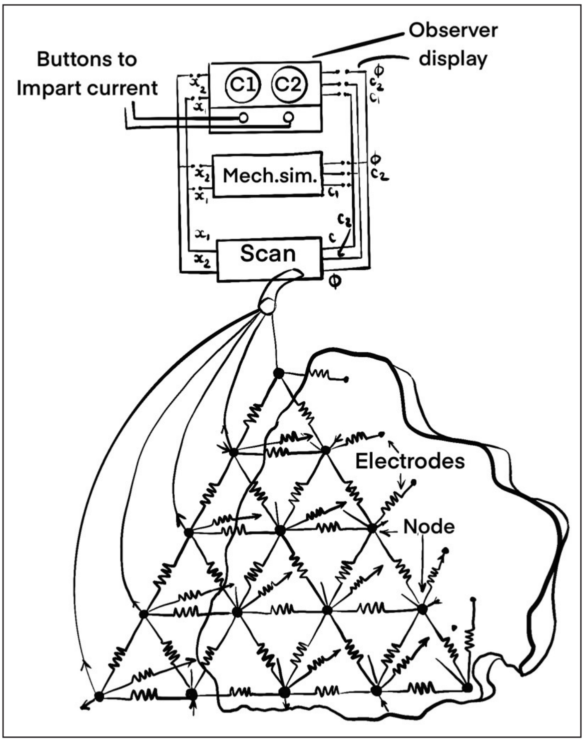

Figure 1 Pask's demonstration of distributed change. Figure created by Shantanu Tilak.

Pask began to apply the metaphor illustrated by his demonstration to design tools and scenarios for distributed human-computer interaction. Having staged musical comedies as part of the Sirendelle initiative he set up with Robin McKinnon Wood (a colleague from the University of Cambridge), Pask began to create devices like Musicolour (Pickering, 2010, p. 314), which used color wheels to produce a light show of varying intensity in response to a performer's input, whether piano or another instrument. The interaction between the performer and device acted as a conversation manifesting as an engaging and improvised performance. The system would signal "boredom" by reducing output intensity when the performer's input became repetitive, prompting them to vary their instrumental/voice (Pickering, 2010, pp. 316–17).

Never wedded to a particular technology, Pask worked with Stafford Beer in the 1950s to take forward Ashby's endeavors to develop a machine prototype of the brain (Pickering, 2009). They realized the human nervous systems could be replicated in machines to resemble Ashby's homeostat. The two worked together in Britain, developing fungoid whisker systems (copper wires in ferrous sulphate solution) that discerned frequencies on a sound spectrum upon being reinforced with current, evolving an "ear" (Cariani, 1993). They concluded machines that could be reinforced to perform basic functions represented a precognitive mind with finite output. This discovery led them to apply cybernetics to create complex sociotechnical systems applied to educational and industrial settings (Tilak et al., 2022). In sociotechnical systems, humans and technology engage in symbiotic goal-directed collaboration (Behymer & Flach, 2016), within a certain problem domain (to solve issues emerging in the environment) (Figure 2).

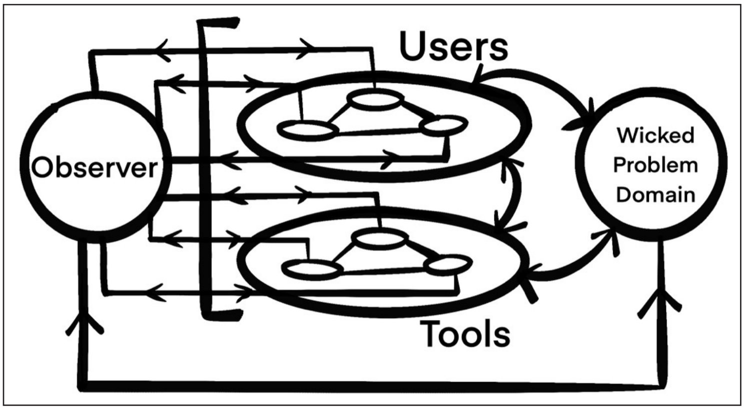

Figure 2 Sociotechnical system. Figure adapted by Shantanu Tilak from Behymer & Flach (2016).

As an avenue to understand how to design conversations in social systems, Pask investigated the use of responsive mediating technologies in learning environments (Pickering, 2010). During the later part of his career, Pask worked at the University of Amsterdam to study processes of collective action. Rather than focusing solely on problem-solving, Pask developed two cybernetic approaches—conversation theory, or CT, and interaction of actors theory, or IA. These two approaches could be applied to design human-to-human, human-to-machine, and machine-to-machine conversations (both well-governed problem-solving and unstructured collaboration) by treating users and tools (Pask, 1975) as a homeostatic whole (Beer, 2001).

In this three-part paper, we provide overviews of conversation theory (CT) and interaction of actors theory (IA) that can be applied by educational psychologists, designers, and programmers. The first part of this paper briefly outlines Pask's two approaches (Pask & De Zeeuw, 1992; De Zeeuw, 2001). The second part highlights how technologies designed using Paskian cybernetics treat users as co-designers. We use the example of Pask's course assembly systems (Pask, 1975) and the more recent ThoughtShuffler (Tilak et al., 2023) search interface, which builds on Pask's nascent technologies, in order to apply Pask's cybernetic principles to Internet contexts. The third part outlines two practical pathways to apply Paskian cybernetics to design learning technologies and informal Internet tools.

PART I: CONVERSATION THEORY AND INTERACTION OF ACTORS THEORY

Pask's conversation theory and interaction of actors theory provide a domain-general analytic distinction to understand how to design technologies to augment human thinking and action, and apply technologies to create learning scenarios. Pask developed the basic theorem that would later inform CT and IA while collaborating with Heinz von Foerster at the University of Illinois, Urbana, as a visiting scholar at the Biological Computer Laboratory (BCL). Ideas similar to Pask's about learning and technology, later discussed at the Center for Intercultural Documentation conference in 1971, were applied by von Foerster to designing cross-disciplinary project-based courses offered to undergraduates in the electrical engineering and English literature departments. These classes culminated in the publication of four texts co-authored by von Foerster and BCL students: the *Whole University Catalogue*, *Metagames*, *Ecological Sourcebook*, and *Cybernetics of Cybernetics* (Dubberly & Pangaro, 2015). In speaking of collaborative educational scenarios, Pask states:

> If a system is legitimately said to *teach*, then it must be able to *learn from its student* who may reverse the roles to play at *teacher*, I submit it is what *teaching* (in contrast to indoctrination, instruction, or ill-disciplined cavorting with knowledge) really means. (Pask, 1972, p. 243)

This theorem describes a user-centered social context like a classroom, where moments of excellence emerge through iteratively evolving feedback loops that lead to the creation of varied project-based artifacts. The theorem suggests that to fully replicate the richness of values, metaphors and emotions in language, a machine must communicate in similar metaphors with the specific user in accordance with current and potential cultural experiences, like Musicolour did in interaction with performers (Pickering, 2010). The idea of a machine being able to engage in interpersonal perception and attune itself to emergent needs/experiences of users, and the fact that such a machine can be designed and (re)designed by an observer and/or user to change how it is built to match the needs of the widest variety of humans are central to both CT and IA. This ethos opposes the current dominant paradigm of reverse engineering human preferences based on past digital history; as well as re-engineering learning environments based on past insights, rather than understanding the emergent needs of learners. In the next sections, we describe these approaches, and set the stage to apply them to study informal and formal technology-mediated learning.

