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Giving Technology the Place It Deserves in Creative Problem Solving

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by

Yves De Smet

An Abstract of a Project

in

Creative Studies

Submitted in Partial Fulfillment

of the Requirements

for the Degree of

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ABSTRACT OF PROJECT

Giving Technology the Place It Deserves in Creative Problem Solving

This project explores the potential for using artificial intelligence (AI) in Creative Problem Solving (CPS) to facilitate a creative process. It invites members from the technology and CPS communities to see the opportunities for AI-augmented creative problem solving, and to join forces to turn those opportunities into reality. To this end the author looks at creativity through a knowledge-centered lens. He proposes a model based on how the human brain makes connections, to enable AI developments that help transform the knowledge residing in a team and/or from external resources into creative solutions. A vision of how AI could be leveraged in specific CPS tools and the facilitation of an unconference session are some of the other outcomes presented.

Keywords: artificial intelligence, creative problem solving, connections, knowledge

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December 6th, 017

Buffalo State

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I am very grateful to my academic advisor Prof. John F. Cabra for helping me to shape my thoughts and crystallize them into words. Prof. Cabra undoubtedly invested many hours of his nights and weekends in suggesting alternative approaches and constructive criticism. He kept my enthusiasm alive and got me unstuck when I got stuck.

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Finally, I thank my family, friends, fellow Euriginals and all academic staff of the International Center for Creative Studies in Buffalo, NY for allowing me to pursue my passion and enabling my development into a more creative person.

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SECTION 1: BACKGROUND TO THE PROJECT

Purpose and Description

The purpose of this project is to conceptualize the merger of two communities that until today seem to largely live on planets circling around different stars: creative problem solvers on one hand and technologists on the other. The project will theorize how the CPS Thinking Skills Model (CPS TSM), and artificial intelligence (AI) – which by themselves both still are broad areas - might facilitate a creative process. This is not to suggest that other types of technology could not benefit creative problem solvers (and vice versa), or that other creative problem solving schools of thought (e.g., Synectics, to name but one) could not take advantage of AI.

First, the project involves reaching out to the AI community and utilizing its ideas to conceptualize how technology might be integrated into CPS TSM facilitation. Second, this master's project intends to raise the reader's awareness, namely facilitators of creative processes, regarding the missed opportunities and consequences should they continue to ignore the integration of technology with creative collaboration. Note that this work targets the more tech-savvy facilitators. Third, provide examples of AI and CPS facilitation integration at the tactical level.

Today's real-world AI solutions have been developed for organizations that have the resources and the willingness to pay for them, as in the high-tech, social media and financial service industries. However, no longer are these industries alone in benefitting from AI. An ever-growing trend suggests that wherever creative collaboration is extant, the organization is using AI at some scale, or is considering its integration with group work to solve vexing problems. In this project I have strived to accomplish the following:

1. Categorize AI business applications by the functionalities and solutions they offer to organizations.
2. Select and then connect the applications most likely to benefit the operationalization of CPS TSM; and
3. Conceptualize applications of AI for the CPS practitioner at the tactical level.

Rationale for Selection

Too many people are solving complex problems inefficiently (whether using CPS or otherwise) and in manners going back to the 20th century (e.g., using only pen, sticky notes and flipcharts, and a very limited number of people as their resource group). Most creative problem solvers have not kept up with, or have completely ignored technological progress. In fact that is a general issue in our society. Whether it involves the two elder gentlemen in the waiting area of a car shop struggling to get a coffee out of the vending machine with a touch screen, or my mom's inexperienced handling of the remote control of the TV set, or the sales representative wearing a smile, suit and tie, but unable to get his presentation slides onto the screen, or the professor teaching a virtual class using the wrong audio device settings, the pattern is similar. And then there is me, short of time to read all that I'd like to read, having to ignore a pile of interesting literature, which might well contain the basis of a groundbreaking connection or idea. People can't keep up with the waves of technology that are introduced in the market; the changes these technologies introduce are exponential and too fast for anyone but a technology geek to keep up with.

The key drivers for the recent rise of AI are the fast and increasing computational power, together with the abundance of data and the democratized means to capture them. These data serve as the basis for a chain of information, namely information that produces knowledge, knowledge that produces intelligence (and the wisdom and insights that stem from this intelligence). That entire chain plays an important role in this project. Yet, despite the information that is freely available to creative problem solving facilitators, they struggle to make sense of this deluge and consequently, they in turn limit themselves from making it their best ally. That is where and why I see huge opportunities for the use of AI in CPS. After all, knowledge is a key component in creativity, something Ruth Noller's famous formula for creativity continues to remind us of (Parnes, Noller, & Biondi, 1977).

Ruth Noller, a mathematician, devised a way to describe creative behavior. She saw creativity as a formula that can be described as follows: $C = f_a(K, I, E)$. In this formula, the degree to which an individual will achieve creative outcomes is represented by the letter C and is a direct function of three factors: (1) the amount of knowledge (K) the person possesses regarding the task, situation, or problem; (2) the extent to which the person is able to apply imagination (I) to generate novel responses to a task, situation, challenge or problem; and (3) the level of productive critical evaluation (E) the person can apply to develop the most promising creative idea to address the situation more effectively.

This formula provides a framework for thinking about how to nurture higher levels of creative behavior. In fact, in the above formula both I (imagination) and E (evaluation) in turn are dependent on, hence functions of K (knowledge), so it would be appropriate to rewrite the formula as

$$\text{Creativity} = f_a[K, I(K), E(K)]$$

As such it becomes clearer that knowledge is a key ingredient, if not THE key ingredient. And one would expect that maximizing the knowledge present or available during or for a CPS situation would be desirable. In practice, people accomplish this by inviting a group of (typically 5-10, with eight being standard) people (often called the resource group) to help the facilitator solve a client's problem. As such, a diverse knowledge base is available to draw from. Obviously before and during the CPS session external knowledge can be accessed from additional sources such as experts, literature or the Internet. It goes without saying that all the above – internal and external knowledge combined – is nothing but a mere, albeit probably well-chosen sample of all the knowledge available in this world. Are we leaving opportunities untouched to solve some of the world's hardest problems, by limiting us to the human intelligence present in a small resource group, and by not augmenting CPS with AI? Are we perhaps overestimating the power of human intelligence, which is but the result of electrons racing through circuits? Isn't it so that there is no law in physics that says that those same electrons could not produce greater intelligence when racing through computer circuits?

It needs to be said that there are other schools of thought… Some claim that not knowledge, but imagination is the more important ingredient of creativity. Einstein said that "imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world." Also, it takes imagination to generate new knowledge (Puccio, Mance, Barbero Switalski, & Reali, 2012).

The Creativity and Change Leadership Master's program at the International Center for Studies in Creativity (ICSC) in Buffalo, NY has provided me with a close-up view of the next generation CPS practitioners and their tools of the trade. I have observed that technology is used at a minimum. Technology-based CPS does not appear to be an area of focus in the way that the Creative Problem Solving strand of the Master's program is delivered today.

To further my observations, open a contemporary book on the topic of creativity (and innovation for that matter), that is assigned in the creative studies program, and you'll be less than likely to come across a chapter dedicated to technology. One example is the book by Dawson and Andriopoulos, Managing Change, Creativity & Innovation (2014). I think this gap presents a very important opportunity to evolve CPS and make technology its ally. The few works that focus on technology used in CPS limit themselves to the use of virtual collaboration methods and digital look-alikes of CPS tools used in a live situation (Burnett & Cabra, 2013; Sullivan, 2017; Uribe & Cabra, 2010; Uribe-Larach & Cabra, 2011). Examples include how to use software like Skype or Zoom while limiting communication shackles, or programs that allow ideas or other input to be captured, and manipulated electronically. Not surprisingly our use of technology in CPS has stayed limited to a very human-centric way of running CPS. While these hacks certainly have merit, they are a long way from the amazing accomplishments of AI as used in for example the medical, financial, or high-tech industries. Nowadays most problem solvers have computing power in the palm of their hands that exceeds that of the team that put the first man on the moon, and brought him back alive in the sixties. We ought to be more ambitious with our endeavors to make the best of technology in CPS.

My interest in ‘information’ and its relationship with data, knowledge, and sense making has existed for at least 15 years now. It is my belief that more knowledge should result in more and better connections, hence lead to better results in CPS. The best way to get better ideas, is to have more ideas, right? Well, aren’t ideas just combinations of previously uncombined pieces of knowledge (Berkun, 2010; Torrance & Safter, 1999; Young, 2009)? The more information one soaks up, the more knowledge one builds, the more associations, connections, thoughts that could come out of that. So instead of leveraging the diversity in the thinking of five or eight people in a CPS session, one could tap into the diversity of twice, 20 times or 2 million times that – while keeping the rest of the CPS process manageable. The results could be impressive. Now, as explained above, the dizzying rate of technology development and information production are leaving many behind. They simply cannot keep up with an abundance of information and ongoing technology introductions. All the books sitting in my private library, or those in the public library, just like the four hard disks filled with stuff that I deemed too interesting to put to waste yet still must read, they are not going to help me combine previously uncombined thoughts.

In this project I use CPS – The Thinking Skills model, its seven steps (assessing the situation, exploring the vision, formulating challenges, exploring ideas, formulating solutions, exploring acceptance and formulating a plan) and the corresponding thinking skills as the backbone to structure questions like the following. How might we use machines to somehow ease our task, for example by letting them structure all that unused information, to make it easier to read and process by humans? Or could we train a machine such that it finds all the possible, surprising, and/or original connections to a given problem, which are buried inside the libraries and hard disks at our disposal?

I bet something can be worked out – and this project is my mission to find out what. I believe in hybrid CPS – where woman or man and machine collaborate. Because we should never stop trying to improve creative problem solving in a world with so many unsolved problems, leaving too many people starving and putting the future of life on this planet in danger.

SECTION 2: PERTINENT LITERATURE AND RESOURCES

The literature consulted fits into one of 3 categories: technology (with focus on artificial intelligence), CPS - the Thinking Skills Model and its associated tools, and the tree consisting of 'data, information, knowledge and intelligence'. Key literature resources from each of these three categories can be found in the References section at the end of the paper.

I scheduled casual talks with several experts in technology, creativity, artificial intelligence or any combination thereof. This includes people from industry (Google, KnowInnovation, IBM, Lux Research, Accenture, Procter and Gamble, and Canva), institutions and universities (Buffalo State College, Thinking Futures) and authors.

SECTION 3: PROCESS PLAN

Plan to Achieve My Goals and Outcomes

My goals for this project were as follows:

- Create a clear, well-structured overview of how and where AI is being used in today's business world, using language that can be understood by a layperson.
- Put together a similar overview of how information, knowledge and intelligence play a role in CPS. I elaborate on the challenges we are facing - due to our limited brain capacity, the limited time available to us, and our short attention span - to turn the abundant information we have at our disposal into knowledge
- Paint a picture of what the future might look like if we were to put AI to work to reduce or close the gap mentioned before. Screen CPS skills and tools and identify a few them that could easily be "technologized" by tweaking or adapting AI solutions used in business.

Thanks to this project I got up to speed about AI used in business (AI is quickly becoming a very hot topic in any media source and in more industries). I also have a well-formed opinion on how information, knowledge and intelligence interrelate, and which roles they fulfill in CPS. At the end, I aspire to become a go-to person for discussions involving technology's integration with CPS facilitation.

What I also see myself doing is to publish an article about creativity and technology, and run a workshop about this topic at CPSI 2018 ('the Creative Problem Solving Institute') on how well-known CPS tools could be hybridized and upgraded using technology.

Project Timeline

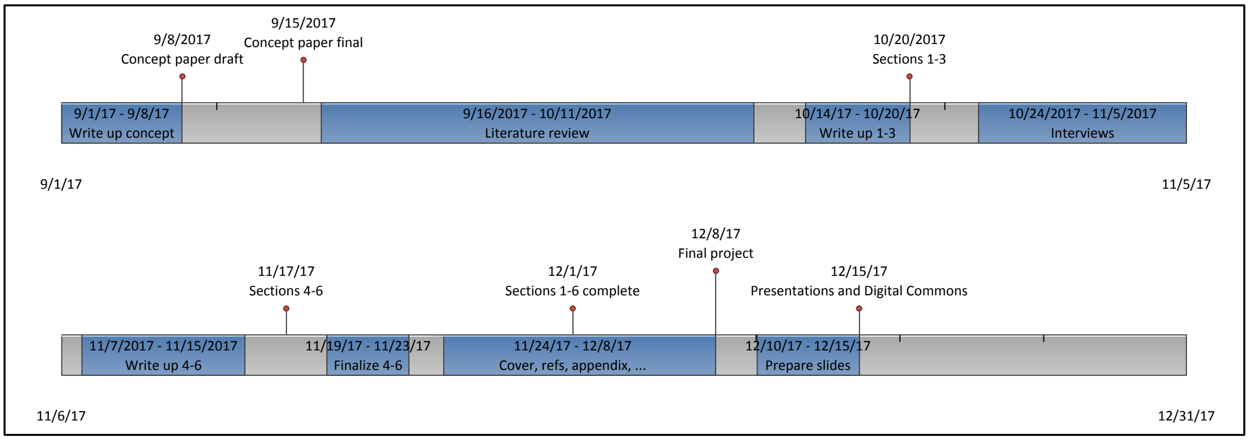

Figure 1. Timeline showing the milestones and time planning for this project.

Evaluation Plan

I have my fellow student Dr. Jennifer Gippel as a soundboard, during and after finalization of the project. I intend to share and discuss my project outcomes (Section 4) face-to-face with at least three experts from companies and institutions mentioned in Section 2 to get direct feedback about the merit of this work. Obviously, the discussions with and feedback of Prof. Cabra will be important to measure the value of this undertaking.

Although the acceptance of a peer-reviewed article and a workshop at CPSI will only be known about (perhaps many) months after submitting this project, they will on a personal level count equally much as assessments.

SECTION 4: OUTCOMES

Connecting the Dots

What if a child's game were at the heart of how we revolutionize CPS? I remember the day that I felt like a hero when, in all my ingenuity, I had managed to connect a series of dots to make Disney's Goofy appear on the last sheet of our daily newspaper. OK, the dots were numbered – but still – I had connected them in the right order. This child's game holds a very powerful metaphor, that of "connecting the dots". In fact, people have been connecting dots to create images for a very long time. The animals that make up the Zodiac signs were created in the minds of people around 1,000 BC, whereby the dots were the stars visible by the naked eye, high up in the Mediterranean sky. Nowadays the metaphor also has a less literal connotation referring to a person's ability to "put one and one together", to associate one idea with another, or to extrapolate from combining several data points by using her or his "common sense". These expressions provide hints to insight or intelligence.

Connecting the dots is also what happens when people learn something new. Literally! Cognitive scientists will tell you that learning is connecting dots in our human brain (Medina, 2008; Stafford & Webb, 2005). The dots in this case are neurons, and the links are axons carrying electric signals between two nerve cells. Axons connect in what is called a synapse. The brain consists of billions of those neurons (dots!) – and each single one of them has a possibility of connections of 1 with 28 zeroes after it (Buzan & Buzan, 1996). That implies that the total number of connected dot combinations in a human brain is 1 followed by 10.5 km of zeroes. This dot connecting in the brain is what gives us our memory, and our ability to analyze, structure and categorize (or ignore) the non-stop flow of signals that our senses throw at our brain (sight, hearing, smell, taste, feeling).

Creativity and by extension CPS also have a lot to do with connecting the dots. Coming up with new ideas is central to creative problem solving, and new ideas typically arise when we connect or combine elements of existing ideas. Moreover, evaluating and selecting ideas is a process whereby we essentially connect those ideas to set criteria. To implement ideas that have developed into solutions, we need to connect those to the realities of life (i.e., the current status, stakeholders and their positions, constraints and limitations, and resistance to change).

For example, connecting the two dots “house” and “wheel” may have led to the idea to build a caravan. How the existing ideas are connected determines whether the new idea is original and valuable. My own experience is that when one reads about, or discusses creativity, sooner rather than later “making connections” will enter the scene. It is a very powerful and visual representation (albeit also an oversimplification) of what creativity is largely about. The recent book called “The secret of the highly creative thinker: How to make connections others don’t” (Nielsen & Thurber, 2016) gives a nice overview of the theoretical foundations and of what neuroscientists have to say about connection making.

I started this section with a ‘What if a child’s game…’ phrase. This is where I link connecting the dots on one hand, and enabling more AI to be used in CPS on the other. I want to point out another way machines might support creative collaboration in groups. I suspect that people make connections one at a time, and between two dots – not more. If they connect three dots, they probably do so by first connecting two of them, and afterwards connecting the third dot to the product created from the first connection. People don’t do so well thinking in dimensions higher than 2 or 3. This limits how many and what type of connections people (or a team thereof) can make in a given time span. Machines on the contrary can connect any number of dots, at the speed that electrons move through circuits.

I start this project by developing a language based on 'connecting the dots', to offer a vocabulary that allows the AI and CPS communities to talk to each other (see Figure 2). Let's consider 2 blue dots representing chunks of knowledge of a person named Mr. Blue and 2 yellow dots of another person named Mrs. Yellow. Those 4 dots each represent chunks of knowledge; they could for example be knowledge about (1) methods to produce paper, (2) how materials can be made to change colors when the surrounding light intensity changes, (3) the climate of Buffalo, and (4) the rising cost of energy.

