TOOLBOX

CONNECTING THE DOTS: AI & the Future of Construction

By Dr. Perry Daneshgari & Dr. Heather Moore

Artificial intelligence (AI) is a friend — not an enemy. For now, it can't exist without data and information created by humans, as the taxonomy of human learning, creation, and wisdom is based on the human intelligence learning sequence. In a follow up to the November/December 2023 article that laid out how AI will impact construction,[1] this article expands on how AI is created.

"Transforming Construction: AI's Role in Building the Future" discussed the future of AI as it pertains to the construction industry and dismissed fears of AI taking the place of human workers.[2] As explained in previous articles such as "Founder's Transition: The Time Is Now," both AI and Agile Intelligence™ need to be developed upon good, accurate data and information, collected about and by people.[3]

But the question, then, is *how* to develop the wisdom necessary to feed into AI — that is, how do you teach and transfer tacit knowledge to people in preparation for transference to processes, procedures, and, eventually, AI? To offer answers to this question, this article dives into the taxonomy of learning and the taxonomy of creation, as developed by Dr. Perry.

Key Terms & Concepts

Taxonomy of Learning

How people learn by investigating and testing their beliefs upon exposure to something new. By using what they learn, people can come to develop a deeper understanding of a new subject matter to the point where they can correct mistakes and gaps in their knowledge.

Taxonomy of Creation

How people create upon being exposed to new information. By observing problems in the world, consulting their history, and cross pollinating from their learning and experiences, people can build theories that they will then prove or disprove.

Agile Intelligence™

The result of data that has been translated to information and knowledge through human experience, distinguishing Agile Intelligence™ from artificial intelligence.

DCI Construction®

Digitalization, Commonization, and Interconnection® (DCI Construction®) decentralizes information with multiple processes and tools into a centralized database, which can be used for decision-making and modeling results.

The Industrialization of Construction®

This describes the trajectory of the construction industry through the development of technology such as AI to streamline processes.

IMLS® Approach

The Integrated Material Logistics Solutions (IMLS®) approach describes how contractors and distributors can cooperate to optimize logistics, from job setup to deployment.

THE FOUNDATION FOR LEARNING & CREATION

Exposure

The taxonomy of learning and the tax onomy of creation start from exposure, which ultimately differs from Bloom's taxonomy of learning, which begins with remembering (recall, define, duplicate, memorize).[4]

While Bloom's taxonomy applies well in a classroom environment, it does not account for the ability to learn through exploration and observation. It lacks the assumption of preexisting biases toward different types of information and focus es on the idea of learning as is most often found in children — learning about a completely new topic of which there has been no exposure.

For example, in learning to make an apple pie, Bloom's taxonomy begins at teaching what an apple is and what the different types of apples are. It does not account for the knowledge of a worker from an apple orchard. Someone with more experience is going to have different goals for their learning than someone with no experience.

Agility

After exposure, the process of learning and/or creating can begin. The ability and pace to go through the next layers depends on the individual's agility in both adapting their current frame of mind and connecting the dots through observation.

Consider the metaphor of seeing a circle when all you know is a square. People with no experience related to a particular subject (such as children) have no biases or barriers against learning new information and making changes to them. On the other hand, someone with these barriers and biases will therefore have resistance to new ideas and changes.

If the knowledge you want to pass on looks like a circle but the only thing a person knows is a square, then just showing them a circle is likely not going to help.

As shown in Exhibit 1, the first step to seeing the circle starts with rounding the edges. It allows the person to take a step toward the new direction (the circle) without losing their past reference point (the square). Depending on a person's adaptability and resistance to change, they will eventually begin to see the circle.

Exhibit 1: Seeing the Circle From the Square

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A practical example of this transition is a foreperson who has been working in the field for decades and has established a routine for doing their work. This worker is going to have a different reaction to incorporating prefabrication into their work as compared to the reaction from an apprentice who has been trained on prefabrication from the beginning of their work in the field.

The foreperson has their own experiences and biases to work through in addition to learning about this new topic — and they will almost inevitably resist the new change. The apprentice has known no other way than the way being introduced to them now. In this instance, the foreperson can be represented by the square while the apprentice is the circle. The foreperson has the ability to work with prefabrication, and it is possible for them to carve the square into the shape of the circle. Different learning steps and processes can round the square into a circle over time.

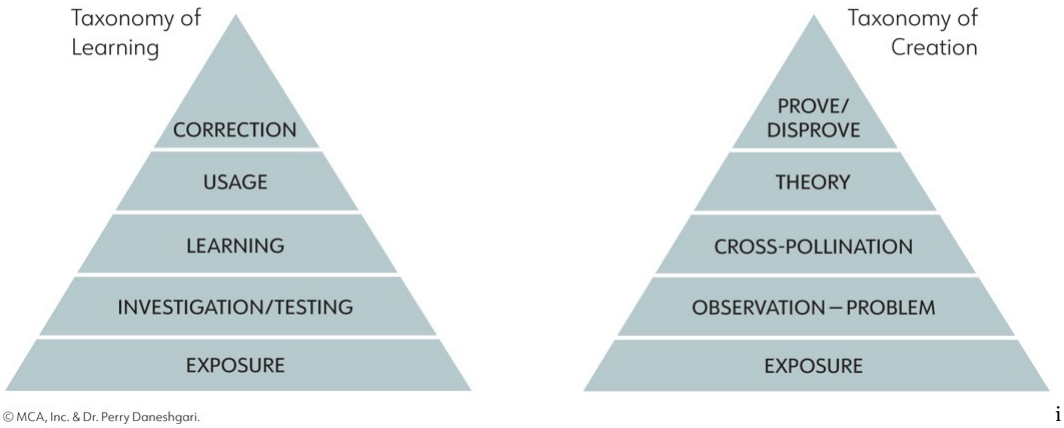
For the apprentice, perhaps Bloom's taxonomy would be acceptable for teaching; however, it was not built to account for previous knowledge and experience and would therefore almost certainly fall short in teaching the foreperson.