CONVERSATION THEORY AND INTERACTION OF ACTORS THEORY: TWO SIDES OF THE SAME COIN

CT extends Pask's (1972) first theorem and provides a framework to simplify understandings of psychological mechanisms of human-machine, human-human, and machine-machine conversations in specific goal-oriented settings guided by a set of concepts (e.g., a classroom focusing on concepts of probability). Pask later expanded CT, developing IA to account for spontaneous conversations not necessarily governed by structured ideas (e.g., conversation between two members of an online gaming community leading them to discover new interests) (De Zeeuw, 2001). Regarding the relationship between the two theories, De Zeeuw (2001, note 2) quotes a letter from Pask, who says:

> It is quite true that I.A. is an extension of C.T. and Lp [protologic], but it is a very considerable one. The extensions accomplished are, however, of a major kind and lay emphasis upon the importance (which you [De Zeeuw] have always placed) upon interaction, the matters of self and other reference, the imaging of selves, be they societal, personal or organizational.

The main difference between these approaches is that CT requires an exemplary set of strict rules or learning contracts for the nature of conversations to be iteratively gauged. IA grants priority to the conceptual repertoires possessed by the material agents participating in face-to-face or digital conversations, suggesting that these concepts and ideas interact to produce new conceptual operators (Pask & De Zeeuw, 1992). Both approaches can be applied to designing technologies and learning scenarios, since proposed constructions and design prototypes are negotiated by conversing with users, understanding preferences, and changing interface design (Pangaro, 2008). The cross-disciplinary application of CT and IA position them at the boundaries of design, computing, education, and psychology, showing capacity to map cognitive transitions at the core of using computers or any tool. Both approaches were meant to redesign scientific practice in the social sciences to listen to the voice of the user without sacrificing a structured theoretical framework (De Zeeuw, 2001). The specific application of CT is to understand how shared agreement is produced between agents connected by technologies in specific settings guided by a constrained set of concepts (e.g., classrooms). While CT proposes ways to create cogent shared languages and critical thinking in a structured rule-based environment, IA generalizes this purpose to investigating collective action at large, including understanding larger problems like pollution and global warming, that may arise even from spontaneous everyday conversations (today, these occur both online and in person). While these differences do exist, the same vocabulary of terms guides both approaches.

M- AND P-INDIVIDUALS

While working with von Foerster at the BCL, biologist Humberto Maturana studied the process of brain-body systems being coupled with their environment, which Maturana and collaborators Francisco Varela and Ricardo Uribe called autopoiesis (Maturana et al., 1974). Autopoiesis suggests that living agents are composed of self-creating circular organizations that can act to reproduce themselves down to the cellular level, leading to iterative evolution of organisms in their environment. Pask, acquainted with Maturana, built on these ideas, suggesting that while brain-body systems reacted to their environment to regulate internal states, psychosocial systems could learn from others and evolve iteratively, or preserve standpoints/traits despite influence (Scott, 2004). The consideration of shared psychosocial processes was intended to facilitate cybernetic inquiry into learning, education, complex decision-making, design, and human creativity (De Zeeuw, 2001). Pask's and Maturana's approaches differ slightly, with operators leading to reproduction in Pask's approach being conceptual. Maturana focuses on the circularity in biological processes.

Perceptions, language, and culture are emergent products of networked interactions, produced as organisms (systems of cells) interact with other organisms and their environments. Living and social systems are organizationally closed but informationally open. For example, in a classroom, each peer and instructor can be connected by engaging in group discussion (organizationally closed) in a closed community, but individuals may bring information into the classroom even from the Internet (informationally open) (Tilak, 2023). Informational openness spurs language and meaning-making within a social system, making observership different for each agent. Each conversant responds to incoming stimuli with cognitive and motor cues in an emergent fashion to execute psychosocial processes (Scott, 2021). Humans do not merely store information in their minds like hard drives; it becomes a tool in generating awareness about one's own ideas and those of others.

Pask used the terms M-individual (mechanical individual) and P-individual (psychological individual) to create an analytic distinction between material and conceptual operators in collective human to human, human to machine, or machine to machine activity. An M-individual is any system with material presence (i.e., flesh, hunk of metal, hardware). A P-individual is a conceptual operator (analogous to software) that can be embodied by an M-individual. Such a P-individual can comprise concepts, topics, or rule systems (e.g., the logic used to redistribute goods in Egypt after a flood, the principles of Euclidean geometry; De Zeeuw, 2001). Several M-individuals (machines, humans) can engage in joint psychosocial activity, and one M-individual can engage in several concurrent psychosocial processes (Scott, 2021; Figure 3). This means conceptual operators are always processed by one or more mechanical bodies (machine or human), showing that cognition is unbounded (Pask, 1975). P-individuals can change or preserve themselves depending on the nature of context specific interactions.

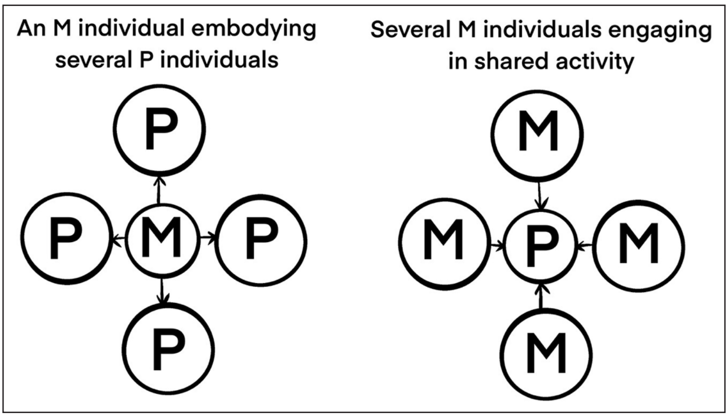

Figure 3 M- and P-individuals. Figure by Shantanu Tilak, reproduced from Tilak & Glassman (2022).

Living systems, through the P-individuals they embody, can create emergent shared languages (Pask, 1961; Scott, 2021). For example, in a classroom, a conversation between teacher and student may involve the student repeatedly presenting counterarguments leading to constant dynamic change in the P-individual embodied by the participants. When saturation is reached, a stable P-individual is maintained (De Zeeuw, 2001).

To engage in shared understanding, a conversant can make a deduction about what another thinks (e.g. an argument about probability theory), and this is placed against what the other thinks in practice; knowing the nature of the conceptual repertoire possessed by a conversational partner can enable governing the conversation to reach coherent conclusions.

This interpersonal perception was later termed as metacognition by John Flavell (1976). Individuals can even conceptualize thoughts about a conversation they have (Figure 4), or a P-individual representing the conversation, and take them to other social situations where they can be expanded upon.

Pask applied the nomenclature of the M- and P-individual within a CT framework to design learning technologies that responded iteratively to the needs of students and helped them master specific concepts. Pask (1987) also contributed to research at the University of Amsterdam on social support systems while developing IA. In the next sections, we showcase how technologies (broadly, what Pask called epistemological laboratories; Pask & Kopstein, 1977) and scenarios for their use in formal learning and informal settings can be designed using both CT and IA. Following such a process can afford the productive construction of conceptual operators (either based on a given ruleset, or from spontaneous interactions) in formal and informal conversational contexts mediated by technology.