In row 1 (in the grey frame) just 4 of many possible "ideas" are shown (an idea is a white frame). Ideas consist of dots (chunks of knowledge) and the connections between them. In reality person Yellow and person Blue each have more than 2 dots that are relevant to a situation or problem – so things would easily become very complicated in case each person brings hundreds, thousands, or more chunks of knowledge to the table. Hence, in the example above, connecting the first two dots (both blue) could result in an idea for how to develop a paper type that changes its color, to make it easier for a person to read what is written on it – regardless of whether there is a lot or very little light in the room.

Each of the white frames in row 1 (in the grey box) can be considered as dots of their own – and they are of a "dot-level" one up from the earlier blue and yellow dots. I'll name such idea a 'first order dot'. Let's say for instance that the second idea from the left in the grey box is a great idea, worth remembering, developing, and implementing. Then we can connect some of the yellow and blue dots with that higher order dot. Some of the possible ideas consisting of connections between that higher-order dot, 1 blue, and two yellow dots are shown in the green box, in row 2. And one could keep going this way. The first white frame in the green box, if it is a worthwhile idea, is a dot of the second order, which can in turn be combined with dots. Some examples thereof are in the purple box; they are ideas made up of connections between three 0^{th} order dots and one 2^{nd} order dot.

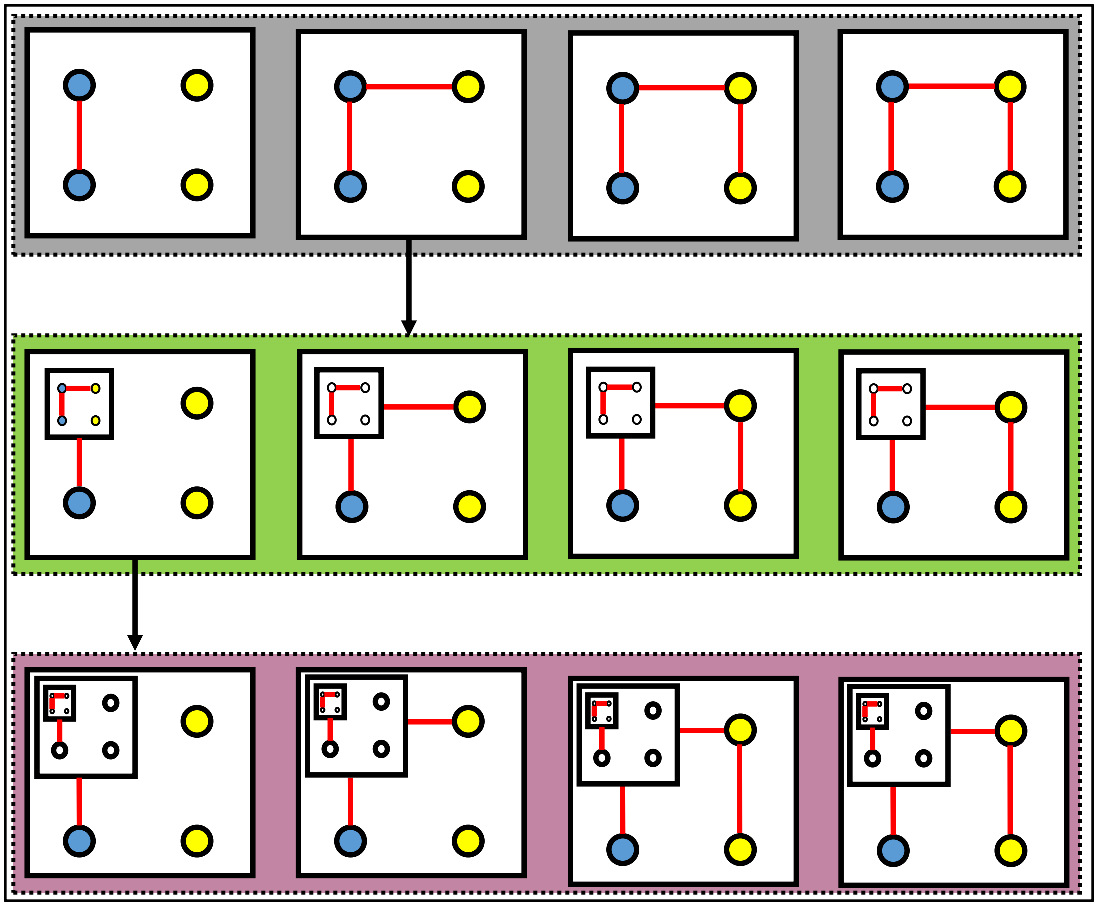

Figure 2. 'Connecting the dots' vocabulary – proposed abstract language to support communication between the AI and CPS communities.

As more information becomes freely available, especially for people with an Internet connection, existing knowledge can be combined with more and more dots. More dots than people can manage. The number of dots increases exponentially thanks to technology. More and more potentially game changing or world changing connections are left unrealized, just because we only have so much brain power and time available.

This is where machines could come in. Given sufficient memory and computation power, machines don't get tired nor impressed by the number of combinations of dots that can be made from any given amount of knowledge chunks. They could help us make sure that any potential combination of dots gets made and vetted.

To allow machines to augment our capacity to connect the dots we could use above imagery or coding as a basis. We probably need to develop a more structured language for CPS, to allow machines to help us. Having statement starters to add structure to our problem statements like HMW (how might we), H2 (how to), WMBAT (what might be all the), … is a good example. We could extend that by agreeing on additional rules for the rest of these statements. Outcome Driven Innovation, a methodology marketed by the company Strategyn, puts this into practice (Ulwick, 2005). They propose to list 'customer jobs' and corresponding 'job outcomes' for each. The latter need to be written up in the following structure (the latter two terms are optional):

[Direction of improvement] + [Unit of measure] + [Object of control] + [Contextual clarifier]

For example, for a customer in the printing industry, a relevant customer job would be 'Reduce the time of production stops caused by empty ink reservoirs'. One of the outcomes of that job could look like:

[Minimize] + [The time it takes] + [To refill the ink vessels] + [Of printing press #4]

This kind of structured language makes it easier to analyze, compare, track, … all the outcomes that people have been trying to solve for. Another example from the innovation world where structured language is applied, is TRIZ (Mann, 2002). AskNature (2017) runs a website where biomimicry is used to help solve human problems. They too use a structured language centered on 'functions' from nature; furthermore, they use statement starters (HMW) the way we do in CPS.

With this background (the metaphor of connecting dots, and the examples of structured language from existing innovation methods) I want to conclude this section with an open question directed at the AI developers: WMBAT criteria that a future ‘connecting the dots’ language must fulfill, to augment human connection making with the help of AI machines?

The Data Information Knowledge Wisdom Pyramid

The dots being connected in CPS essentially are pieces of ‘information’. That same information however “is currently one of the most important, most widely used and least understood of our mundane and technical concepts” (Floridi, 2003, p. 459). And since we will often run into concepts like data, information, knowledge and intelligence in this work, some definitions are required to distinguish data from information, information from knowledge, and knowledge from intelligence. This section provides these definitions.

Russell Ackoff (1999), a scholar in the field of creativity, decided to shed some light on this family of terms. He is known for coining the “DIKW hierarchy” – in which DIKW stands for data, information, knowledge, and wisdom. He presented his idea as a pyramid to indicate that there is a hierarchy (with wisdom at the top and data at the bottom) and that “each of the higher terms in the pyramid includes the categories falling below it” (Ackoff, 1989, p. 3). See Figure 3. For example, all knowledge is also information (but not all information is knowledge). Wisdom is the highest good; data is at the bottom. As I went through the literature about DIKW I realized there is no real consensus amongst authors about the definitions for each of the levels in the pyramid – except for the bottom layer, data (Ackoff, 1989; Cooper, 2016; Frické, 2008; Rowley, 2007; Zeleny, 1987). The reason for the lack of agreement on one definition for each appears to be the multitude of perspectives from which DIKW is examined. Information science and knowledge management are the two most important research domains studying the layers of the DIKW pyramid.

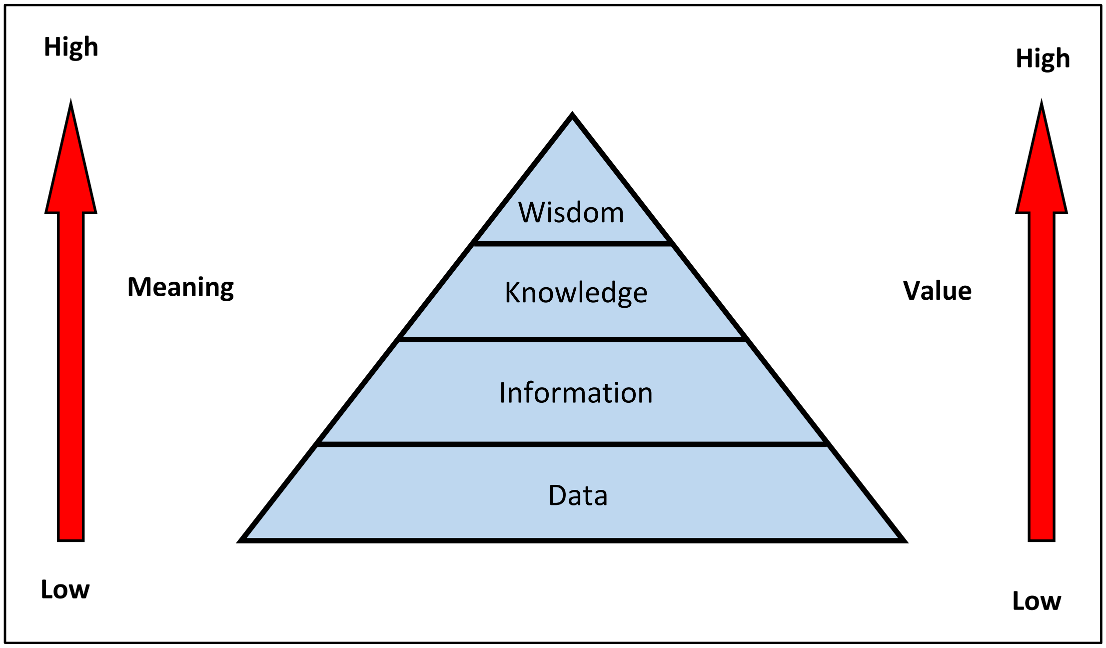

Figure 3. The DIKW pyramid (Chaffey & Wood, 2005)

Ackoff also added ‘understanding’ and ‘intelligence’ to the pyramid, between knowledge and wisdom (hence DIKUIW would have been a more appropriate name than DIKW). Bellinger et al. (2004) argue that understanding is not a level of its own, but merely supports the transition between levels: moving from data to information takes understanding relations, moving from information to knowledge takes understanding patterns, and moving from knowledge to wisdom takes understanding principles. Table 1 compares Ackoff’s and Zeleny’s definitions of data, information, knowledge and wisdom.

Below are definitions and characteristics for data, information, knowledge and wisdom, as summarized from (Rowley, 2007).

- Data consists of transformed signals, which people structure (sense and select), whether using (only) our senses or with the help of technology (a camera for example). Data has no value, because it is without context and interpretation. Other characteristics of data are:

unorganized, unprocessed, meaningless, mere observations or facts, descriptions of things, events or activities.

Table 1

Comparison of Ackoff's and Zeleny's definitions of data, information, knowledge, understanding and wisdom (Rowley, 2007)

	Zeleny	**Ackoff**
Data	Know nothing	Symbols
Information	Know what	Data is processed to be useful; provides answers to who, what, where and when questions
Knowledge	Know how	Application of data and information; answers how questions
Understanding		Appreciation of why
Wisdom	Know why	Evaluated understanding

- Information is typically defined in terms of data. It is a particular type of data, characterized by its format. The latter makes data meaningful, valuable or useful for a purpose, or to help people understand a subject. It is processed, structured, interpreted and understood. Processes to transform data into information include: classifying, sorting, aggregating, calculating, selecting. Again, these processes can be performed with or without technology. Important to note here is that whether something is considered data or information is decided by a human receiver – who chooses to cognitively structure data into information. This cognitive structuring is a way of connecting dots using experience and/or existing information.

- Knowledge is a whole lot more ambiguous and more difficult to define than data and information. It is data and information topped up with expert opinion, skills and experience, in the end enabling action or decision making in the context of a specific situation or problem; knowledge is actionable information. It is a property of people (whereas data is a property of things). Knowledge often involves the synthesis of multiple sources of information over time. Information is transformed into knowledge by linking it to already existing knowledge (by "connecting dots"), through study and experience, by internalizing it with reference to existing cognitive frameworks.

  Explicit knowledge can be recorded in information systems (books, reports, courses), hence can be shared with others, whereas tacit knowledge (often referred to as knowhow) cannot be recorded, since it is part of the human mind.

- Wisdom is accumulated knowledge, which allows one to understand how to apply concepts from one domain to new situations or problems (Jessup & Valacich, 2003). "Wisdom is the highest level of abstraction, with vision foresight and the ability to see beyond the horizon" (Awad & Ghaziri, 2004, p. 40).

Perhaps the following examples help to clarify the above.

We could say that information, knowledge and intelligence are about 'doing things right', whereas wisdom is about 'doing the right things'. Figure 4 shows to what extent each of the layers is dependent on human respectively computer input.

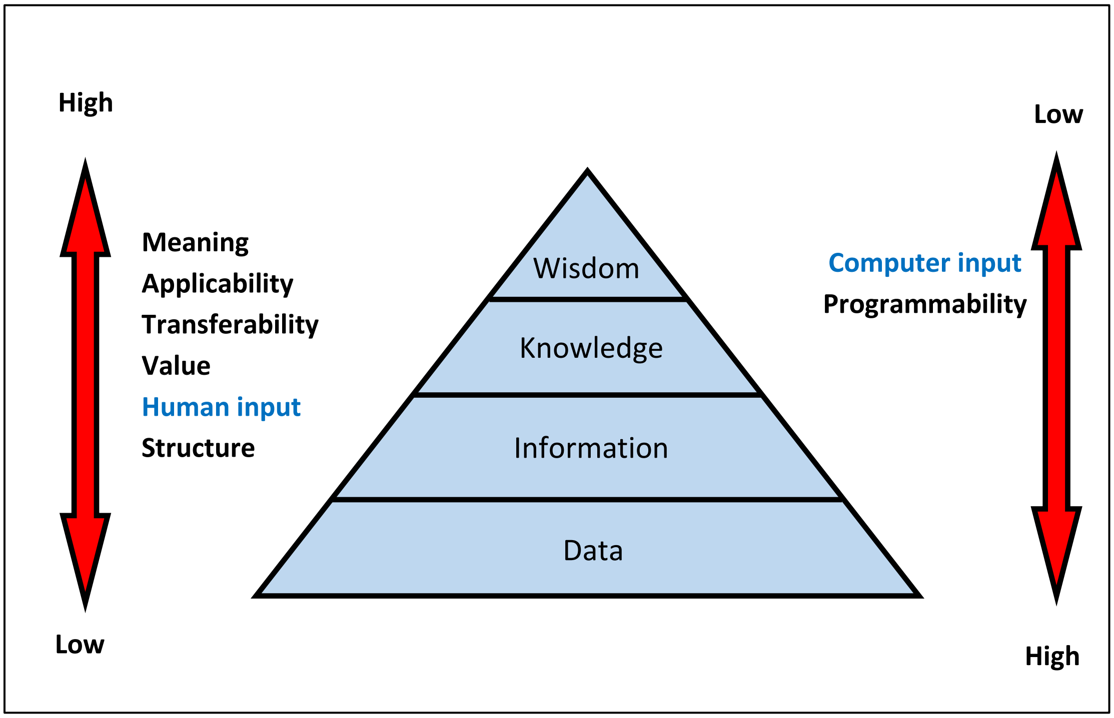

Figure 4. The extended DIKW pyramid (Rowley, 2007)

Here is an example to clarify these definitions further. 1 megabyte of numbers is just data. Those same numbers structured in an excel sheet in three columns with headers 'pixel color', 'X coordinate', 'Y coordinate' make up information (it's a map of Buffalo). Suppose now that I need to get from my hotel in Buffalo to Buffalo State College in less than 20 minutes walking. This 'problem', when combined with above information, generates 4 possible routes to get to my destination: I have generated knowledge. If route 1 passes through the field, which is littered with puddles from several days of rainfall, then that is not the best option. So, I choose not to take that route. That is intelligence. If route 2 passes through a shopping street with a famous specialty liquor store, I better avoid that: I tend to spend too much money on buying rare single malt whiskies. So, I choose either route 3 or 4. That is wisdom.

Let me introduce an analogy to discuss the possibilities provided by information. In physics potential energy is the energy form that can perform labor (but isn't yet). Think of a weight hanging on a rope 1 meter above the ground. It has the potential to break (an example of performing labor) a glass window lying underneath, but it doesn't – until someone cuts the rope and the weight falls. As an analogy with the physical concept of potential energy, information could be considered as 'potential knowledge'. Information is left untapped and is not adding to one's knowledge until it gets contextualized into someone's situation or problem, and topped up with experience, opinion and skills of someone. Once this happens, it is transformed into 'creative energy' – energy that drives a problem solver to a creative solution for a problem. Knowledge is built by an intelligent system (whether human or machine) with information as its input.