Figure 4 Adaptation of an illustration by Pask that depicts conceptualizing the self/others, created by Shantanu Tilak.

APPLYING CONVERSATION THEORY AND INTERACTION OF ACTORS THEORY

Both CT and IA employ a goal-directed object language L used to analyze collaboration and conversations between human and/or machine entities. L can be accompanied by a protologic (L_p) that can be applied to group knowable topics and understand the strategies that can be learnt using a machine or in collaboration with a human conversational partner (Pask, 1979). The representation of topics arising from the emergent activity of each learner/user in interaction with a learning technology was termed by Pask as an entailment mesh (EM). These EM comprise relationships between terms belonging to L, and thus can be legitimately represented in terms of these coherences. The unique characteristic of L_p is that it can allow the user to become an intermediary that can edit the interface, rather than just a consumer. When L is constrained, the user can operate upon the entailment structure (ES) of the machine (all possible concepts to be explored) and abstract their own interpretations of the L agreements or EM they end up exploring during their learning journey. While an EM represents a subset of hierarchies and relationships between terms, the ES represents all possible topics that can be explored. When L is unstratified or not decided beforehand, EM are constructed iteratively as the conversation progresses. The entire dynamic process turns the technology-assisted conversation into a participatory environment for interacting human users and designers.

Both conversation theory (CT) and interaction of actors theory (IA) become a vehicle allowing the concrete operationalization of L_p to create a collaborative learning environment mediated by a digital interface. Pask called this interface an epistemological laboratory (EL), since it could allow users/learners to navigate concepts relevant to them, and designers to optimize the features of the machine to facilitate learning. In this section, we explain how human agents, the EL, and EM can be conceptualized as parts of a homeostatic whole (Beer, 2001) in a technology-assisted conversation using the principles of both conversation theory and interaction of actors theory.

In both cases, the human agents interact with the machine (a surrogate conversant). M-individuals embody P-individuals, and these P-individuals interact, creating new P-individuals that are representations of what agents have learnt from using the tool, and conversing with other users. However, as we have outlined earlier, the conceptual repertoire or entailment structure to be explored in a technology-mediated environment is constrained to specific topics when CT is applied to a formal learning setting. These entailments are constructed by participant conversants iteratively when technology-mediated activity is looked at through an IA lens. The scenarios we present in the following sections highlight the differences inherent to the application of CT and IA.

CONVERSATION THEORY: ENTAILMENT STRUCTURES AND FORMAL LEARNING

In the case of CT, the representations embodied by learners/users as P-individuals arise in interaction with a prescribed ES (another P-individual) (De Zeeuw, 2001). The ES provides a sequence of the totality of topics that students can explore in a formal learning environment and thus defines the object language L. This ES represents an expert's knowledge specific to a course or topic (Tilak & Glassman, 2022). L is thus curated by the instructor or course designer to stratify learning and allow a sequential exploration of ideas, gradually amplifying successful attempts.

An example would be concepts in probability theory that students can gradually master in a sequence of their preference to become more proficient on the topic (Pask, 1975), being asked to answer questions and provide demonstrations until deeper understanding is achieved. The student would explore the topics in a sequence that matches the conceptual knowledge they need to accrue to master the course. However the P-individuals they embody would arise only in interaction with the ES representing the totality of knowledge in the course (see Figure 5, which depicts cyclical interaction between the individual M and machine EL; the interaction is constrained by limiting inputs and outputs to fit within the ES), assuming no other learning has occurred outside that setting for that concept or topic.

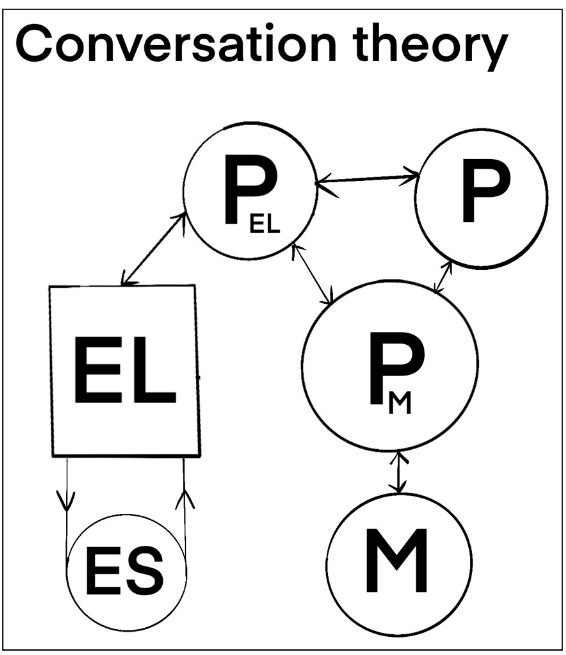

Figure 5 Human computer interaction from a conversation theory lens. Figure by Shantanu Tilak.

The P-individuals embodied by the student and machine interact, becoming abstracted by the learner at a degree of separation from the ES. The quality of the output (written, or other) can be analyzed to reveal the nature of P-individuation. While CT can be applied to formal learning settings guided by a constrained set of ideas and forms of thinking, everyday conversations are more spontaneous. Pask developed interaction of actors theory (IA) to account for this emergent quality of informal collective action (broadly) in everyday lives.

INTERACTION OF ACTORS THEORY: EMERGENT SHARED LANGUAGES

The potential for conversation theory to be employed within a participatory framework to provide live assistance to learners using responsive learning technologies shows how Gordon Pask was a forward thinker who wanted not only to understand phenomena guiding learning but also to use these understandings in the given moment to augment this process for the learner. Taking this participatory framework a step further, Pask generalized CT, formulating interaction of actors theory (IA) to listen to the voice of the user in spontaneous everyday conversations that may not be guided by an expert-driven object language and prescribed entailment structure. Much of this work was done at the University of Amsterdam, while Pask served as a professor there (De Zeeuw, 2001).

Since informal, everyday conversations and collective actions at large do not have a prescribed end and can move in tangential directions, IA theory suggests that the EM is constructed bottom-up. M-individuals (the machine and/or humans) interface through the P-individuals they embody, constantly creating new knowledge that may or may not be conventionally "linguistic". A disengaged P-individual (that is not embodied by any M-individual) representing an ES does not provide a basic blueprint to govern collective action in informal, everyday human-computer interactions on platforms like social media, that may support online communities with rule systems exercising varied levels of control on user activity. The P-individuals possessed by the machine arise from human input, and those within the human agent's mind interact, creating a new P-individual without relying on a constrained ES.

M-individuals realize collective action by embodying P-individuals. These M-individuated P-individuals, or P-individuals embodied by M-individuals (Pask & De Zeeuw,1992), interact, producing a new P-individual that can preserve its structure when collective values are strengthened in cohesive groups that iteratively come to a shared understanding of how to navigate their social world. These processes can be made observable to social scientists (e.g., for educational psychologists observing classrooms) through an iterative analysis of open-ended human-human in-person activity, and computer mediated communication. De Zeeuw (2001) provides a more general example of the traffic jam to showcase how collective action need not be purely "linguistic" in the classical sense and outlines three types of such actions that emerge in this context.

In a traffic jam, people in their cars become M-individuals, who each embody a P-individual that may contain ideas about navigating the clogged road. Together, these P-individuals interface as traffic moves, creating a P-individual for the entire system. The first type of action that emerges between interfacing M-individuated P-individuals is one that may be used to fulfil actions and roles that may not be necessarily part of the system; delivering food and groceries to customers in nearby neighborhoods after navigating the traffic jam is an example of such actions. The second type of action

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is that of the participants in the collective to improve the system; maintaining lane discipline (not a prescribed rule, but favorable) would be an example of such an action. The third type of action requires that participants not defer from the prescribed rules guiding collective action; adhering to the speed limits and driving in the correct direction would be examples of adherence to this type of action. The fourth type requires that participants act in either predictable or unpredictable ways in interaction with others but maintain the integrity of the system. Exhibiting road-rage would be an example of a spontaneous action that could disrupt the system. This example illustrates that these types of collective actions do not involve clear, demarcated processes. They involve systems-level phenomena, which, when directed towards maintaining the stability of the collective, allow faster navigation of the traffic jam. Participants must process their surroundings, the actions of others, and use this understanding in real-time. A traffic controller can act as an observer who can govern the interactions of the collective, embodying a P-individual that relates to governing the flow of automobiles. Similar collective action can be exhibited in online communities, and in tasks involving single humans in computer-mediated activity, such as information search; with designers of technologies acting akin to traffic control personnel.

Here, we provide two examples of Internet activity of the individual and collective variety through an IA lens. The first is an individual (M) interacting with a search interface (EL). The EM of search terms and keywords on which results are based is constructed through the interaction between the M-individuated P-individuals embodied by the EL and the human agent. Rather than prescribing the keywords and the set of results to be relied on beforehand, these become a product of user activity; produced from an initiation of user search queries (Figure 6, Panel 1). Also in Figure 6, in Panel 2, is a process diagram depicting collective action between two individuals (M1, M2) in a Reddit community (EL) that already houses a P-individual

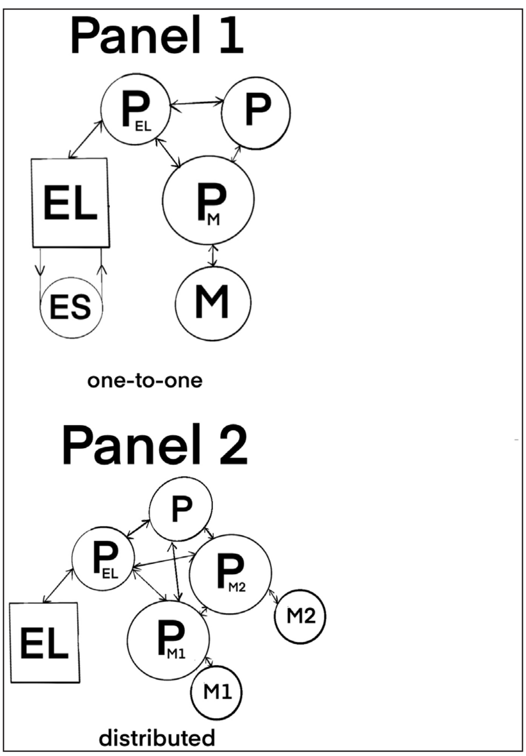

Figure 6 Human computer interaction from an interaction of actors theory lens. Figure by Shantanu Tilak.

comprising pre-existing user posts and contributions. The entailment mesh produced by the interaction occurs by posting and reading the posts of others (depicted using two-way arrows between the P-individuals). The products of these interactions may be analyzed to reveal insights about this entailment mesh.

Through our explanation of the relationships between ES and EM, human agents (M), machines (epistemological laboratories or EL), and conceptual operators they embody (P), we have showcased how both CT and IA can be operationalized to design computer-mediated individual and collaborative activity in formal and informal settings. In the next sections, we provide specific examples of the embodiments of L_p, viewed through a CT and IA lens.

PART II: PASKIAN MACHINES AS EMBODIMENTS OF PROTOLOGIC

Pask and his students Bernard Scott, Paul Pangaro, and Dionysus Kallikourdis operationalized L_p through digital tools that could imitate conversations focusing on specific topics or conceptual domains within a CT framework, to spur formal learning and understanding in users. Pangaro (2008) further extended this line of work to create an information search tool called ThoughtShuffler, to generalize Pask's earlier technological interface designs to facilitate information search on the Internet. In this section, we describe how Pask's nascent learning technologies (CASTE and THOUGHTSTICKER) and the more recent ThoughtShuffler can be interpreted using a CT and IA framework, respectively.

CASTE AND THOUGHTSTICKER: INTELLIGENT TEACHING SOFTWARE FOR FORMAL LEARNING

One of the first technologies that Pask created with Bernard Scott and Dionysus Kallikourdis was the Course Assembly System and Tutorial Environment (CASTE) (Figure 7). The device consisted of three panels. The first was a communication console to help the student indicate what topics they wanted to explore. The second panel was a modelling facility to elicit demonstrations and explanations. The third panel was a Belief and Opinion Sampling System (BOSS) to record students' level of uncertainty about a topic based on their demonstrations and problem-solving skills.

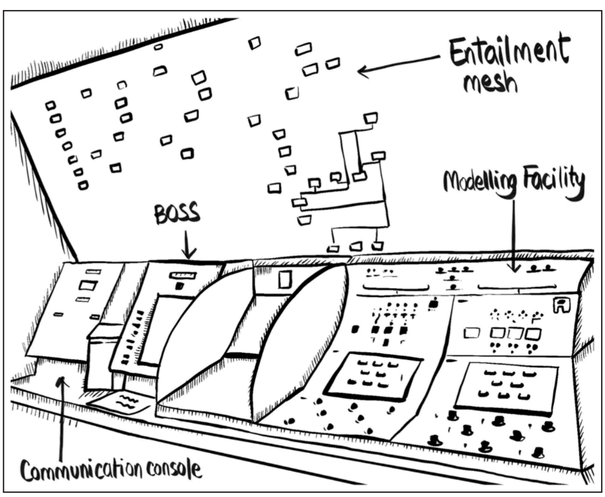

Figure 7 CASTE. Figure by Shantanu Tilak, reproduced from (Tilak & Glassman, 2022).

A digital display above the three panels contained all possible concepts that could be learnt within a domain of nodes linked together in an entailment structure (Wilson & Scott, 2017). Pask and colleagues tested the use of the device with students from art and technical colleges (Pask et al., 1973) to teach probability theory.

Students pick out a part of the entailment structure to learn about in an open-ended manner, and the machine, monitored by an observer, would ask for demonstrations and explanations until a satisfactory understanding was achieved, indicated by green light on the topic node on the display. The learner would navigate the ES, in a sequence most aligned with their previous knowledge. The observer could record best use cases using BOSS (Wilson & Scott, 2017). Pask and colleagues' studies show that matching students to preferred strategies to process information (serialist, holist, or versatile; which focus on relationships between concepts, and differ from contemporary conceptions of learning styles based on perception and processing; Pashler et al., 2008) by using CASTE produced successful outcomes and that teachback of ideas produced more effective learning than tests (Pask et al., 1973). The learners using CASTE are informationally open to corrections, feedback and new topics. CASTE is informationally open to nuances of conceptual and demonstrative cues provided by students; providing feedback based on certainty and correctness measures that the observer can use to fine-tune the interface.