Enormous (and growing) amounts of information out there is never tapped into and stays behind as potential knowledge that problem solvers can't use as a resource; it fails to "do labor" to help solve a problem creatively. One could say we are drowning in information yet starved of knowledge. Our intuition and Noller's formula for creativity lead us to believe that having access to more knowledge during creative problem solving should lead to more or higher quality creativity. For example, because more and richer connections could be made if more dots become available, regardless of whether that extra knowledge is added by making the team bigger and ideally more diverse, or by increasing the knowledge of the individuals on the team. I wonder if Guilford's 'threshold hypothesis' (Guilford, 1967) - which states that there's a positive correlation between low creativity and low intelligence scores, but none at higher scores - remains valid when machines come into play. His hypothesis would imply that using machines to 'add knowledge' and more intelligence to the table would have no effect. I would think this is incorrect. It should be interpreted as 'intelligence is necessary, but not sufficient condition for creativity'. This is not in contradiction with saying that more knowledge is better – provided other conditions crucial for creativity are met.

An important challenge to address is the quantification of knowledge. Information theory is about how to quantify information (Claude Shannon pioneered that field halfway the 20th century). Information science is all about gathering, storing, protecting, retrieving, disseminating, sharing and analyzing data. Computer science is about processing data and information. These fields are mature nowadays, and most organizations have an 'IT' (information technology) department in the meanwhile. We know how to express information in strings of 0's and 1's (bits) (Stone, 2015). And the world is piling it up on Internet. Indeed, if information is about 'to know what' (see Table 1), 'www' (worldwide web) could just as well stand for the 'worldwide what'. Perhaps it is not information overload that is our biggest problem; perhaps it is not knowing how to filter out what's useful (Shirky, 2008).

As we saw above however, knowledge only becomes just that, after some intelligent person (or machine?) processes and contextualizes information. That complicates things – to say the least. Besides I don't know of many companies that have a 'KT' (knowledge technology) department… Is this world focusing on the wrong level in the DIKW pyramid? Are we spending any, or enough, R&D money on tools that helps us turn information (which is growing at a pace no human can keep up with) into knowledge? How might we turn the 'worldwide what' into the 'worldwide how' (Lewis, 2013)? Add to this our limited attention span, and therefore we get used to skimming headlines, and to seeing 140-character, shallow (Twitter) messages as the standard. It is a strange contradiction, but I'm afraid there is truth to the following: on one hand the exponential rise in information becoming available – and mostly for free, on the other hand people, by not reading as much (information) in depth anymore, gaining less knowledge instead of more.

I visualize knowledge quantification in Figure 5. It shows three humans named H_1, H_2 and H_3 (let's say Herb, Hillary and Henry), and one machine M. Each of these four 'players' bring dots of knowledge to the party. I use 'dot' for lack of an existing term describing the knowledge analogue of information 'bit', and to be consistent with Figure 4. Human 1 for example offers one dot named $K_{1,1}$, Human 2 offers two dots, named $K_{2,1}$, and $K_{2,2}$, and Human 3 is the most knowledgeable among the 3 colleagues, even offering three dots. Machine M finally – being AI and possessing access to the cloud, filled with exabytes of information and knowledge that it built up though many hours of learning – brings most dots (K_j) to the session. Imagination of the people present, and processing power in the case of the Machine, followed by evaluation and selection perhaps, then generates many interesting connections –new dots of knowledge or new ideas get created. These are represented by the double-edged arrows. They could be expressed in the language of an earlier brainchild or in terms of dots of 1^{st}, 2^{nd}, or higher order.

It is hard to imagine that mankind hasn't made strides in quantifying knowledge and knowhow. Exploring what is out there and summarizing it for the AI experts to take that and develop machines that brainstorm alongside Henry, Hillary and Herb, would make a great topic for a separate project… To say it like Alan Turing – arguably the inventor of 'the machine' (computer) that we keep referring to: "We can only see a short distance ahead, but we can see plenty out there that needs to be done" (Turing, 1950, p. 460).

Definitions of Terms Related to Artificial Intelligence (AI) and Machine Learning (ML)

I put together a list of definitions of terms that we are bound to come across when reading about AI (Dull, 2016; What is IoT? IoT basics for your business, 2017). I added a few examples for most terms.

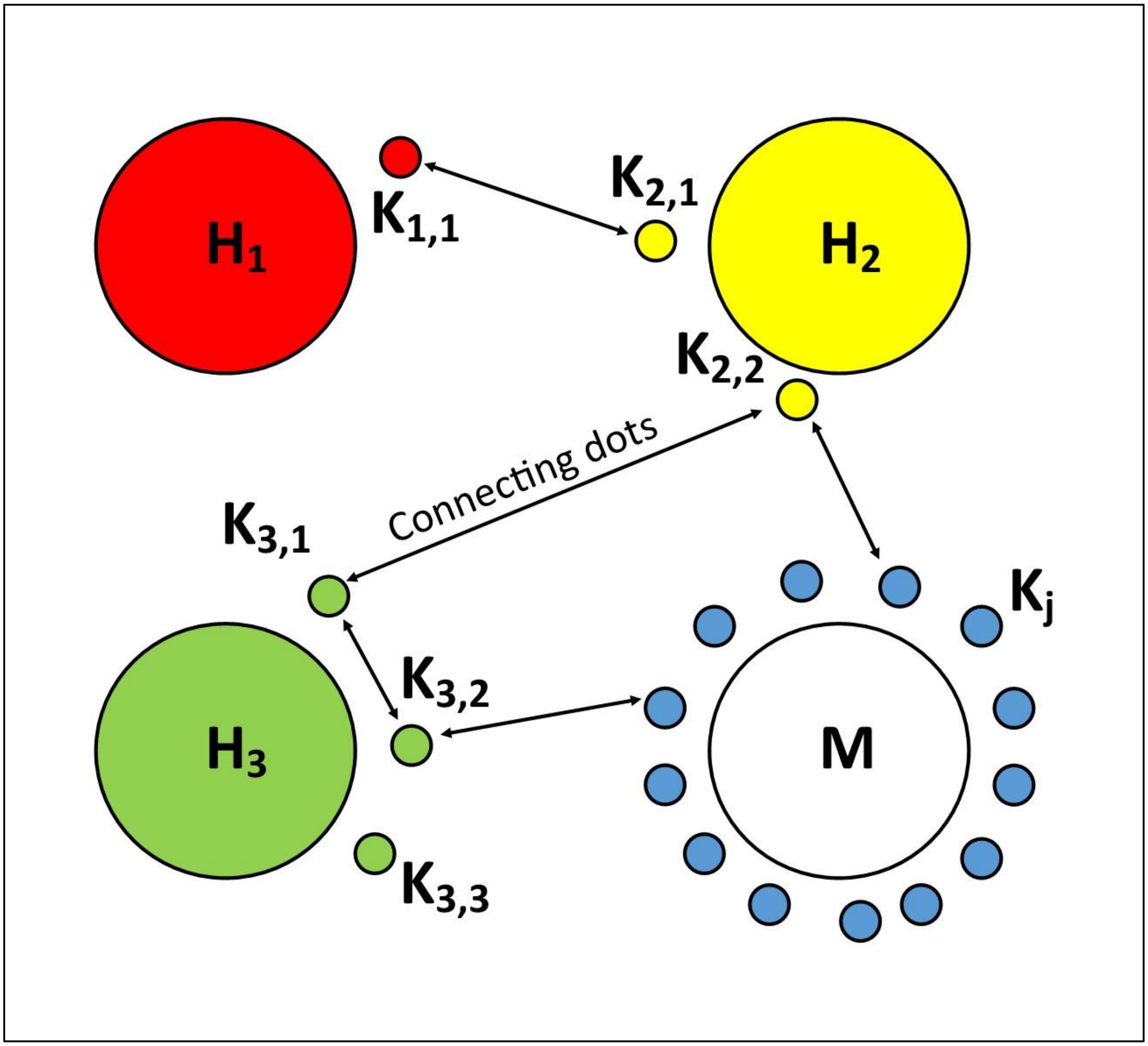

Figure 5. Visualization of 3 humans and 1 machine connecting their dots.

Artificial Intelligence (AI)

1. AI is human-like intelligence exhibited by machines, sometimes referred to as machine intelligence. For example, AI focuses on making machines perform equal to or better than a human when it comes to accuracy, capacity and speed.
2. AI is software that perceives its environment and takes actions that maximize its chance of success at a random goal. For example, when a machine uses cutting-edge techniques

to competently perform or mimic "cognitive" functions that we intuitively associate with human minds, such as "learning" and "problem solving".

Examples: Google Maps and Waze mobility applications. Facebook using computer vision to recognize faces when you upload a photo. See also below: Deep Learning, Machine Learning.

Algorithm

An algorithm is a software procedure, i.e., a set of instructions designed to perform a specific task. Since there's typically more than one way to complete a task, an algorithm may be modified over time to improve its performance, efficiency or even accuracy.

Augmented Reality (AR)

AR is the blending of virtual reality (see below) and real life. AR appeals to the senses by inserting computer-generated sounds, videos, graphics or GPS data into an existing real life setting.

Example: IKEA has an augmented reality catalogue to allow shoppers to visualize how pieces of furniture could look inside their home. This app also measures the size of the items against the surrounding room and what's in it (Evans, 2014).

Big Data

Amounts of data that are so large that traditional technologies cannot handle their transfer or analysis.

Example: The detailed shopping transactions (who buys what in which store at what time…) at Walmart, in digital format.

Bits and Bytes

A bit stores a 0 or a 1 and is the smallest unit of information. A byte groups 8 bits into a string (for example 10001010). I have witnessed the order of magnitude of information that was 'common language' increase by a factor of 1,000,000,000,000,000 (10^{15}) between the time I first worked with a computer in 1995 (kilobyte was a huge unit back then) and today: we are commonly using the term 'exabyte' nowadays (10 to the power 18). In fact, in 2010 – admittedly ages ago in the context of computer technology – more than a 1,000 exabytes of digital data were produced worldwide (Lewis, 2013). The common prefixes used as short hand for very large numbers are shown in Table 2.

Chatbot

Like a voice assistant, chatbots are services you access through a chat interface. Some chatbots are powered by AI and some by a set of rules.

Example: Some large companies already have chatbots (machines) answering the phone when you call for help with, for example, an IT-related problem. They use natural language processing (NLP; see definition below) to listen to your problem and guide you through steps towards a solution.

Table 2

Common prefixes used as short hand for very large numbers.

Prefix	**Power of 10**
Kilo	3
Mega	6
Giga	9
Tera	12
Peta	15
Exa	18
Zetta	21
Yotta	24

Cognitive Computing

Sometimes described as the holy grail of AI. Imagine asking a machine a question (like you do with Siri or Alexa) and having the machine answer. Then imagine the machine providing you with additional information about your question you never thought to ask, along with a narrative summary and suggestions on how to analyze further. This is how cognitive computing works. It brings the ‘smarts’ to the Internet of Things (IoT - see definition below).

Data Lake

A data lake is essentially a storage repository that can hold all types of data in its original format. Unlike a data warehouse, the data doesn’t have to be cleaned up or structured before it’s stored. This makes it easy for organizations to quickly capture and store all their big, IoT data.

Deep Learning

1. Deep Learning is a subfield of Machine Learning (see below), which uses several layers of neural networks (algorithms that mimic the human brain). It involves feeding a computer system a lot of data, which it can use to make decisions about other data. This data is fed through neural networks, as is the case in machine learning. Because Deep Learning work is focused on developing these networks, they become what are known as Deep Neural Networks – logic networks of the complexity needed to deal with classifying datasets as large as, say, Google’s image library, or Twitter’s firehose of tweets.
2. Deep Learning is a technique to implement machine learning, which in turn is a subset of AI. Deep Learning helps automate predictive analytics. It can take lots of unstructured, unlabeled data (like IoT data) and create its own highly accurate, predictive models. It emulates how we learn, as humans, to gain certain types of knowledge. Common applications include image and speech recognition.

Example: IBM’s Watson

Facial Recognition

This uses facial features in a digital image or video frame to identify a person.

Example: Google Photos automatically recognizes faces and tags people in your photos.

Grid Computing

Grid computing reduces costs by maximizing existing resources. This is accomplished with multiple machines working together to solve a specific problem.

Example: SETI@home is a project that bundles the computing power of the machines of many individuals, to analyze data in search for signals from space to detect extraterrestrial life.

Internet of things (IoT), Internet of Everything (IoE)

The concept of connecting physical objects (i.e. “things”) to the Internet (and/or to each other) to make them talk, listen and/or perform tasks. The process of sensing, collecting, transmitting, computing and generating insights. IoE is what we get when connecting things, AND people and processes (Bradley, Reberger, Dixit, & Gupta, 2017).

Example: Your electric coffee maker starts making you a cup as soon as the alarm of your iPhone goes off in the morning. The heating in your home kicks in as soon as your car enters a range of 25 miles around the house, after work.

Machine Learning

Machine Learning (ML) is an approach to achieve AI. Modern ML techniques use a set of algorithms (neural networks) to make a system artificially intelligent, to enable it to find patterns in large datasets and apply the findings to new data. ML can be used to train computers to understand and use human language (text and voice) – referred to as Natural Language Processing, or to identify and analyze images (as in computer vision).

Example: Ride-sharing apps like Uber; spam filters and smart categorization in email applications.

Natural Language Processing/Generation (NLP/NLG)

Understanding and/or interacting in human language. Often used to detect sentiments in written or spoken text (for example, to find out if people are complimenting, or complaining about, your hotel on social media), to discover new or surprising elements or as a taxonomy tool (for example used to automatically route emails to the right department or person). Used in voice-enabled smart watches, smart home applications, context-specific searches, and finding semantic similarities of words and phrases.

Examples: Chatbots, Apple's Siri, Amazon's Alexa.

Neural Network

Computer system used in modern machine learning and deep learning that is patterned after the operation of neurons in our human brain.

Quantified self

The quantified self is all about self-tracking and life logging. Equipped with wearables and body sensors, an individual can keep track of every aspect of his life – from exercise to sleep, heart activity to calorie expenditure, and nutrition to food consumption.

Robot

Machine that performs various complex acts (such as walking or talking) of a human being (Merriam-Webster, 2017).

The term usually refers to machines performing mechanical activity (as in the production of cars) – not cognitive – although there are cases where both can be combined; for example, in the case where Machine Learning is combined with robotics as in the sense above. When a robot is made to resemble a human being, it can also be called 'humanoid'.

Supervised Learning – Unsupervised Learning

Machine Learning whereby the machine is fed with many examples – selected by humans, hence ‘supervised’ - of the right answer to a given problem. Unsupervised Learning machines learn on their own from data collected in their environment.

Virtual Reality (VR)

A three-dimensional, computer-generated environment that you can explore and interact with. It is an immersive experience that makes you feel like you're interacting with your digital environment.

Example: You experience the thrill of a roller coaster while sitting at home in a moving chair with your VR helmet on.

Above terms are quite interrelated. Some of them are special cases or examples of others, some are the input for, enablers or creators of others (see Table 3).

Table 3

Relationships among selected AI-related concepts.

	AI	Algorithm	AR	Big Data	Chatbot	Cognitive Computing	Data Lake	DL	IoT	Facial Recognition	IoE	ML	NN	Quantified Self
Artificial Intelligence	—	Subset of			Means to; Input for	Means to; Input for				Means to; Input for		Means to; Input for	Means to; Input for	
Algorithm	Enables	—	Means to; Input for		Enables	Enables		Means to; Input for		Enables		Enables	Enables	
Augmented Reality			—											
Big Data	Means to; Input for	Means to; Input for		—			Creates	Means to; Input for	Enables		Enables	Means to; Input for	Means to; Input for	
Chatbot	Example of	Example of			—	Example of		Example of				Example of		
Cognitive Computing	Subset of					—		Subset of				Subset of		
Data Lake	Means to; Input for			Subset of		Means to; Input for	—	Means to; Input for				Means to; Input for	Means to; Input for	
Deep Learning	Example of	Example of			Enables	Enables		—		Enables		Example of		
Internet of things									—		Subset of			Creates
Facial Recognition	Example of									—		Example of		
Internet of Everything				Creates			Creates				—			
Machine Learning	Example of				Enables	Enables		Enables		Enables		—	Subset of	
Neural Network	Subset of	Example of			Enables	Enables		Enables				Enables	—	
Quantified Self				Creates			Creates		Example of		Example of			—

Example of	(blue)
Subset of	(yellow)
Means to; Input for	(red)
Creates	(green)
Enables	(grey)

Where and How Is Artificial Intelligence Used in Today's Business World?

There are essentially 2 places where one is most likely to find the state of the art of (any) new technology development: the military and the business world ("industry"). Mostly because they have a lot of money. The military tends to be secretive about what they invest in, and typically only release sensitive intelligence once it is no longer differentiating to them. An example of this was satellite navigation (GPS). We learn more and quicker from the business world, if only thanks to the patent disclosure system, and the fact that business relies on customers or consumers to spend money on their widgets to generate profit. According to Morini-Bianzino (2017) the AI areas that received by far most investment dollars in 2016 were machine learning ($5-7 billion), computer vision ($2.5-3.5 billion) and natural language ($0.6-0.9 billion), followed at a distance by autonomous vehicles, robotics and virtual agents.