CASTE was followed by the development of THOUGHTSTICKER. Groups could use it (one student by one) to tag agreements and disagreements about concepts. Students could construct their own entailment meshes, making the course assembly function offered by CASTE specialized to each user (Pangaro, 2001). Students could then work with the course designer to better optimize the entire entailment structure by looking back and reflecting on their learning journeys. The tutorial messages in THOUGHTSTICKER contained links to concepts in a class's entailment structure (for example, clicking on biology could reveal topics about cells, or evolution).

Hovering over terms in the entailment structure would indicate the meshes and concept navigation journeys that could emerge from that topic (or the coherences between that topic and others in the structure; students could choose which mesh to explore, i.e., which learning path they prefer to take). The interface featured browser-like navigation with back and forward buttons to allow students to access previous and future topics in the sequence. The order of topics would be determined by the preferred learning strategy adopted by the student (serialist, holist, or versatile). One could also navigate to more distal topics using the jumping function offered by THOUGHTSTICKER.

In both CASTE and THOUGHTSTICKER, which act as epistemological laboratories in formal learning settings, the ES for the formal learning setting is constrained by the expert, with THOUGHTSTICKER offering a slightly higher degree of freedom to work on the entailment structure and explore student-specific entailment meshes. However, in contemporary informal internet environments, humans may interact with computer devices to engage in everyday tasks such as information search; the entailment meshes are built spontaneously through the interaction between the P-individuals embodied in the interacting M-individuals. The specialized recommendation systems offered by CASTE and THOUGHTSTICKER are, today, generalized on the Internet's varied commercial and social platforms (Tilak & Glassman, 2022). In the next section, we use the example of the Paskian search interface, ThoughtShuffler to showcase how such human-computer interaction can be viewed within an IA framework.

THOUGHTSHUFFLER: INFORMATION SEARCH AS AN INTERACTION OF ACTORS

Today's information search experiences are based on directing users towards targeted information to appease their needs through a page-ranking mechanism that uses around 200 other algorithmic signals (Tilak et al., 2023). This complex set of algorithms responds to user search queries in the moment, presenting the most cited/viewed sources, and those containing user keywords. As users engage in search, digital histories are accumulated, further fine-tuning the output of each search query. These results are not solely based on the pure conceptual relationships between inputted keywords, and thus, may not always be directly relevant to the user's needs in the moment.

While humans utilizing page-ranked search engines believe they attain greater confidence/certainty through hierarchically ordered results (Oulasvirta et al., 2009), there may be little capacity to use these interfaces to critically compare neighborhoods of concepts. Users often exhibit vertical scrolling behaviors and rely on the initially presented results in the list (Gwizka & Bilal, 2017).

Recent studies also show that those with critical thinking skills wanting to evaluate varied sources may be exposed to low quality information; while only those prepared to grapple with misinformation engage in effortful source comparison (Aslett et al., 2023). Designing a tool for reflection in search may bridge chasms in cognitively perceived and socially observed capacity adolescents and college students exhibit when it comes to critical Internet navigation (Lurie & Mustafaraj, 2018; Martzoukou et al., 2020).

Pangaro (2008) created an information search interface called ThoughtShuffler that purely relies on conceptual relationships directly relevant to the user in their search queries. The landing page for ThoughtShuffler is minimal and allows users to enter keywords that the tool parses (Figure 8). We input "cybernetics" as our first search keyword in the example we present.

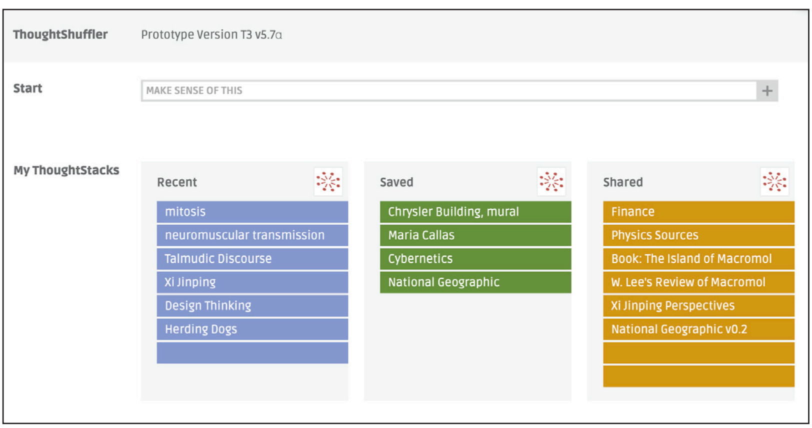

Figure 8 ThoughtShuffler's landing page.

Entering a keyword or search query opens up an interface where keywords are parsed from the query and can be manipulated on the left hand side. The tool analyzes sources presented by Google and also suggests related keywords from these results. We input the keywords "cybernetics", "Norbert Wiener", and "Gordon Pask" to initiate a richer search query.

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Information from each source containing co-occurring keywords inputted by the user, and suggested by the tool is parsed to enable brief reading (Figures 9 and 10) based on pure conceptual relationships rather than additional algorithmic signals. The co-occurrences providing the richest information and prompting users to explore more (i.e., those with the highest co-occurrences between keywords) are presented first in the array of results.

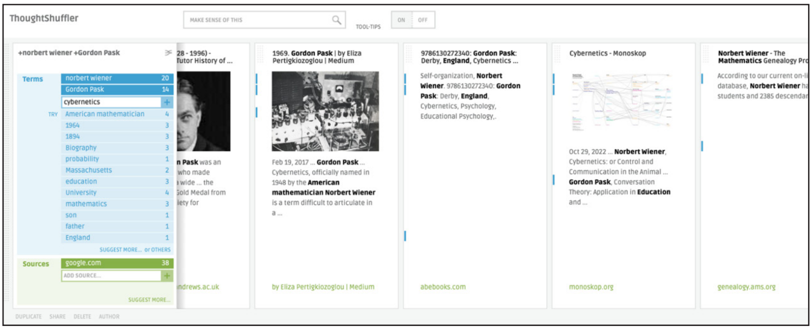

Figure 9 The search interface.

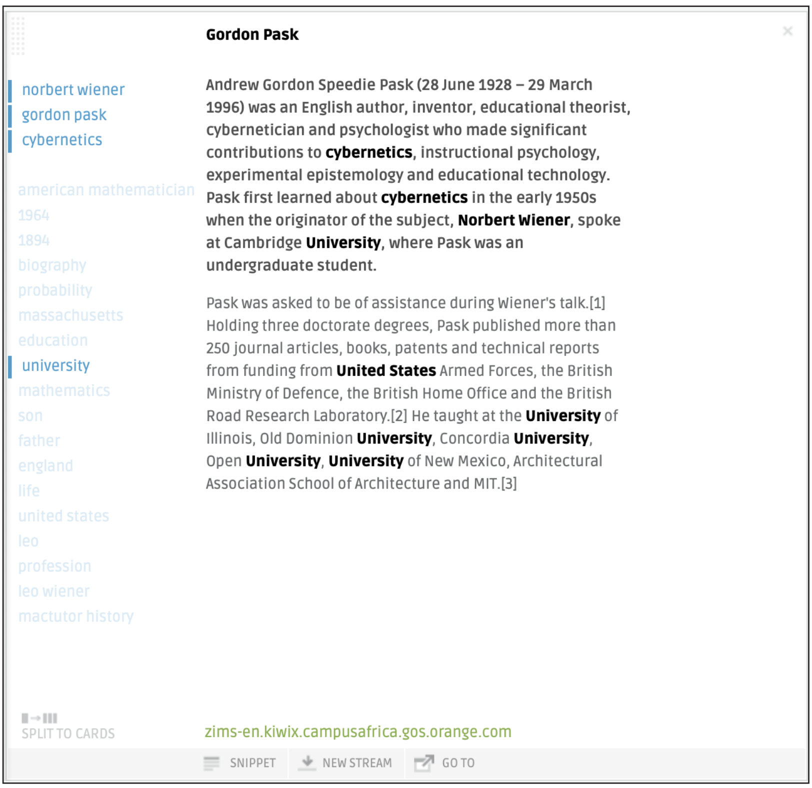

Figure 10 Parsed information.