Consulting firms help companies, small and large, cope with and implement technological advances. I skimmed consulting firm brochures and websites (Bughin et al., 2017; Varadharajan, 2017), and talked to consultants in my personal and business network to create following overview of what AI is doing for business nowadays. The industries that are currently most active in AI include healthcare, commerce, advertisement and marketing, business intelligence and analytics, financial and insurance services, cyber security, and sales - including customer relationship management (CRM). Furthermore, automotive technology, personal assistants, human resources, education, and news, media and entertainment are catching up (Varadharajan, 2017). AI applications can largely be organized in one of two buckets: (1) perception and (2) cognition. Examples of AI currently used in industry follow in Table 4 (Brynjolfsson & McAfee, 2017; Varadhatajan, 2017).

Table 4

Examples of AI applications in industry.

Category	Industry	Example
Cognition	Advertisement	Facebook and Google use machine learning to target ads, customized to "segments of 1" (not targeted to for example "all males between 40 and 45 with a college degree")
Cognition	General B2B, B2C	Data have no value, insights are what matter. When an algorithm tells a sales person “Mr A is a prospect for your product”, then that is only somewhat useful, but not very. The sale sperson ends up with 'cold selling'. Now 'machine learning' transforms 'big data' about a prospect and produces arguments that sales people can use: "A is a prospect for your grey Maserati sports car - and here's why! (For example, based on internet browsing behaviour, a machine may have concluded that Mr. A must have inherited a lot of money or earned a thick bonus at work (because looking at websites about investing), loves the color grey (a setting in his Google profile) and might be looking for a new (sports) car (his avatar is a Ferrari).
Perception	Personal assistants	Amazon's voice-controlled assistant Alexa learns from interacting with its owner, and has thousands of skills built-into it. It understands (NLP) and replies to (NLG) questions in seconds. See also Apple's Siri assistant on iPhones.
Cognition	Banking	Banks use AI to predict (3 months ahead of the facts), that one of its clients is heading towards financial trouble, and take measures to avoid losses.
Cognition	Health care	Neonatal intensive care. A baby born 3 months too early has a brain that is not as developed as it should be for a newborn. So it does things wrong. It cries when happy for example. People/nurses don’t know what to do. Using ML with input such as brain waves, sound (various frequencies and intensities in the babies cries), body temperature, heart beat rate, … and expert nurses: now there is a monitor above the premature baby's cradle which states “happy”, “hunger”.
Both	Broad	Chatbots listen to a consumer's problem and offer solutions or support. This job used to be outsourced to Bangalore, India...
Both	Automotive	Tesla's autopilot function learns (in real-time - since the car is always 'online') from every situation where a driver regains control of her vehicle, improving the reliability of the autopilot service.
Cognition	Financial services, investment banking	Financial analysis and reporting used to be a very time consuming job. Financial analysts are very specialized, well-paid and in high demand. Machines started taking over the analysis part of the job first (turning raw data into processed data, and generating visuals) and are now making inroads in the customized (textual) report-generating step of the process, using NLG-technology (natural language generating).
Perception	Airports	Remember the days that every X-ray machine has 1 person next to it, watching a monitor as your bag, laptop, shoes … went by on a belt? Those days, and most of those people and jobs, are gone. AI has taken over the image analysis, in search of suspicious looking stuff. When the machine is in doubt about your bag, it will pull it out of the queue and order a manual search. The learning from that search gets fed to the machine, which becomes better and better at the search job.
Cognition	Broad B2B	IBM Watson provides mines the web and utilizes cognitive computing services such as: keyword extraction and concept tagging (NLP), sentiment analysis , taxonomy, linked data and relationship extraction.
Cognition	Leisure and entertainment	Machines beat the best human players of chess, poker and Go.
Cognition	Engineering	Google's Deepmind team used ML to improve the cooling effiviency in their data centers by more than 15% - after human experts had "optimized" the system.
Perception	B2C -broad	Facebook's AI tools recognize faces and tag people in pictures. The same technology is used to give blind people 'sight'; an app uses voice technology to tell them what a camera is looking at (their kid, an outdoors scene, a photo, or the cover of a magazine). A picture is worth a thousand words... but sometimes only 2-3 are sufficient to make a blind person smile.
Perception	B2C	Self-driving cars spot pedestrians on the sidewalk; error rate less than 1 in 30 million.
Perception	Mobility	Dictation of text, which a machine "types" for the user almost flawlessly (error rate below 5%) - far faster than a person could.

How and Where Neural Networks Work

An artificial neural network is inspired by a biological neural network, hence mimics the workings of the human brain. As human brains do, neural networks learn by exchanging data/signals between neurons. Depending on how connected those neurons are – in the case of the brain the connections are called synapses - a signal gets passed on entirely, in a weakened form, or not at all. When a neuron transmits a signal, we say that ‘it fires’. NN take inputs (data provided by people in the case of supervised machine learning), and adapts the connections between its neurons (by ‘weighting’ them), to end up with an output that is expected. Hence the neural network reinforces or weakens connections between neurons as it maps more and more input data to expected outputs (during ‘training’). In this iterative process a connection is “rewarded” (reinforced) when it contributed to finding an answer close to what was expected, and it is penalized and weakened when it contributed to an answer that is too far from what was expected.

Neural networks typically are depicted as a series of parallel layers. Each of those layers counts a set number of neurons. Each neuron within a given layer can be connected to every neuron in the adjacent layers. See Figure 6, in which a very simple NN is drawn. It has one input layer with three neurons, one hidden layer with four neurons, and one output layer with two neurons. The black arrows signify connection between the neurons. To make this concrete, the input layer could for example consist of 3 integers, the output layer of respectively their sum and their average.

In Figure 7 I show what is going on at one neuron in the hidden layer. It is receiving a signal equal to the weighted sum of the signals from the three input neurons. The weighted signal is nothing more than its original strength (input value x) multiplied by a weighting factor with a value between 0 and 1 (weight w). The sum of these three weighted signals, called the net input signal (n), is then compared to a set threshold value. If n is larger than the threshold, the blue neuron fires a signal through all the connections that tie it to the next layer. If it is smaller, no signal passes.

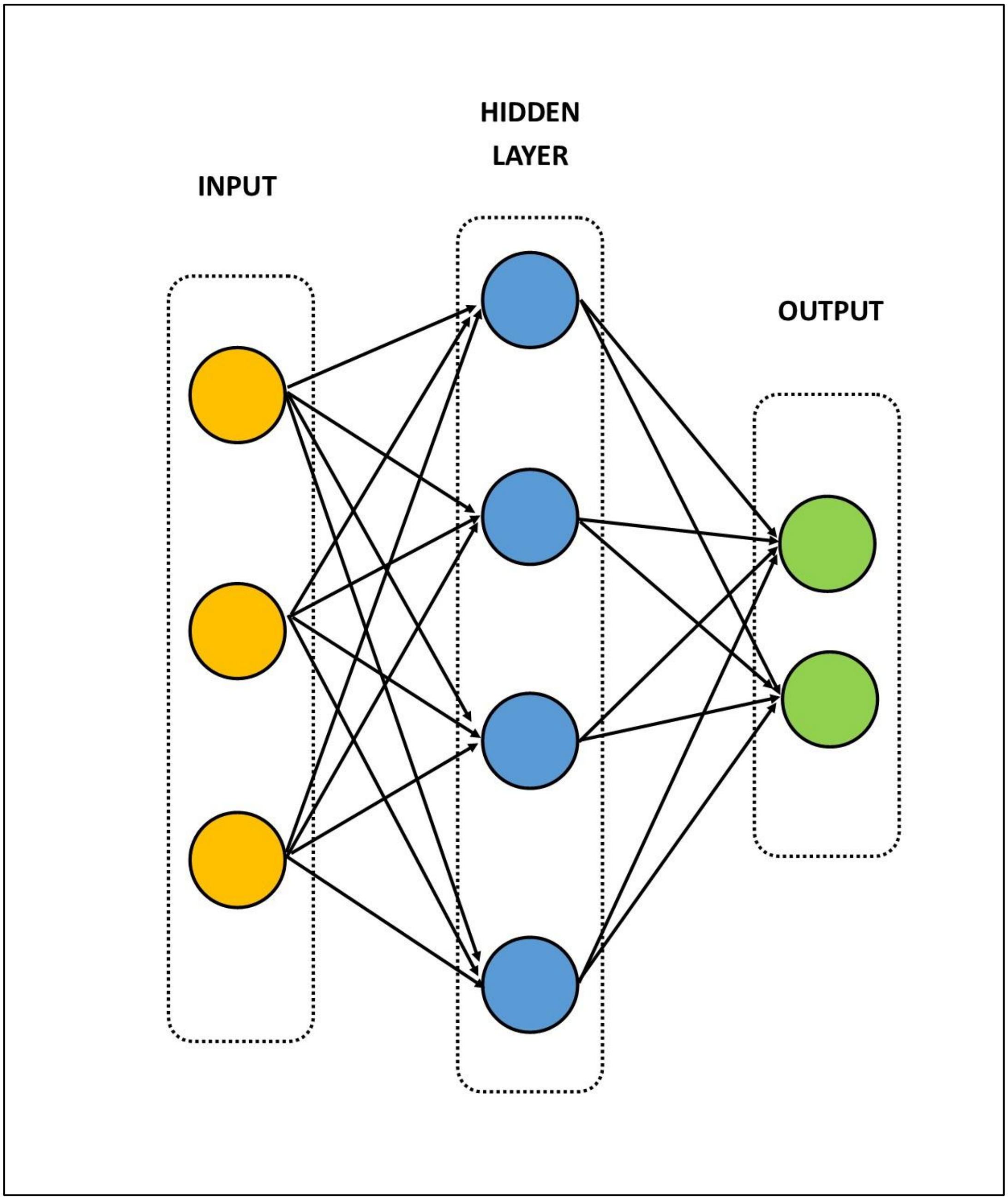

Figure 6. A neural network with three layers and 10 neurons.

This is happening at each neuron that receives signals from other neurons. In real life the numbers of hidden layers and neurons per layer can be far more than just the few from the example we just discussed. Also, things get far more complicated mathematically, because developers often use so called transformation functions to make the networks more powerful and more impressive ‘learners’ – but that is too technical a matter for this context.

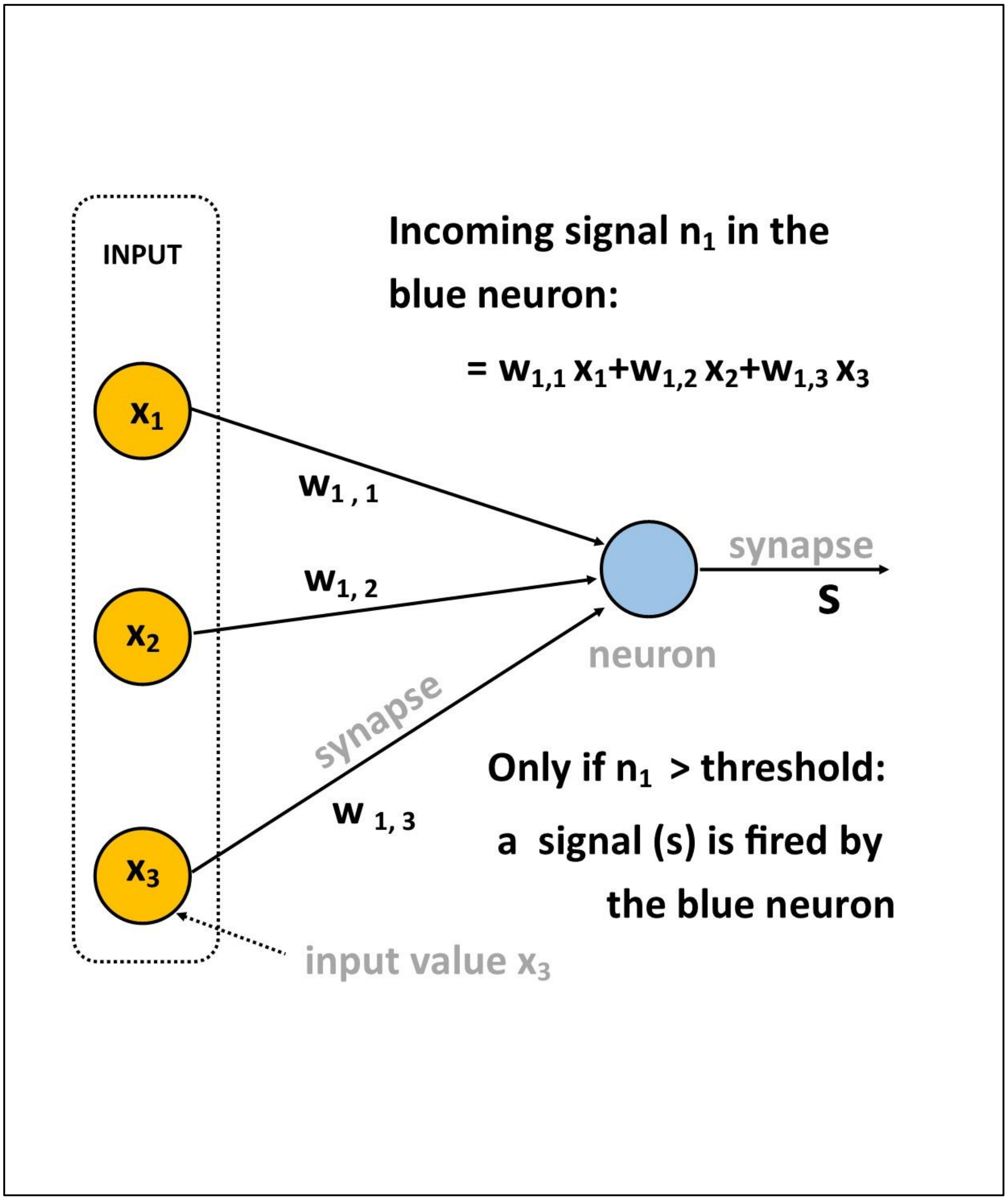

Figure 7. Close-up of the incoming signals in one neuron from Figure 6.

Neural networks need to be tuned by human experts; they design and tweak the architecture (number of layers, and number of nodes in each layer) to make the NN as efficient (a balance between speed and capability) as possible for a given type of problems. Intuitively one understands that the more layers and the more neurons are involved, the more capabilities the NN has (the more complex the problems it could solve), yet also the more cumbersome it will be to train it and the slower it will become (it will take more computation to run from input, through all connections to output). Besides for feeding the NN with data, human intervention is also required to initiate the NN (they 'seed' it: they need to set the starting values (strengths) of the weights of the connections between all nodes, before the NN processes its first data set.

Once the NN is trained enough (i.e., it has learnt through experience), it can infer complicated rules or find patterns in complex data sets, far better than human brainpower ever could. Of course, humans can also compute the sum and average of three numbers, only slower than a calculator or a neural network. Humans however don't do so well detecting the license plate number of a criminal in 5,000 hours of video from a security camera at the border between two countries – unless they watch, well, about 5,000 hours of video without falling asleep. A neural network would do this in a fraction of the time that a large team of people requires to do so.

Also, note that once a NN is trained to do something (for example, solve a problem or detect a pattern), that algorithm can easily be copied onto another machine. Whereas training a human being for a task can be a long and slow process, 'teaching' 200 other machines to do what one machine has been trained for and learnt as a result, takes as little time as copying an algorithm into their memory. This has far ranging consequences – not in the least for the business case of using machines for tasks that in the past took highly educated, well paid employees.

Creative Problem Solving - The Thinking Skills Model

Brief History and Where AI Could Fit In

(Barbero Switalski, 2017; Hicks, 2004; Puccio, Mance, & Murdock, 2011)

Osborn and Parnes are the fathers of the original Creative Problem Solving (CPS) model (Osborn, 1942, 1952, 1953; Parnes, 1967). CPS is “a well-known approach that engages people in bringing order to the sometimes-chaotic creative process” (Puccio, Murdock, & Mance, 2005, p.44). Originally a seven-step process, it was later modified to contain only three: fact-finding, idea-finding and solution-finding. An important characteristic of CPS is the deliberate separation of a divergent (with deferral of judgement) and a convergent (using affirmative judgment) phase in each step. Isaksen, Dorval and Treffinger (1994) made CPS componential (as opposed to a step-by-step process), implying that one could start anywhere in the process, according to the context. They called the three components (1) understanding the problem, (2) generating ideas and (3) planning for action, and added a metacognitive step to the process, called planning for approval.

Puccio et al. formulated an elaborated version of the original Osborn-Parnes CPS model and baptized it CPS - The Thinking Skills (Puccio, Mance, & Murdock, 2011; Puccio, Murdock, & Mance, 2005). They describe three CPS stages (clarification, transformation, implementation), each consisting of two steps (exploring and formulating) - and a 7th, metacognitive step called ‘assessing the situation’. The latter addresses whether there is a need for data or additional information and guides decisions to be made about both content and process, throughout any of the other six steps. They associated cognitive and affective thinking skills to each of those seven process steps. This gave their model a more applied and actionable character, and facilitated the learning process of CPS. On top of that, they list a few overarching thinking skills – both cognitive and affective. These building blocks of CPS – The Thinking Skills Model and the principles and guidelines for divergent and convergent thinking are summarized in Table 5.

In this context it is important to consider what exactly is meant by 'thinking'. Ruggiero defined it as "actively directing the movement of [their] mind" (1998, p. 2). So, does a machine used to create AI actually 'think'? A simple question, but the world has yet to agree on an answer. Alan Turing (1950) probably was the first one to formulate this question, but quickly reformulated it into what is nowadays known as the Turing test. If a machine can converse with a person such that it can fool her/him into thinking that it is a human conversation partner, the machine is considered to pass the test and is called intelligent – or capable of thinking. The debate stays messy until today, with disagreement about what thinking really should be defined like, and without a clear distinction between intelligence, thinking and learning. People looking for a definite answer to the question 'can a machine be creative?' are even worse off (Boden, 1998). The common denominator here is that concepts like intelligence, thinking, and creativity are very broad and that clear definitions still must be agreed on.

I would argue that, since it mimics the human brain's intelligence - which is characterized amongst other by its ability to learn - it does think indeed. I back this up with the support of the revised version of Blooms taxonomy by Anderson and Krathwohl (2011), in which the stages of learning (forms of thinking) are listed as (ranked form low to high complexity) remembering, understanding, applying, analyzing, evaluating, and creating (see Figure 8). Looking at what AI is capable of today, one can argue that learning machines accomplish all of these, although the last one in the series, creating, is up for debate. So yes, for this project, we will go with '(AI) machines think'.

Table 5

Overview of the CPS – Thinking Skills model: steps and skills

Step		**Assessing the situation**	**Exploring the vision**	**Formulating challenges**	**Exploring ideas**	**Formulating solutions**	**Exploring acceptance**	**Formulating a plan**
	Purpose	To describe and identify relevant data and to determine next process tep	To develop a vision of a desired outcome	To identify the gaps that must be closed to achieve the desired outcome	To generate novel ideas that address important challenges	To move from ideas to solutions	To increase the likelihood of success	To develop an implementation plan
Overarching skills	*Divergent thinking*	Fluency - Flexibility - Elaboration - Originality						
	Convergent thinking	Screening - Sorting - Prioritizing - Supporting - Developing						
Principles	*Divergent thinking*	Defer judgment - Go for quantity - Make connections - Seek novelty						
	Convergent thinking	Apply affirmative judgement - Keep novelty alive - Check your objectives - Stay focused						
	Wildcard	Allow for incubation						
Cognitive skills		Diagnostic thinking	Visionary thinking	Strategic thinking	Ideational thinking	Evaluative thinking	Contextual thinking	Tactical thinking
	Definition	Making a careful examination of a situation, describing the nature of a problem, and making decisions about appropriate process steps to be taken	Articulating a vivid image of what you desire to create	Identifying the critical issues that must be addressed and pathways needed to move forward the desired future	Producing original mental images and thoughts that respond to important challenges	Assessing the reasonableness and quality of ideas in order to develop workable solutions	Understanding the interrelated conditions and circumstances that will support or hinder success	Devising a plan that includes specific and measurable steps for attaining a desired end and methods for monitoring its effectiveness
Affective Skills	*Step-specific*	Mindfulness	Dreaming	Sensing gaps	Playfulness	Avoiding premature closure	Sensitivity to environment	Tolerance for risks
	Definition	Attending to thoughts, feelings and sensations relative to the present situation	To imagine as possible your desires and hopes	To become consciously aware of discrepancies between what currently exists and is desired or required	Freely toying with ideas	Resisting the urge to push for a decision	The degree to which people are aware of their physical and psychological surroundings	Not allowing yourself to be shaken or unnerved by the possibility of failure or setbacks
	Overarching	Openness to novelty Tolerance for ambiguity Tolerance for complexity						
Subskills		Ability to bypass mental traps	Imagery	Reframing	Metaphorical/ analogical thinking	Ability to define success criteria	Pinpointing critical variables	Formulating a plan in concrete and measurable actions
		Formulating relevant questions	Story Telling	Problem scoping	Associative thinking	Finding imperfections	Isolating critical stakeholders	Establishing critical paths
		Identifying structures and patterns that underlie a complex situation	Seeing the potential	Identifying strategic priorities	Transformational thinking	Making improvements	Positioning the benefits	Troubleshooting and contingency planning
		Interpreting, formulating hypothesis and drawing						

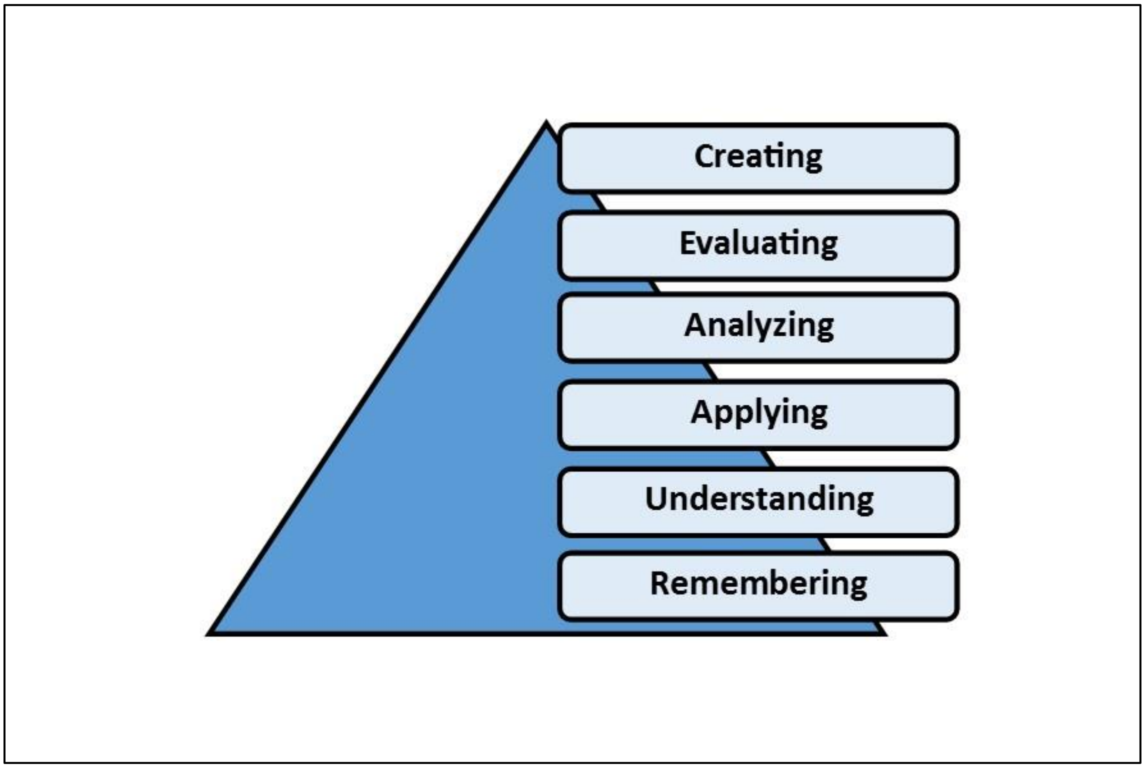

Figure 8. Revised Bloom's pyramid of learning domains.

What about the affective side of machines? Lack of emotional intelligence is what people most often use as an argument why machines can't be creative, because 'machines can't feel, can't be empathic, can't read (or respond to) emotions'. Well, maybe we should reconsider that statement. AI, and more precisely the field called 'computer vision', can analyze pictures and video, looking for the emotional state on faces, to adapt the message sent to the people behind those faces. Machine learning is used to train machines to recognize body language. Soon Amazon's Alexa (digital assistant) could be talking to you in this way: "are you ok my dear, you seem to be worrying about something". Basically, machines can already read your facial expression and match it to one of the many emoji's out there. Are machines as emotionally intelligent (EI) as humans? No. Can they cope with some aspects of EI already? Definitely. Will there be a day that a machine shows equal or even better EI than some people do? We can't exclude this. After all, emotions originate in the brain, through a complex process of countless neurons firing at each other. It's just a matter of particles (yes, electrons) moving through synapses. Once again, there is no law of physics that says that we can't also mimic this process using computers and by sending electrons through circuits in a neural network.

How much AI effort in CPS is enough? How many connections do you want a machine to make for you, how many ideas do you want to consider? An important life lesson I picked up during my studies in science says that life is non-linear. We often like it to be linear, and it serves us well to approximately model many things we see around us in nature. So yes, more can be good, but it is not automatically better forever. There is an analogy to this from the field of economics. Laffer explained that raising taxes is good for the purse of a country, but only up to a point; beyond that point, raising taxes hurts a country's income (see Figure 9). I will argue that exaggerating the dependence on machines could negatively impact the effectiveness of CPS efforts. For example, there certainly is no point in generating more ideas than people can screen.

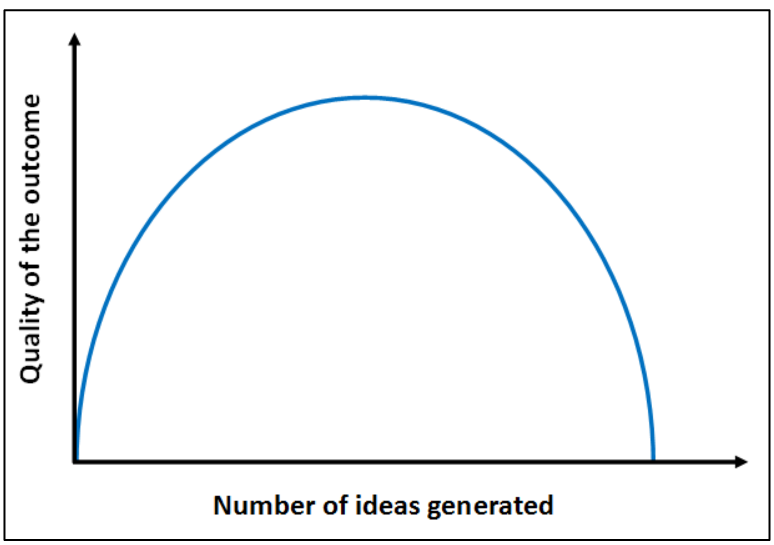

Figure 9. The Laffer curve

Table 6

Thinking tools: overview, classification and indication in which CPS: TSM step they could be useful.

Step		**Assessing the situation**	**Exploring the vision**	**Formulating challenges**	**Exploring ideas**	**Formulating solutions**	**Exploring acceptance**	**Formulating a plan**
	Purpose	To describe and identify relevant data and to determine next process tep	To develop a vision of a desired outcome	To identify the gaps that must be closed to achieve the desired outcome	To generate novel ideas that address important challenges	To move from ideas to solutions	To increase the likelihood of success	To develop an implementation plan
Tools	*Divergent thinking*	5 W's and an H	Invitational language stems	Invitational language stems	Invitational language stems	Invitational language stems	Stakeholder analysis	Generating action steps
		Why/why diagram	Wishful thinking	Statement starters	Brainstorming		Assisters and resisters	How/how diagram
		Powerful questions	Storyboarding	Webbing (WWSY)	Brainwrtiting		Forcefield analysis	Flowcharting
			Wallet checklist	Word dance (Boundary examination)	Forced connections			
				Backward/forward planning	Visually identifying relationships			
				Springboards (goal wishing)	Direct analogy			
					SCAMPER			
					Excursions			
					Rolestorming			
					Attribute listing			
					Morphological analysis			
	Convergent thinking	Hits	Success zones			Paired comparison analysis	Hits	Sequencing
		Mind maps Six thinking hats						
		Highlighting				Card sort	Reverse brainstorming	Performance dashboard
	Divergent AND convergent	SWOT	Visual explorer	Gap analysis		Criteria		Potential problem analysis
		Fishbone diagram	Imagery journalism	TRIZ		PPCO		
		Affinity diagram	Searchig for success zone	Cause and effect analysis		Evaluation matrix		
		KnoWonder	Value stream mapping	Nominal group technique		Impact / feasibility matrix		
						Targeting		
	Metacognitive	4 I's						
		Key word search						
		If-then process analysis						

Computer-aided Problem Solving

There are ample ways in which computers (machines) support the (creative) problem solving process (Hicks, 2004). Which is not to say that any of these are based on artificial intelligence. Electronic versions of existing thinking tools like stick 'm up brainstorming, hits, TRIZ and mind mapping have been commonly available since a decade now. Nielsen and Boccucci (2015) gave a nice overview of what's out there, online. Most of these tools can be used individually or in group settings using virtual/web conferencing – whether synchronous or asynchronous. Although there are definite advantages to these (time saving, not having to type as much and visualization, to name just a few) these are nothing more than a translation of the old analogue into the new digital – and all the thinking involved is 100% human, as opposed to machine-based. At best the only cognitive task that is taken over by the machine (website) is randomization of images, to aid forced connection, or to generate random connections for people to assess and evaluate.

There are more sophisticated tools however. Pro-Innovator (by IWINT), Innovation Suite (by Creax), TriSolver (by TriSolver GmbH) are a few of the software packages that guide the user through the TRIZ problem solving process (Papaioannou, 2008). They contain all or part of the following: a database with the 40 inventive principles, a step-wise guidance through the process, often supported by a nice graphical user interface. It comes as no surprise that TRIZ seems to have attracted a lot of interest from the software development industry, since the tool is all about structure and databases (principles, patents, …) - hence ideal to be 'computerized'.

The author's personal search through the Espacenet website for patents with TRIZ in combination with either 'neural network' or 'artificial intelligence' yielded zero results. For TRIZ alone 61 results, for 'artificial intelligence' 4,695…

There is one patent on computerized TRIZ which mentions the use of natural language processing (which is AI) in the description – but not in any of its claims (USA Patent No. US 2016/0004973, 2016).

How AI Could Give Creative Problem Solving a Boost

Let us look at some of the CPS steps and create a vision for how AI could augment our capabilities (see Figure 10). Each of the visions or challenge statements below could by themselves be addressed as the subject of a CPS session. Going into detail for each of them falls outside the scope of this project.

Exploring the vision – Formulating challenges

These are the two initial CPS steps where many questions are asked and where data are gathered. I'd argue that what is meant here is that information needs to be gathered, information which needs to be ploughed through and made sense of. The bad news here is that the amount of information pertinent to a certain area of interest is exploding – whereas the time we have available (to solve a problem, and in life in general) is not. I am convinced that this is the challenge where AI potentially is human's biggest ally. Machines have near infinite memory, and process (think) information faster than humans do. Before drilling down further into how specifically machines could be of help here – first a few words about how humans process information best: that is, using their eyes.

Our vision trumps every other sense (MIT, 1996). It consumes half of the brain's resources. Brains are hardwired to process visual cues, and to 'think in visuals'. Have you ever thought about why, when you read the letters f-i-s-h, you see a fish in your mind; but, on the contrary, when you see a fish in the water, you do not see the letters f-i-s-h pop up in your mind...?

Pictures and other visuals are mankind's biggest helpers when it comes to learning and remembering. They beat symbols (words, text), whether spoken or written (Medina, 2008). Also, the cognitive load caused by reading text is high. Letters must first be merged into words, and words interpreted (which often involves visualizing): that is a big detour, versus looking at an image corresponding to the same text (Sheth, Sharma, Rao, & Sur, 1996).

This is probably a reasonable explanation for why face-to-face meetings are so much more effective than virtual ones: because body language (which we observe best when present in person) adds so much information (call it color) to the sound we capture when we hear others talk. Although we take in information with the help of each of our five senses, vision accounts for an astonishing 80-90% of the information we get (Porter & Heppelmann, 2017). Hence the saying 'a picture is worth a thousand words': by the mere look at an image we absorb enormous amounts of information – indeed, the equivalent of very many pages of written text.

So, with that background – our vision being such a super-sense, and information being abundant and exploding – here's my vision of future mess and fact finding. Instead of wrestling our way through piles of articles and books, spending hours on web searches, downloading, reading some and ignoring most of it (a selection often based on no logic whatsoever other than lack of time), what if…

What if AI would take these (you name the power of 10)-bytes and turn them into images for us to glance at, flick through, garner insights from? Human eyes only need a fraction of a second of looking at something – and they capture massive amounts of information.

What if AI could turn dull documents filled with mostly text and turn them into easier to grasp, easier to assimilate, mind maps?

What if AI could be used to interpret our first rough list of challenge statements, and use NLP to suggest candidate statements that would fit in a ladder of abstraction (W/WSY tool)?

What of AI could use TRIZ as an engine to come up with analogue problem statements from other domains that solved a similar problem?

HMW use AI for sense making? Given an area to 'watch' (this could include for example a long list of websites, electronically accessible newspapers, journals, …) AI/NLP could detect patterns, or identify recurring opportunities or threats, leading to interesting challenge statements, detect often recurring keywords, etc. People don't have the time or the attention span to read all the information that hits them, machines could come to the rescue.

Exploring ideas and Formulating Solutions

What if we could use NLP to turn ideas that are read out loud (during classical brainstorming) or written down (in brain writing) into pictures? Instead of handing over our post-its during a CPS session we'd just be writing down and reading our idea, and a visual of that idea would appear on the screen for everyone to see. If we don't like what the machine created as a visual, we'd just tell it what to change to get closer to what we intended. Would the resource group find it easier to build on an idea in image form than on an idea in textual form?