Apart from suggesting new keywords, ThoughtShuffler also provides options to refresh and provide a completely new list of search terms. One can also create multiple collections of cards to compare. For example, to understand crosscurrents and differences between Wiener’s and Pask’s work, one may input “Gordon Pask”, “Norbert Wiener”, and “first-order cybernetics” into the first collection and replace the last term with “second-order cybernetics” in the second collection (see Figure 11).

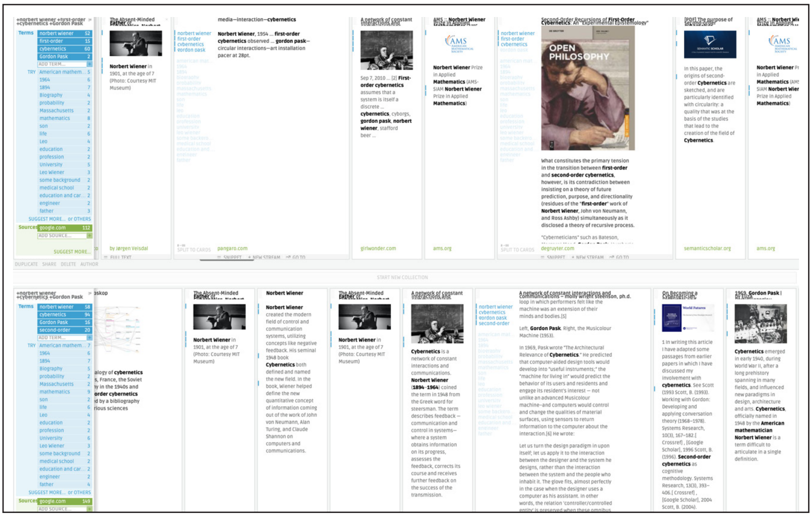

Figure 11 Parallel collections.

The use of ThoughtShuffler can be interpreted within an IA framework. The search interface relies on Google's Internet results rather than a disengaged P-individual represented by a fixed entailment structure; these results vary depending on the learner's keyword input; a repository of results is created when the P-individual embodied by the user interacts with the software. Each search query is processed by the EL (interface), and an entailment of co-occurrences between inputted and suggested keywords is constructed when the P-individual embodied by the user interacts with the tool. The system is informationally open to changes in the search query, and the initiation of several parallel collections of results that may change the thinking of the user. Artefacts such as written texts or recorded videos produced from information search when a user is prompted by an observer/designer become a proxy for the P-individuation process occurring as a result of the human-computer interaction. The designer can analyze the quality of this output to understand the P-individuation process. These insights can be used to create cogent prompts to spur productive search and also to redesign features of the tool to augment concept exploration.

Our research team conducted a four-month long experimental study funded by The Ohio State university to understand the potential of ThoughtShuffler to allow users to effectively explore and critique varied information sources. We recruited 39 adult individuals from the U.S., the United Arab Emirates, and the Caribbean using convenience sampling. Our study compared the level and quality of conceptual exploration spurred by argumentative writing tasks conducted using Google (the most commonly used search tool, with users initiating 40,000 queries per second around the world; Marr, 2018) and ThoughtShuffler as search interfaces. Data sources gathered from the experimental and control groups included essays written in interaction with the search interface (the prompt asked about universal and privatized healthcare), a recording of the search process, and interviews in which participants reflected upon the nature of their information search and writing task.

So far, we have analyzed the lexical structure of essay data produced in our experiment using the Linguistic Inquiry and Word Count software (LIWC), which understands percentage frequencies for varied types of words occurring in string data (Boyd et al., 2022) and lexical network analysis (which understands interrelationships between concepts in string data; Benoit et al., 2018). In our first study involving the LIWC analysis (Tilak et al., 2023), we wanted to understand whether balanced emotions and greater degrees of moral argumentation were exhibited in the ThoughtShuffler essays. Our results revealed lower incidence of anger related words and a higher number of morality related words in the ThoughtShuffler essays. Since critical thinking is often associated with moral pain (Paul & Elder, 2009) and balanced emotionality (Prinz, 2011), our results may suggest that conceptual exploration spurred by ThoughtShuffler owe to its capacity to allow users to compare sources taking up diverse perspectives by parsing results and affording multiple simultaneous queries. Our second study, which is currently under review, involved a lexical network analysis of the terms or words in each of the 39 essays (Tilak et al., 2024). We saw that there were greater transitive or three-way co-occurrences between terms to a greater degree in the ThoughtShuffler essays (with a 28% chance for such three-way interactions in the experimental essays, and an 18% chance exhibited in the control group essays). Our network diagrams acted as an abstract representation of the entailment mesh constructed through the information search activity. Topic models of the dominant themes that emerged in the experimental group essays expanded further upon the initial question ("Should universal healthcare be seriously considered in the U.S. as it has been in other countries or is it worthwhile to continue promoting private healthcare? Why?") than those in the control group, covering issues related to government, citizenship and economics.

Future steps for our work investigating the utility of ThoughtShuffler in spurring critical reflection in search involve analyzing interview and search log data. Further mixed methods research will help us understand whether users felt that features of the tool (e.g., multiple query generation, note taking, horizontal arrays, parsing) could be improved to allow for more efficient source comparison. Expanding our work along these lines may help us better understand the voice of the user in designing ThoughtShuffler, which already offers a high level of malleability in seeking and critiquing varied information sources that are conceptually relevant to user search queries.

PART III: SUGGESTIONS FOR DESIGNING FORMAL AND INFORMAL TECHNOLOGY-ASSISTED LEARNING

This article provides brief overviews of Pask's CT and IA. It also explains how formal learning technologies and informal Internet technologies operationalize these approaches in practice. The third goal of this paper is to help educational psychologists, teachers, programmers, and designers understand the value of a participatory scientific method to design tools and scenarios for technology-assisted communication (whether for formal learning or informal purposes). In this section, we outline two pathways for designing formal learning technologies and informal Internet technologies that may emerge from Pask's approaches.