HMW combine TRIZ with either the visual or the forced connections tool? AI could be fed with a contradiction that we try to solve for, mine the 40 inventive principles, and identify successful combinations of these principles (which have resolved that same contradiction elsewhere), and produce or retrieve images that serve as inspiration for the resource group.

Other (including 'assessing the situation' and facilitation in general)

What if AI were used to put together the ideal resource group to solve a problem, in a large company for example? Based on the FourSight profiles or any other information (background, experience, emotional intelligence…) the AI machine would compose a group with the right level of diversity, yet consuming minimum company resources. It would do this for every step in the CPS process (the dream team for visioning could look very different from the dream team for ideating).

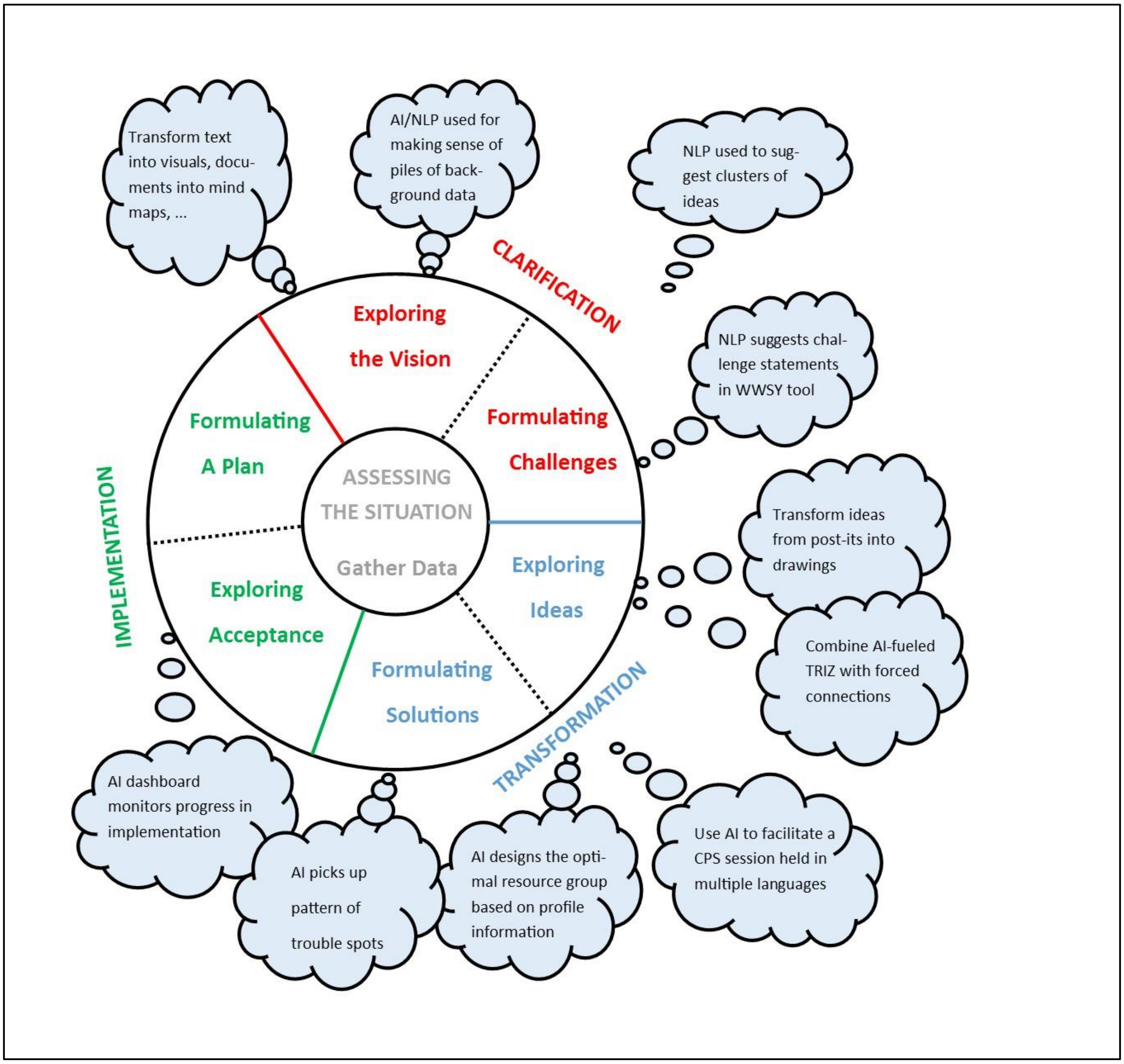

Figure 10. Examples of how we might use AI in CPS.

The machine would perhaps be able to simulate all possible scenarios for various team compositions, and highlight possible explosive situations to be avoided, to the facilitator.

Alternatively, given a group and the profiles present, the machine could suggest appropriate tools for each CPS step, or indicate the risk of focusing too much on one step and ignoring another.

What if AI would allow us to take whatever every individual has contributed to a session (data, questions, visions, statements, ideas, …) and create a report for that individual and/or the facilitator? It could contain suggestions for how to improve for example the team member's fluency or flexibility. I could analyze the diversity of the output of the various people and suggest making changes in the team composition for future sessions.

What if people were wearing a sensor that measured their physicals (heart beat rate and variation, blood pressure), and computer vision assessed their body language, posture and emotions (passion, anger, ecstasy, disappointment, sadness, disbelief…)? They and/or the facilitator could be warned if there were visual or physical cues of the gator brain taking over, of them being emotionally hijacked.

What if the output of any kind of divergent thinking tool (often tens to hundreds of post-its!) were captured digitally, and AI/NLP automatically clustered it based on semantics? What if AI detected the key words in those clusters? What if AI detected the traces of novelty in those clusters?

What if NLP were used to enable CPS with remote people participating in all kinds of languages? AI could translate whatever is being produced elsewhere into your language, and it would be just as if you were in a CPS session with only people speaking your language. Here comes CPS with you, 2 Inuits, a Japanese, 3 Koreans and 2 guys from Hungary.

What if AI tore apart the assumption that 8-12 is the ideal group size? Maybe that is just because with more people things slow down and the process becomes inefficient. Maybe a machine facilitator and AI bells and whistles could handle facilitating 400 people at the same time. Maybe a machine could simultaneously facilitate 40 sessions being run synchronously in 40 different locations. Machines can have multiple (name a number!) conversations at once – we humans can handle one and at best pick up fragments from a second – although then we get confused about the first.

HMW use AI in combination with VR or AR to facilitate incubation? Based on 'natural incubation habitat' information (a forest, the shower, a bench by the lake…) of participants, we could let all of them incubate in one and the same meeting room. We could spice the experience with images, sounds, sensations that have been cleverly chosen to keep their thoughts centered on the objectives or the problem to be solved.

HMW bring a 'Clippy' into creative problem solving? Clippy used to be the virtual assistant in Microsoft Office that was popping up every now and then with suggestions about how to get certain things done while working in a Word, Excel or PowerPoint document. That was an early kind of AI – but there was no real-time learning involved for Clippy. What if we developed a virtual (AI) assistant (called Bulby: as good a name as any) that follows the discussions during problem solving and that offers leads, comments, supporting documents and images, renowned experts that you could get in touch with, etc.? Bulby would be topping up the team's knowledge on the fly, tweaking and optimizing the diversity present around the table as you go through the process, suggesting areas based on TRIZ that have solved a similar problem. This development could be guided by

- Mathematical disciplines like 'graph theory' (essentially graphs made up of nodes and networks – with nodes being individuals, companies, …) and
- The use of 'weighted networks'. Not every node is equally relevant or important in the graph. Compare this to the 'rich club phenomenon' analogy; some people or dots in a graph have more weight – are more influential – than other (Hinssen, 2014).

Provocative and Interesting Questions

If AI-augmented creative problem solving were proven to be better (in any way whatsoever), would the CPS community be willing to give up its human-centric view on CPS? Would they be prepared to take on a machine-centric point of view?

To what extent do the CPS guidelines for divergent and convergent thinking need to be adjusted when machines come into the picture?

Aren't some of the human strengths versus machines (see below) – such as empathy, emotional intelligence – only relevant in situations where teamwork is required to solve a problem? Are they still relevant if 1 person solves the problem with the help of machines?

How do we not upset people when they are confronted with the power and possibilities of AI? Lisa Buseaglia, one of the participants in my unconference session approached me afterwards and asked: "what will become of the children that (today already) drop out of school due to learning disorders, illness, difficult situations at home, and poverty?" Machines and their perceived potential to replace jobs puts people on the defensive.

What Makes Humans Unique Versus Machines in the Context of CPS?

During this project I've spent much time wondering and seeking opinions about what makes humans unique, and about why people would argue that machines would never be able to match human capabilities – in the context of creative problem solving. In what follows I summarize the results of clustering and rephrasing the many answers I have collected, interwoven with my own views and learnings from the master's program that this project concludes.

The following are considered clear human strengths and machine weaknesses:

- Wishing, desiring, and imagining the future – coming up with vision statements.

- Our ability to ask questions is a very human trait. In fact, it differentiates us from all other species. It is also machine's greatest weakness. This is very relevant to formulating challenge or problem statements.
- Intuition, gut feeling.
- Common sense, which is an important guide in assessing the situation, during a CPS process, and ethical behavior to guide our decision making to do the 'right thing'. Human norms and values guide evaluation and selection in each of the stages of CPS: when choosing the right vision to pursue and the right problem to solve, the right idea to develop, the right solution to implement, in the right way for as many stakeholders as possible.

Emotional intelligence (EI) is an interesting strength. It is often referred to as impossible for machines to learn. The Theory of Mind (Siegal & Varley, 2002) teaches us that our ability to predict and/or understand the motivations of the people (and pets) that we live and work with, characterizes humans very well. There are no or only very few physical signs telling us about the inner workings and motivations of others, yet our ability to read those workings is a unique human talent that sets us apart from other species. It is what facilitates that people collaborate and tackle societal and other problems. Not surprisingly scientists are working hard to pinpoint the brain structures and neural networks that lie at the basis of this ability. Through machine learning a computer can be taught to recognize facial expressions, corresponding emotions, and to tune its actions to take these emotions into account. This is only one aspect of EI, but it justifies rejecting any claim that rules out machine EI.

Unconference Workshop at CEE 2017 – Summary Report

A large part of the outcomes of this project was used to create, well, more outcome… At the Creativity Expert Exchange (CEE), held October 13-15, 2017 at Buffalo State College, I facilitated an Unconference session about creativity and AI. The unconference concept is a rather recent development at conferences. Presenters pitch their topic to the conference attendees, who then choose a session of their likings (and walk off to another session if they feel they are not learning or contributing sufficiently). I was pleasantly surprised to see that about 25-30% of all unconference participants had chosen to attend my session (they had a choice of 8).

The slides I used for that event are reproduced in Appendix A. I introduced the topic (the impact of AI on creative problem solving) with 8 light-to-digest, mostly visual slides, and then opened the discussion with a few open questions to engage the group. The 90 minutes we were granted flew by, and the energy level in the room was amazing. Nobody walked away; to the contrary, a few people joined us halfway.

I received valuable and constructive criticism and suggestions from Ron Beghetto (University of Connecticut) afterwards, and one participant connected me on the spot to her brother - who happened to be a director at one of Google's AI divisions. One element that stuck with me was the extent to which the AI topic polarized the audience into pro and contra. Some people seemingly felt threatened and defended 'the human facilitator' against heartless machines; others were ready to grab the added potential provided by powerful machines with both hands.

An important lesson learnt for me was that choice of language and storytelling would be very important if I want to rally the creative problem solving community behind using AI as an ally. Furthermore, the audience raised and debated several intriguing questions. I list a few of them here:

- How big of an issue is the lack of (machine) empathy for the formulation of problems and ideas?
- Will AI facilitators one day take human facilitator jobs?
- How do we as CPS practitioners and facilitators have to evolve in the light of AI becoming so important in the rest of our lives, and perhaps in problem solving?
- Does AI only help people with the K (knowledge) in Noller's formula? If K contributes to I (imagination), doesn't AI automatically also help people with imagination?
- HMW use a variant of Google for problem solving – and what would it have to look like?

My Application to Facilitate a Spark Session at CPSI 2018

In 2017 I attended the Creative Problem Solving Institute (CPSI) conference in Buffalo, NY for the first time, as a participant and student. My experiences from facilitating the unconference at CEE were so positive that I want to go a step further. I decided to apply to facilitate a full day Spark Session at CPSI in the summer of 2018. See Appendix C. Six months from now I expect to know a lot more about AI and its potential in CPS. I want to leverage this project work and my further studies in the subject of AI and its potential in CPS, to facilitate CPS sessions about how technology and AI could augment creative problem solving in the future.

SECTION 5: KEY LEARNINGS

Process Learning

This project was a major CPS exercise. I fell in love with the subject of technology and its use in CPS during the 'current issues in creativity studies' course (CRS625). For a long time, I felt as if I failed to describe in precise enough terms what the scope of this project was. I think I resisted or refused to make it 'small' and too narrow-focused, and I kept seeing it broad. Or phrased positively, I kept an open mind and resisted premature closure. The good side was that I kept discovering interesting links with stories I was reading or hearing about; the bad side was that it delayed the point at which I could start writing up the content in a targeted way.

I sometimes forgot to check my objectives (which I had written out in Section 1) and found myself going into one rabbit hole after another, not resisting my curiosity and the temptation to read yet another interesting fact about ML/AI – although that next extra interesting fact wasn't necessarily required to achieve my objectives. AI turned out to be a very broad field covered with so many interesting areas that I failed to ignore. I filled a notebook with over 80 pages of handwritten scribbles, loose thoughts, things to get back to, or to connect into something bigger. In other words, my divergent thinking efforts were not in proportion to the time for convergent thinking that I had left for myself, as the deadline to submit started creeping up on me. Indeed, a common flaw in CPS facilitation, and I must admit, one that I had already made while practicing CPS in some of the earlier courses of the Master's program.

In hindsight I could have picked a big, hairy and audacious goal much earlier on, and worked my way through the gap between what was and that goal – and nothing but that. With more focus I might have produced more tangible models and outcomes.

Content Learning

I met many people that reacted with great enthusiasm when I explained what the topic of the project was. 'You're on to something' is a phrase I heard several times. The people at CEE in the unconference session were truly engaged, some even passionate about the topic. I do believe that I have pinpointed an area of CPS and its facilitation that will be researched soon – not just by myself.

During the fact finding and data gathering step of this project, I found myself studying subjects that enriched my knowledge base in areas that were either totally new to me, or that I had only very basic understanding of:

- The use of AI in industry
- The vocabulary of AI, ML and related concepts
- Neural networks; the science behind it and the challenges to put them to work in practice
- The DIKWI hierarchy

Personal Learning

I rediscovered my love for abstract thinking and for modeling complicated concepts in mathematical terms. I confirmed my interest in information as a physical concept and how it can be measured and quantified. More importantly I got very intrigued by the absence of an analogous theory for knowledge – and the challenge of modeling knowledge so that it can be put to work in an AI framework.

I had a long list of professionals, some working for big-name firms, willing to help me out, accepting to be interviewed and to advise me. In the end only three of them helped me in a concrete way. No such thing as free lunch in most cases, I guess.

SECTION 6: CONCLUSION

Things I Now Know About Creativity and Change Leadership That I Didn't Know When I Began the Project

As I was producing images of what the future might look like, with AI augmenting human creative problem solving, I often found myself smiling, just being happy. It felt as if I was experiencing a runner's high. Creative thinking can be such fun, and its effects so powerful, and I feel the urge to share this fun and power with people around me – as a father, as a friend, as a colleague, as a mentor.

I became overwhelmed when I discovered the pace at which AI is making itself part of our daily lives and work. In fact, I got worried about how few people seem to care, or in fact, how few are even aware of this happening. We, the CPS community, cannot afford to wait with investigating the potential of AI in more detail. We should be the force that drives the development of AI applications in CPS. This is not to hop on the doom thinking train, of AI or automation taking out yet another type of jobs: human facilitators are likely to remain in control of CPS, and here's why. The jobs least likely to be automated or substituted by AI machines, are those that involve managing others, applying expertise to decision making, planning and creative tasks, and finally stakeholder interactions (Chui, Manyika, & Miremadi, 2016). These descriptions have CPS facilitation written all over them! Hence, my message is not about instilling fear of AI; to the contrary, it is about a call to embrace AI, to make us better and more efficient at CPS. My message is also about letting people do and focus on what humans do best, to realize that some things are done better and faster by machines. Further, I assert we should embrace AI as means to raise the odds that we find solutions for some of the world's problems that humans seemingly fail to solve.

This invites us to think about a tweaked CPS – TSM model, one supported by 1 M (machine) in addition to the 4 P's (see Figure 11). Whether that machine refers to a computer, handheld smartphone, or the cloud, or piece of electronics planted under our skull and connected to our brains capable of steering some of our nerves (it is a scary thought – but it already exists), it doesn't matter. In the future the ratio of human effort to technology in CPS might well reverse from a very high number to a number closer to 1, or to very tiny. As machines get more and more powerful and faster, the probability of the second and the latter will increase. If engineers figure out how to make quantum computing affordable, the tiny number is a more likely scenario than the number 1.

Who knows, AI might accelerate our understanding of human creativity (we have our ways to go) – so that in turn we can teach machines better how to mimic it.

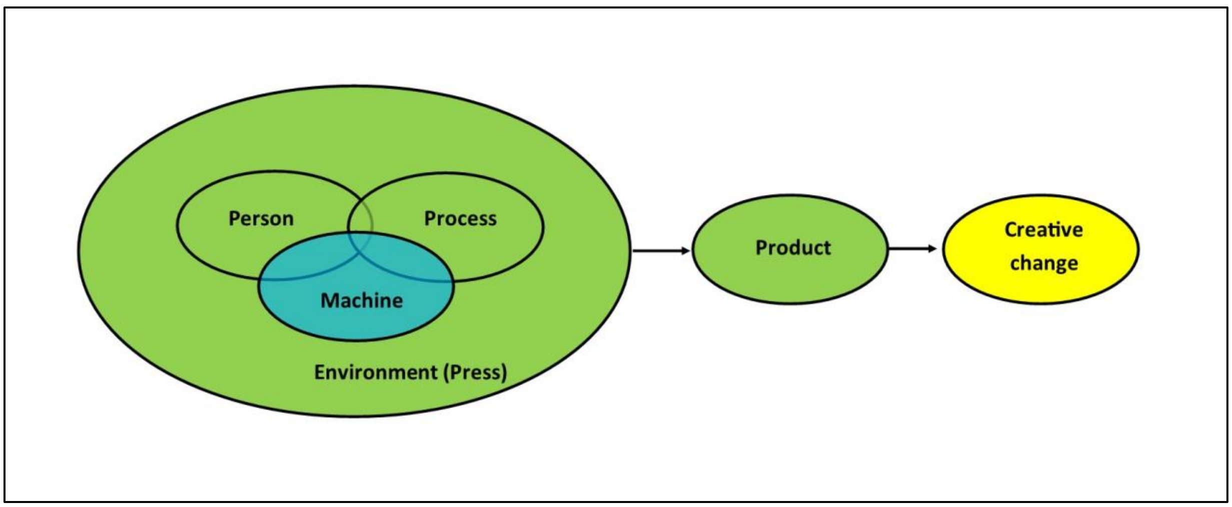

Figure 11. The 4P + M model visualized. Adapted from Puccio, Murdock, and Mance (2005).

What I See Myself Doing Next

The business world is driving developments in AI already, and can be expected to continue to do so for the years to come. For this project I took the approach of looking at business and industry, to use that as a gallery to steal ideas from, to paint a vision of the future for AI in

CPS. Trends suggest that organizations will demand more from technology, adding more fuel to their search for competitive advantage. Therefore, I plan to continue that same approach to stay abreast of commercial AI developments.

College-level courses are available for free, online, about any subject nowadays. Also about AI, NN, ML, … I will school myself to better speak the AI language, to facilitate my interaction with AI experts from the industry and academia.

I will explore what potential data holds for CPS. Big data are power food for AI; it is used to train machines. If we want to have something to train machines with, to help us make them better at augmenting CPS – what would we be monitoring, collecting, annotating and tagging for? This question is on my exploration list.

Likewise, how can we exploit the sharing economy wave? I want to see if there is a way of leveraging the cognitive surplus in the world, whether with AI or another type of technology. How might I leverage the seas of free time that now go to waste on playing candy crush or scrolling a Facebook page, to solve problems, or to set up a CPS platform fueled by the crowd?

I will continue trying to contact TRIZ experts, to investigate how it could best be combined with AI.

I will submit an article about AI and CPS for publication in a journal within the next 12 months.

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APPENDIX

Appendix A: Slides Used at CEE 2017 – Unconference Session

Let's change the "technology in CPS" paradigm

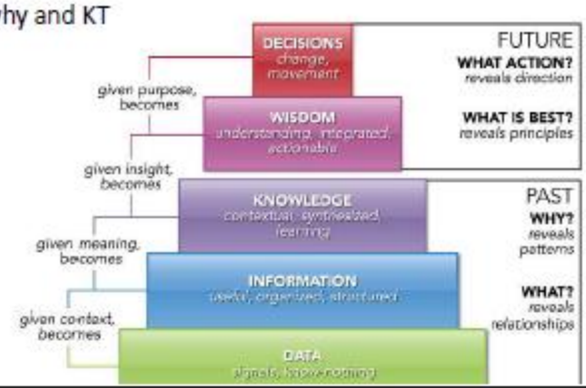
Ruth Noller's formula for creativity

$$C = f_{a}(K, I, E)$$

Knowledge

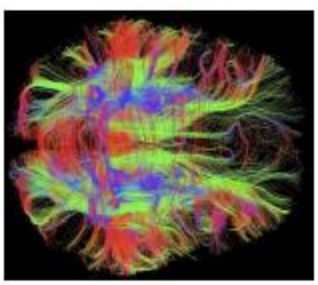
We have: a world wide what and IT

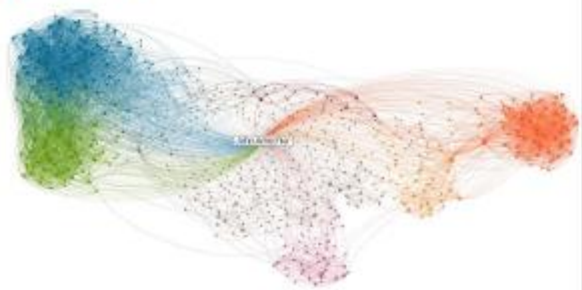
We need: a world wide why and KT



Knowledge is about Making Connections

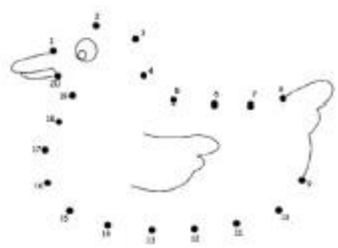
As individual, in a team or in a network





So … CPS is about making connections

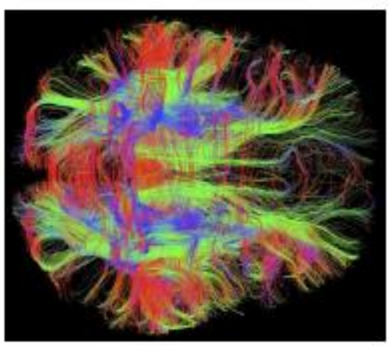
at age 4

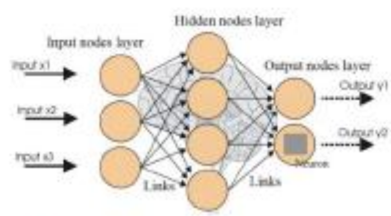


at age 45

AI – augmented intelligence

80 billion neurons and there are up to tens of thousands of possible connections from each neuron



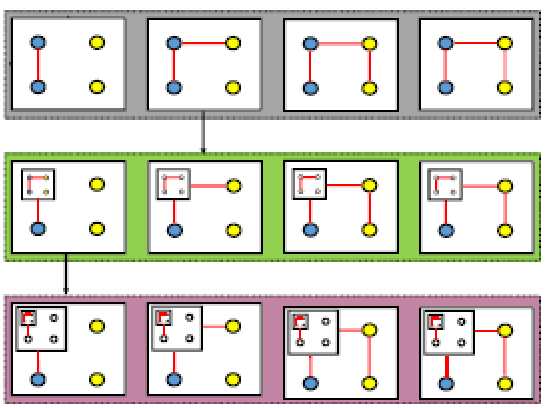


Intelligence: information processing performed by elementary particles (electrons mostly) moving around. No law of physics that says this can't be done (better) outside the human brain

We are not that special … 4 on 1 USB stick!

Open discussion

What if we could design Google for CPS?



Why are humans indispensable in CPS?

What makes us unique, what do we do better than machines?

What are the limitations of the human brain?

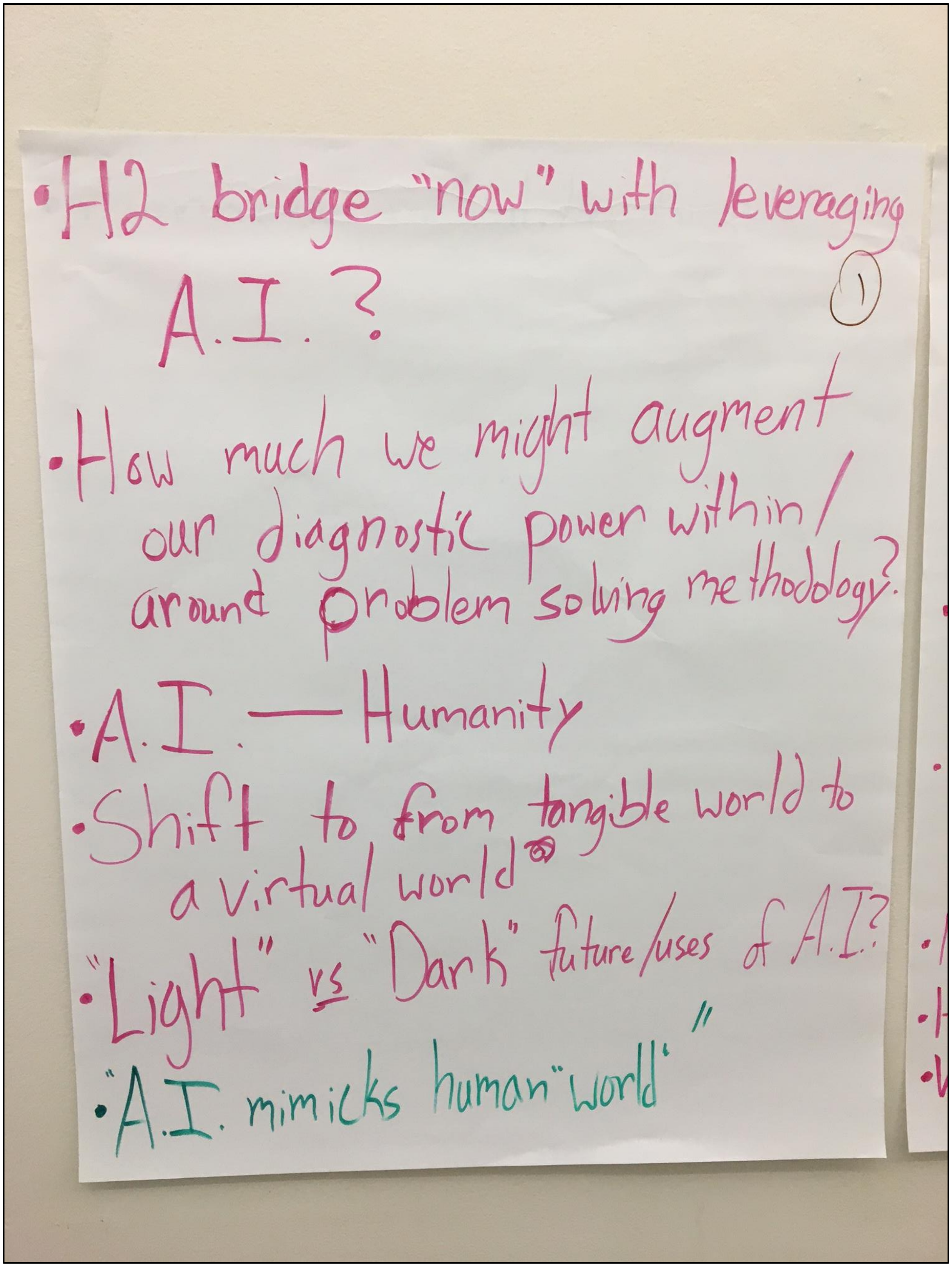
In the context of CPS

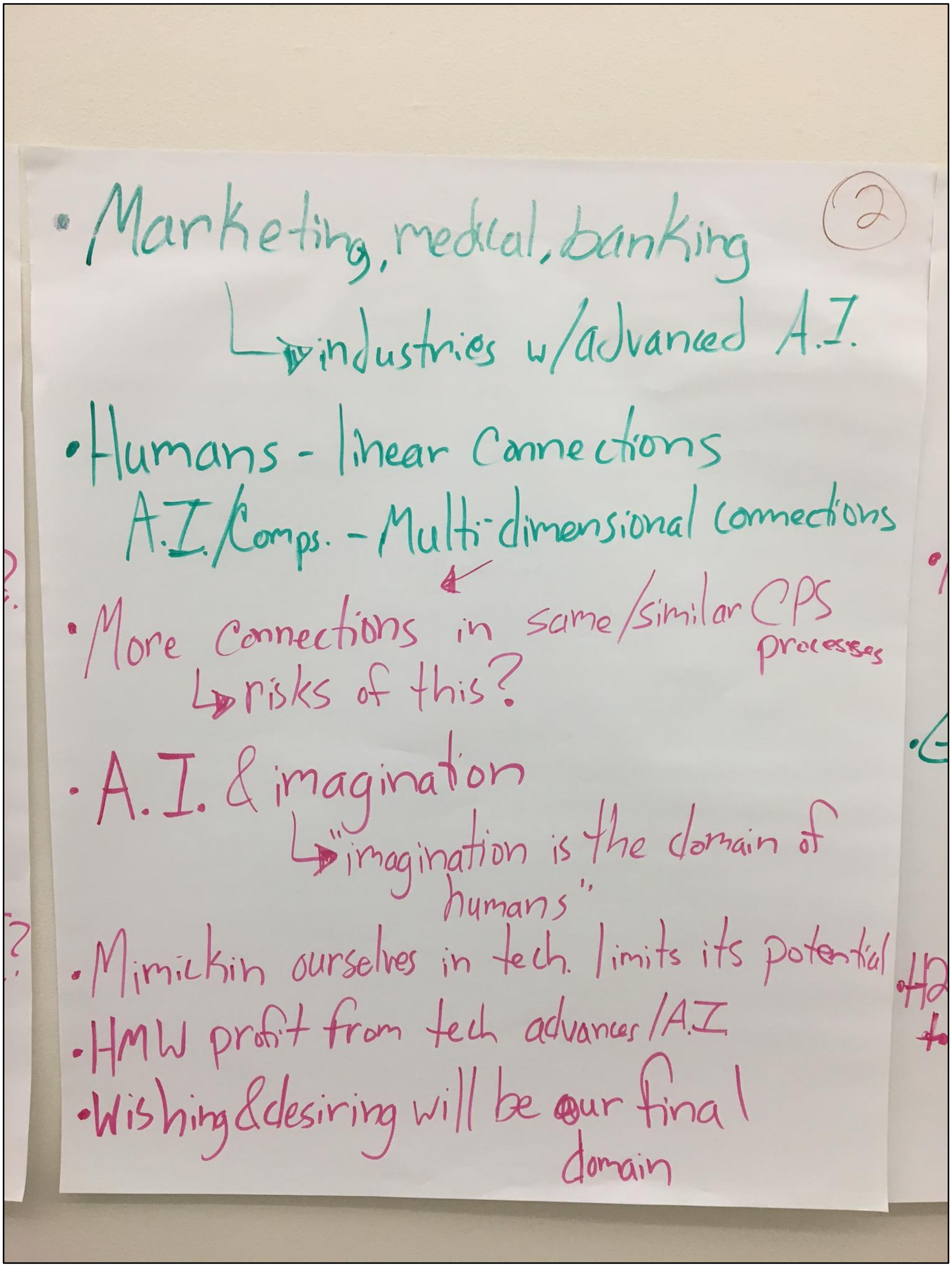
How is K contributing to I and E?

$$C = f_a(K, I, E)$$

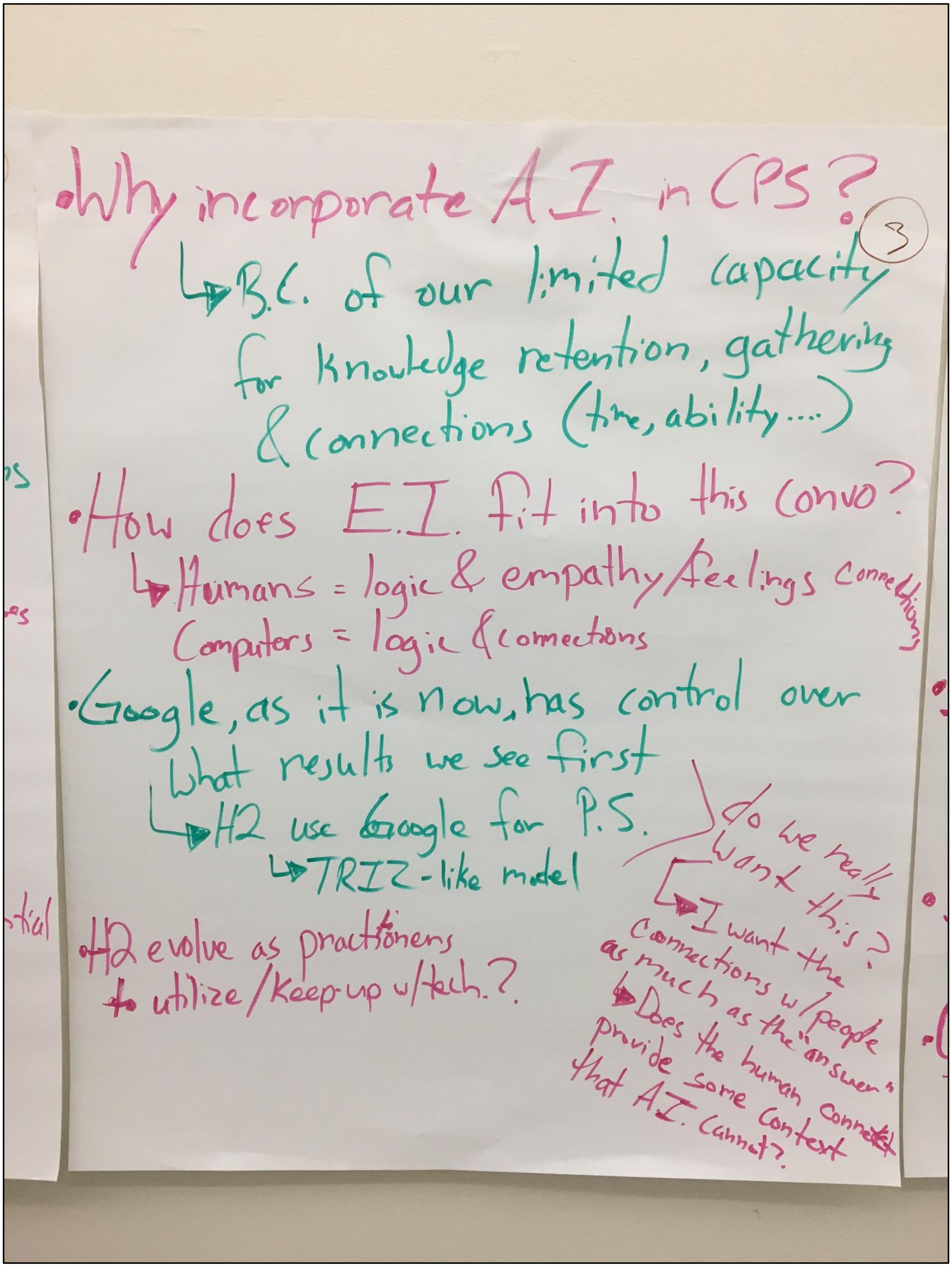
WMBA analogies ‘connecting dots’ – CPS?