Path I: One of the goals of Pask's approaches is to iteratively redesign technologies and learning scenarios based on live observations of user activity and inferences derived from them. This is the first design pathway (Path 1) that emerges as a suggestion for practice through the use of Paskian cybernetics. Pask desired an understanding of processes guiding learning and communication, but also wanted to use this understanding to augment the development of collective value systems between conversants/participants in real-time. This desire was embodied through the creation of tools such as CASTE and THOUGHTSTICKER that could be customized by observers/teachers in real-time such that the conceptual exploration journeys or "curriculum" that each learner navigated matched their skill-level (Tilak & Glassman,

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2022). These tools produced metrics that indicated the level of uncertainty students had with a topic that could be used by the course designer/engineer to improve the learning experience. Our proposed efforts to redesign ThoughtShuffler based on user feedback from our interview data and from analyzing search log videos are also a way to operationalize Path I.

Path II: The idea of a tool having interpersonal perception (Pask, 1972) is made possible when the user is put in the driving seat, navigating a very malleable interface; the tool should be able to learn from the user, and vice versa, in real time. The creation of such an interface is a way to operationalize Path II. When algorithms become less abstract to users, it may become possible for them to be intermediaries rather than consumers. ThoughtShuffler's parsing mechanism that relies purely on keyword co-occurrence (as opposed to 200+ algorithmic signals), lateral result arrangement, and multiple query generation capabilities all give the user greater impetus for deep conceptual exploration during information search; all while being sure of the algorithmic processes at play. The interface serves as a good example of one-to-one human-computer interaction that affords higher user agency and transparency with algorithms. Many-to-many communications may be harder to design in such a way, but platforms embodying this possibility do exist. Mastodon allows users to build, customize and act as administrators in their own servers (Zulli et al., 2020). However, managing and programming an online community requires expertise and commitment to civil discourse.

Treating the user of a technology as a producer of knowledge is a possibility that can be unearthed through the analytic distinction and scientific methodology offered by Gordon Pask's cybernetics. Pask's approach allows the measurement of sharp change, and iterative changes to dynamic human-machine systems without sacrificing an elegant, structured framework. Our overview of conversation theory and interaction of actors theory and examples/suggestions for their applications to practice showcase ways for educational psychologists, teachers, programmers and designers to embrace a participatory shift in the scientific method as society moves deeper into the 21st century.

ETHICS AND CONSENT

The reported results from our work on the use of ThoughtShuffler for argumentative writing were approved as a human subjects study by the Institutional Review Board at the Ohio State University. The reference number for the study was #2023E0456.

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

Tilak wrote the body of the paper and worked with Manning to parse out the historical foundations of Pask's work in second-order cybernetics. Scott assisted with correctly interpreting notation and diagrams elaborated as part of sections on conversation theory and interaction of actors theory. Pangaro assisted with fleshing out sections on learning technologies. Glassman helped edit the paper and provide suggestion and feedback for it to appeal to a wider interdisciplinary audience.

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REFERENCES

Ashby, R. (2016). Homeostasis. In C. Pias (Ed.), *Cybernetics: The Macy conferences 1946–1953. The complete transactions* (pp. 73–108). Diaphanes. (Original work published 1952).

Aslett, K., Sanderson, Z., Godel, W., Persily, N., Nagler, J., & **Tucker, J. A.** (2023). Online searches to evaluate misinformation can increase its perceived veracity. *Nature*, *625*, 548–556. DOI: https://doi.org/10.1038/s41586-023-06883-y

Barzilai, S., & **Chinn, C. A.** (2020). A review of educational responses to the "post-truth" condition: Four lenses on "post-truth" problems. *Educational Psychologist*, *55*(3), 107–119. DOI: https://doi.org/10.1080/00461520.2020.1786388

Beer, S. (2001). A filigree friendship. *Kybernetes*, *30*(5–6), 551–560. DOI: https://doi.org/10.1108/03684920110391779

Behymer, K. J., & **Flach, J. M.** (2016). From autonomous systems to sociotechnical systems: Designing effective collaborations. *She Ji: The Journal of Design, Economics, and Innovation*, *2*(2), 105–114. DOI: https://doi.org/10.1016/j.sheji.2016.09.001

Benoit, K., Watanabe, K., Wang, H., Nulty, P., Obeng, A., Müller, S., & **Matsuo, A.** (2018). quanteda: An R package for the quantitative analysis of textual data. *Journal of Open Source Software*, *3*(30), 774–774. DOI: https://doi.org/10.21105/joss.00774

Boyd, R. L., Ashokkumar, A., Seraj, S., & **Pennebaker, J. W.** (2022). *The development and psychometric properties of LIWC-22*. University of Texas at Austin. https://www.liwc.app/static/documents/LIWC-22%20Manual%20-%20Development%20and%20Psychometrics.pdf

Cariani, P. (1993). To evolve an ear. Epistemological implications of Gordon Pask's electrochemical devices. *Systems Research*, *10*(3), 19–33. DOI: https://doi.org/10.1002/sres.3850100305

De Zeeuw, G. (2001). Interaction of actors theory. *Kybernetes*, *30*(7–8), 971–983. DOI: https://doi.org/10.1108/03684920110396864

Dubberly, H., & **Pangaro, P.** (2015). How cybernetics connects computing, counterculture, and design. In A. Blauvelt (Ed.), *Hippie modernism: The struggle for utopia*. Minneapolis, MN: Walker Art Center. https://www.dubberly.com/articles/cybernetics-and-counterculture.html

Evans, M., Trolli, E., Pierson, A., & **Tilak, S.** (2023). Designing courses with sustainable virtual learning communities: A STEM teacher candidate course that extends beyond higher education. *Journal of Computing in Higher Education*. DOI: https://doi.org/10.1007/s12528-023-09391-0

Flavell, J. (1976). Metacognitive aspects of problem-solving. In L. Resnick (Ed.), *The nature of intelligence*. Lawrence Erlbaum.

Glassman, M. (2016). *Educational psychology and the internet*. Cambridge University Press. DOI: https://doi.org/10.1017/CBO9781316155134

Glassman, M., Tilak, S., & **Kang, M. J.** (2023). Transcending post-truth: Open educational practices in the information age. *Distance Education*, 44(4), 637–654. DOI: https://doi.org/10.1080/01587919.2023.2267468

Gwizdka, J., & **Bilal, D.** (2017). Analysis of children's queries and click behavior on ranked results and their thought processes in google search. In R. Nordlie & N. Pharo (Eds.), *Proceedings of the 2017 conference on conference human information interaction and retrieval* (pp. 377–380). Association for Computing Machinery. DOI: https://doi.org/10.1145/3020165.3022157

Lurie, E., & **Mustafaraj, E.** (2018). Investigating the effects of Google's search engine result page in evaluating the credibility of online news sources. In H. Akkermans, K. Fontaine & I. Vermeulen (Eds.), *Proceedings of the 10th ACM conference on web science* (pp. 107–116). Association for Computing Machinery. DOI: https://doi.org/10.1145/3201064.3201095

Marr, B. (2018, May 21). How Much Data Do We Create Every Day? The Mind-Blowing Stats Everyone Should Read. *Forbes*. https://www.forbes.com/sites/bernardmarr/2018/05/21/how-much-data-do-we-create-every-day-the-mind-blowing-stats-everyone-should-read/?sh=52f83d1960ba

Martzoukou, K., Fulton, C., Kostagiolas, P., & **Lavranos, C.** (2020). A study of higher education students' self-perceived digital competences for learning and everyday life online participation. *Journal of Documentation*, *76*(6), 1413–1458. DOI: https://doi.org/10.1108/JD-03-2020-0041