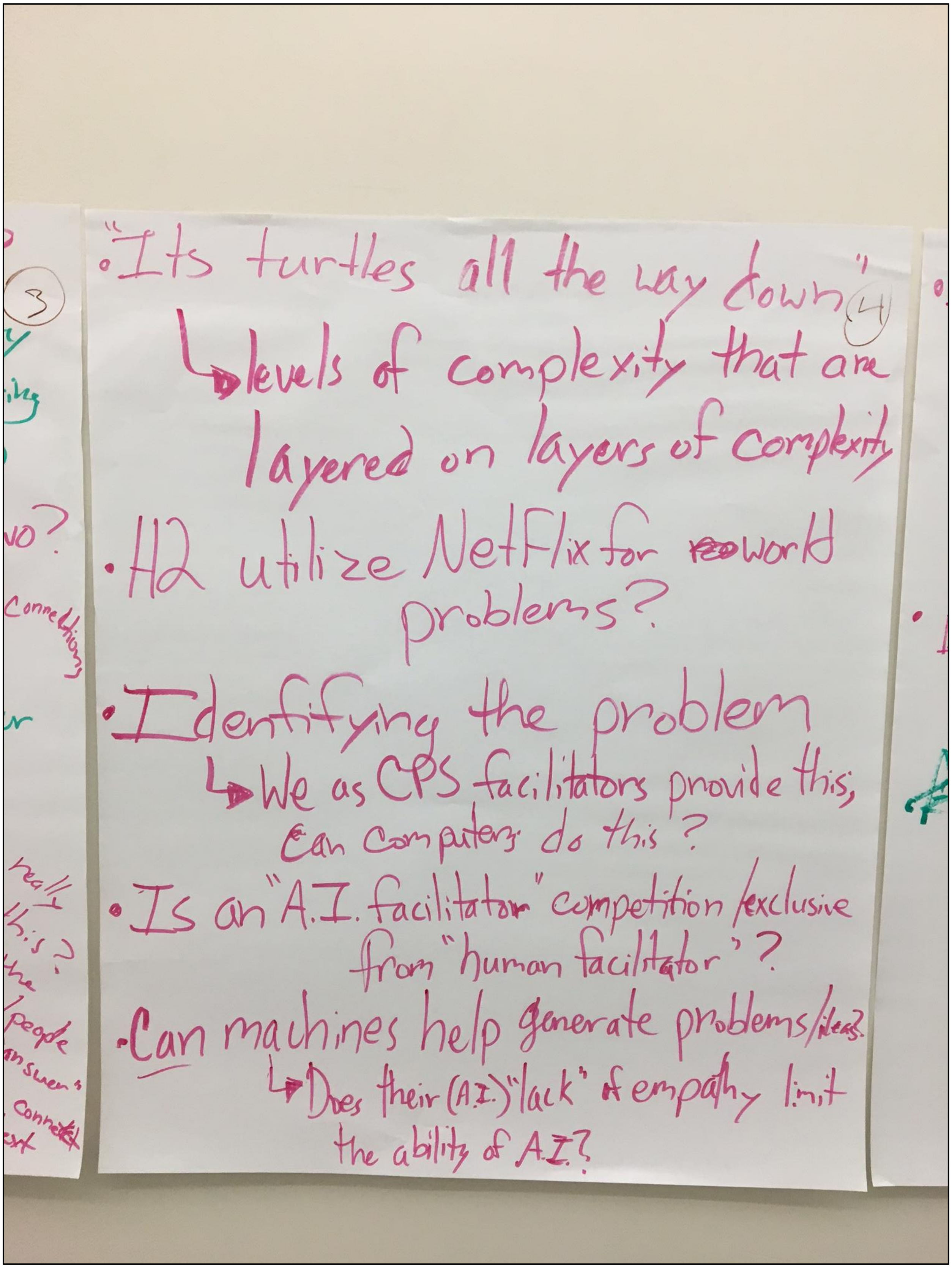
Appendix B: Output (Flip Charts) from CEE 2017 – Unconference Session



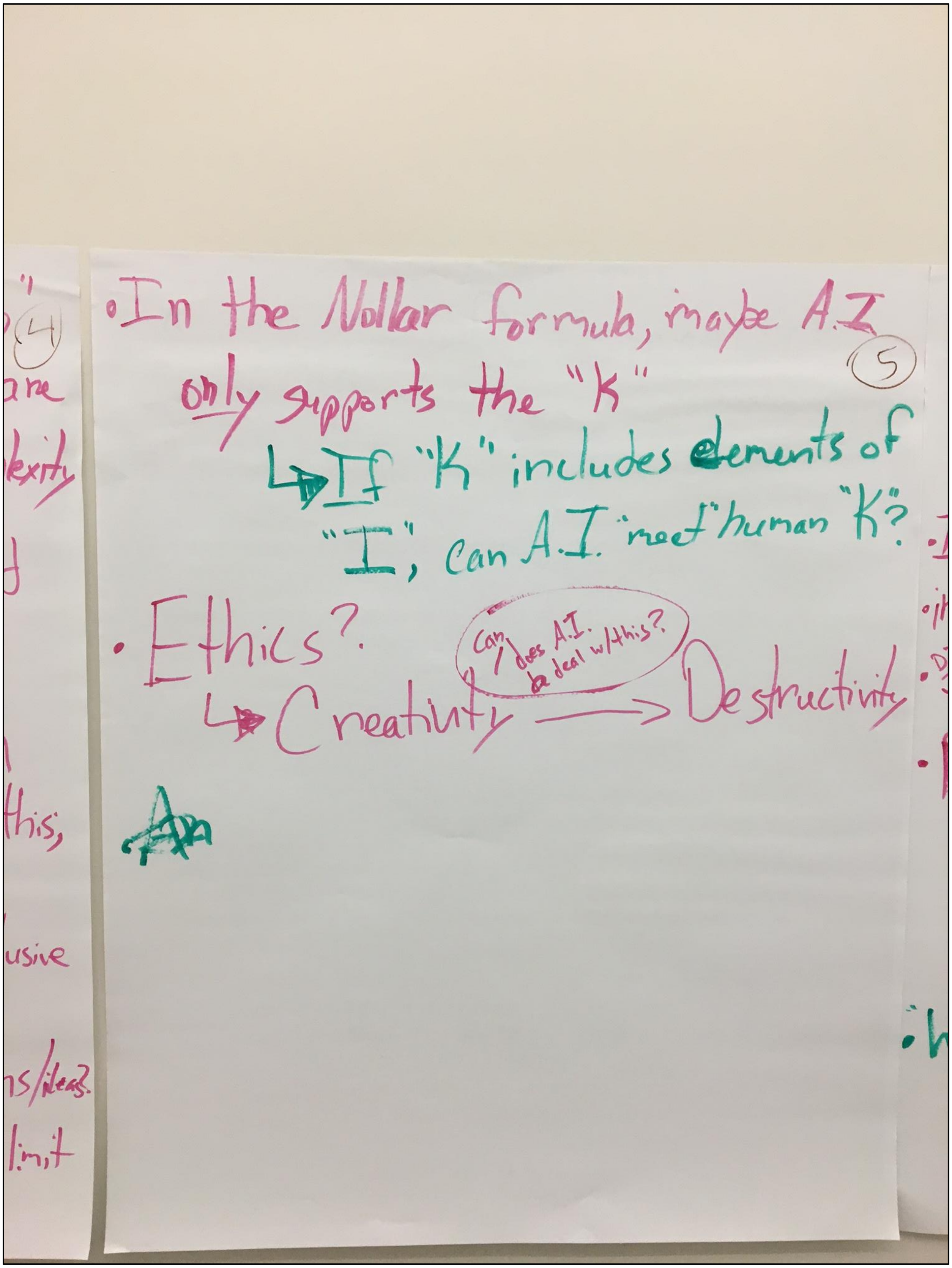


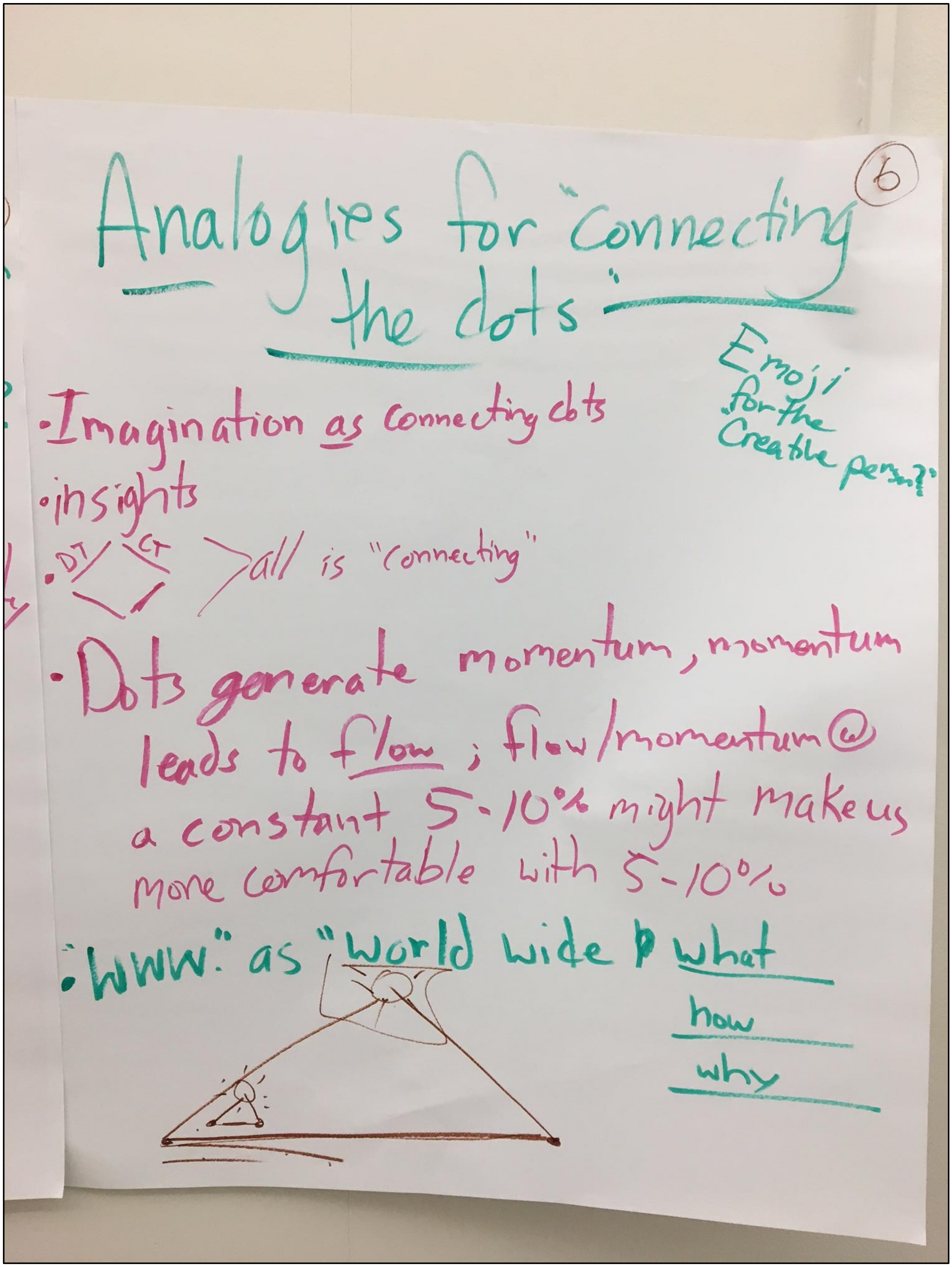
(2)
• Marketing, medical, banking
↳ industries w/advanced A.I.
• Humans - linear Connections
A.I./Comps. - Multi-dimensional connections
• More connections in same/similar CPS processes
↳ risks of this?
• A.I. & imagination
↳ "imagination is the domain of humans"
• Mimickin ourselves in tech. limits its potential
• HMW profit from tech advances/A.I.
• Wishing & desiring will be our final domain


• Why incorporate A.I. in CPS?
③
↳ B.C. of our limited capacity for knowledge retention, gathering & connections (time, ability....)
• How does E.I. fit into this convo?
↳ Humans = logic & empathy/feelings connections
Computers = logic & connections
• Google, as it is now, has control over what results we see first
↳ H2 use Google for P.S.
↳ TRIZ-like model
do we really want this?
↳ I want the connections w/people as much as the "answer"
↳ Does the human connect provide some context that A.I. cannot?
• H2 evolve as practioners to utilize/keep up w/tech.?



• "Its turtles all the way down"
④
↳ levels of complexity that are layered on layers of complexity
• H2 utilize NetFlix for world problems?
• Idenfifying the problem
↳ We as CPS facilitators provide this; Can computers do this?
• Is an "A.I. facilitator" competition/exclusive from "human facilitator"?
• Can machines help generate problems/ideas?
↳ Does their (A.I.) "lack" of empathy limit the ability of A.I.?


•In the Nollar formula, maybe A.I
only supports the "K"
5
↳If "K" includes elements of
"I", can A.I. "meet" human "K"?
•Ethics?
Can / does A.I. deal w/this?
↳Creativity ⟶ Destructivity


Analogies for "connecting the dots"
6
Emoji "for the Creative person?"
• Imagination as connecting dots
• insights
• DT CT
>all is "connecting"
• Dots generate momentum, momentum leads to flow; flow/momentum @ a constant 5-10% might make us more comfortable with 5-10%
• "www." as "world wide ▶ what
how
why

Appendix C: Application Details for a CPSI 2018 Spark Session

Session/Program Description:

Provide a brief description of your proposed session/program, limited to 200 words. Include three short bullet-point learning objectives for the session (i.e., At the end of this session, you will be able to ..."). Please include what is unique about this session. Be specific in explaining precisely what your session will offer. What practical techniques, strategies or ideas will you share? Use clear, simple, jargon-free and sales-free language.

There is an opportunity for the creative problem solving community to get more out of technology. When it does so, it needs to be in a more imaginative way than by just creating electronic versions of the post-it-and-flip-chart (PIAFC) approach.

In the meanwhile, artificial intelligence (AI) is quickly immersing the world around us – and many are not even aware of the impact it has on important aspects of our lives. The creativity community however has yet to make a start to embrace the near infinite possibilities AI might have to offer for creative problem solving.

In the first part of this workshop, we will explore what technology is out there, and we will co-create a next gen digital version of PIAFC. In the second part, we will shift our attention to AI and co-create the first gen version of 'human CPS augmented with AI'.

Learning objectives:

- Learn how technology is and could be used in creative problem solving
- Understand what AI is about, and what it is capable of
- Apply CPS to 'HMW augment human creativity with technology in general, and AI in particular?'

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I hereby grant permission to the International Center for Studies in Creativity at Buffalo State college permission to place a digital copy of this master's Project (Giving Technology the Place It Deserves in Creative Problem Solving) as an online resource.

Yves De Smet

December 6, 2017