Maturana, H., Varela, F., & **Uribe, R.** (1974). Autopoiesis: The organisation of living systems: Its characterisation and a model. *Biosystems*, *5*(4), 187–196. DOI: https://doi.org/10.1016/0303-2647(74)90031-8

Oulasvirta, A., Hukkinen, J. P., & **Schwartz, B.** (2009). When more is less: the paradox of choice in search engine use. In J. Allen & J. Islam (Eds.), *Proceedings of the 32nd international ACM SIGIR conference on research and development in information retrieval* (pp. 516–523). Association for Computing Machinery. DOI: https://doi.org/10.1145/1571941.1572030

Pangaro, P. (2001). THOUGHTSTICKER 1986: A personal history of conversation theory in software, and its progenitor, Gordon Pask. *Kybernetes*, *30*(5/6), 790–807. DOI: https://doi.org/10.1108/EUM0000000005697

Pangaro, P. (2008). Instructions for design and designs for conversation. In R. Luppicini (Ed.), *Handbook of conversation design for instructional applications* (pp. 35–48). IGI Global. DOI: https://doi.org/10.4018/978-1-59904-597-9.ch003

Pashler, H., McDaniel, M., Rohrer, D., & **Bjork, R.** (2008). Learning styles: Concepts and evidence. *Psychological Science in The Public Interest*, *9*(3), 105–119. DOI: https://doi.org/10.1111/j.1539-6053.2009.01038.x

Pask, G. (1959). Physical analogues to the growth of a concept. In *Mechanization of thought processes: Proceedings of a symposium held at the National Physical Laboratory on 24th, 25th, 26th and 27th November 1958* (Vol. 2, pp. 877–822). Her Majesty's Stationary Office.

Pask, G. (1961). *The cybernetics of evolutionary processes and of self organising systems* [Text of an invited paper delivered at the 3rd Congress of the International Association of Cybernetics, Namur, Belgium]. Systems Research Ltd.

Pask, G. (1971). Interaction between individuals: Its stability and style. *Mathematical Biosciences*, *11*(1–2), 59–84. DOI: https://doi.org/10.1016/0025-5564(71)90008-3

Pask, G. (1972). Anti-hodmanship: A report on the state and prospects of CAI. *Programmed Learning and Educational Technology*, *9*(5), 235–244. DOI: https://doi.org/10.1080/1355800720090502

Pask, G. (1975). *Conversation, cognition and learning*. Elsevier.

Pask, G. (1976). *Conversation theory: Applications in education and epistemology*. Elsevier.

Pask, G. (1979). An essay on the kinetics of language, behaviour and thought. System Research Ltd. https://www.pangaro.com/pask/pask%20essay%20on%20kinetics%20of%20language.pdf

Pask, G. (1987). *Conversation and support*. Universiteit van Amsterdam.

Pask, G., & **De Zeeuw, G.** (1992). Interactions of actors, theory and some applications. Unpublished manuscript.

Pask, G., & **Kopstein, F. F.** (1977). Teaching machines revisited in the light of conversation theory. *Educational Technology*, *17*(10), 38–41. https://www.jstor.org/stable/44421243

Pask, G., Scott, B. C. E., & **Kallikourdis, D.** (1973). A theory of conversations and individuals (exemplified by the learning process on CASTE). *International Journal of Man-Machine Studies*, *5*(4), 443–566. DOI: https://doi.org/10.1016/S0020-7373(73)80002-1

Paul, R., & **Elder, L.** (2009). Critical thinking, creativity, ethical reasoning: A unity of opposites. In T. Cross & D. Ambrose (Eds.), *Morality, ethics, and gifted minds*, (pp. 117–131). Springer. DOI: https://doi.org/10.1007/978-0-387-89368-6_8

Pias, C. (2016). *Cybernetics: The Macy conferences 1946–1953. The complete transactions*. Diaphanes.

Pickering, A. (2009). Beyond design: cybernetics, biological computers and hylozoism. *Synthese*, *168*(3), 469–491. DOI: https://doi.org/10.1007/s11229-008-9446-z

Pickering, A. (2010). *The cybernetic brain: Sketches of another future*. University of Chicago Press. DOI: https://doi.org/10.7208/chicago/9780226667928.001.0001

Prinz, J. (2011). Is empathy necessary for morality? In A. Coplan & P. Goldie (Eds.), *Empathy: Philosophical and psychological perspectives* (pp. 211–229). Oxford. DOI: https://doi.org/10.1093/acprof:oso/9780199539956.003.0014

Scott, B. (2004). Second-order cybernetics: An historical introduction. *Kybernetes*, *33*(9/10), 1365–1378. DOI: https://doi.org/10.1108/03684920410556007

Scott, B. (2007). The cybernetics of Gordon Pask. In R. Glanville & K. H. Muller (Eds.), *Gordon Pask, philosopher mechanic: An introduction to the cybernetician's cybernetician* (pp. 29–52). Echoraum.

Scott, B. (2021). Cybernetics for the social sciences. *Brill*. DOI: https://doi.org/10.1163/9789004464490

Tilak, S. (2023). *Design insights from user perceptions of the functionality of learning management systems and social media for college classrooms of the Internet Age* (Doctoral dissertation, The Ohio State University). https://eric.ed.gov/?q=cybernetics&ff1=eduHigher+Education&id=ED639107

Tilak, S., & **Glassman, M.** (2022). Gordon Pask's second-order cybernetics and Lev Vygotsky's cultural historical theory: Understanding the role of the Internet in developing human thinking. *Theory & Psychology*, *32*(6), 888–914. DOI: https://doi.org/10.1177/09593543221123281

Tilak, S., Glassman, M., Kuznetcova, I., & **Pelfrey, G. L.** (2022). Applications of cybernetics to psychological theory: Historical and conceptual explorations. *Theory & Psychology*, *32*(2), 298–325. DOI: https://doi.org/10.1177/09593543211053804

Tilak, S., Kadir, L., Wen, Z., Pangaro, P., & **Glassman, M.** (2023). Designing sociohistorically sensitive information search: Experimental analyses of essays written using ThoughtShuffler and Google. *Cybernetics & Human Knowing*, *30*(1–2), 133–151. https://www.ingentaconnect.com/contentone/imp/chk/2023/00000030/f0020001/art00008;jsessionid=tt2844q9ifox.x-ic-live-01

Tilak, S., Porto., A., Pangaro, P., & **Glassman, M.,** (2024). Comparing the lexical diversity of essays written using the ThoughtShuffler and Google search interfaces [Manuscript submitted for publication]. Center for Educational Research and Technological Innovation, Chesapeake Bay Academy.

Wiener, N. (1961). *Cybernetics: Or control and communication in the animal and the machine* (2nd ed.). MIT Press. (Original work published 1948). DOI: https://doi.org/10.1037/13140-000

Wilson, C., & **Scott, B.** (2017). Adaptive systems in education: a review and conceptual unification. *The International Journal of Information and Learning Technology*, *34*(1), 2–19. DOI: https://doi.org/10.1108/IJILT-09-2016-0040

Zulli, D., Liu, M., & **Gehl, R.** (2020). Rethinking the "social" in "social media": Insights into topology, abstraction, and scale on the Mastodon social network. *New Media & Society*, *22*(7), 1188–1205. DOI: https://doi.org/10.1177/1461444820912533

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