A revised question, then, is how do you develop learning in people who have already formed their own methods and ideas? How do you feed said learning into AI?

TAXONOMY OF LEARNING

Exhibit 2 shows how humans build on exposure by investigating or testing from their initial reactions and then learning something new.

Exhibit 2: The Foundation for Learning & Creation



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For example, a foreperson turned project manager (PM) preparing for their first job cost review meeting will gain exposure to financial information. To learn, they need to investigate the concepts and their company's specific application of job costing and financial projections, either through their own research or talking with their peers or company's construction financial professional.

From there, the PM may test what they see and hear[5] (usually by running scenarios in spreadsheets, but this can be overcome with DCI Construction®). Using the results of

their learning, the PM may find this knowledge to be incomplete or incorrect.

This awareness brings exposure and new learning, and the PM will continue the cycle, eventually connecting all of those learnings to the circle, as in the correct reflection of their job's financial status.

The Industrialization of Construction® will require significant shifts in mindsets from the current norms of construction to a new way of doing business in the field and office, including the role of vendors as logistics managers rather than material suppliers. These shifts can be accelerated with a better understanding of how humans learn.

TAXONOMY OF CREATION

From this taxonomy of learning comes the taxonomy of creation. Both pyramids in Exhibit 2 start with exposure, but the difference in the exposure of AI is the exposure to humans for the information from which it needs to build. For humans to create, it's critical that they use their exposure, observe issues, think through their history, and cross-pollinate from learning and experience. This allows them to build a theory and then test it.

Smaller business owners may supplement their gaps with others' knowledge because no one will have their skills, making it more difficult for any single person to take over. Collective human knowledge doesn't have an equivalent sample in their smaller businesses, as it always trumps individual genius.

If AI is put in place to study and anticipate obstacles in the work environment, then the decision-maker (e.g., doctor, pilot, electrician) can make an informed decision based on the collective experiences and learning.

Don't confuse automation with AI; it's just that — artificial. Only when humans are part of the input and output of the process does AI become used for agility (hence, Agile Intelligence™).

DATA TO INFORMATION TO KNOWLEDGE TO WISDOM

Data should always be part of the learning and creation processes. It may not be formal data, but any kind of observations or tests (e.g., "If this happens, then I expect that outcome") will generate some findings. Translating these findings into information and then into knowledge and wisdom requires asking the right questions.

As covered in "Transforming Construction: AI's Role in Building the Future" from the November/December 2023 issue, intelligence is not artificial; it is based on the human process of translating data to knowledge by building on others' learnings and creations.[6]

CONNECTING THE DOTS

AI needs to have a capability to connect the three topics — the taxonomy of learning, the taxonomy of creation, and the data to wisdom transition — to create the information needed for use by humans. The capability to make this connection is dependent on the data source.

As mentioned, the current theories (in the case of learning) and usage (in the case of creation) have been built in construction based on the same foundation of exposure; however, the path upward is very tacit. Most construction technicians learn by doing and create by trial and error. There is no database housing these dots, but they can be connected through DCI Construction®.

THE DOTS: DATA SOURCES

Through years of research by MCA recognizing where data exists in construction, DCI Construction® is built on these sources:

Centralized Databases

In construction, the most common of these databases is accounting, led by construction financial professionals who take care of the money in a data-driven environment. Most construction companies also have an estimating database. Neither of these databases are built nor intended to house field data.

Decentralized Spreadsheets

Due to the absence of field data and process and procedure in construction contracting, PMs (and others) create their own digital tools for managing data, typically in the form of spreadsheets (Excel, Google, Smart sheets, etc.). Sometimes they are used as calculators or for tracking information. And, they can grow out of control with columns, colors, and formulas and become a reference point without having gone through the taxonomies explained previously.

Despite their shortcomings, the intent behind the creation of these spread sheets must be understood to avoid a mismatch between database and reality so they can be commonized in one centralized location rather than on individual computers. A PM may go through a permutation of several spreadsheet sources to get ready for a financial review on their project, all disconnected from what is really happening on the jobsite:

1. Inputting data put into a job cost worksheet (some from accounting software and some from their own knowledge or other tracking)
2. PM permutation prior to the job review meeting (trying to explain the numbers and adjust the forecast)
3. Job financial review meeting (official "published" financial status in preparation for what accounting will reflect in the work-in-progress (WIP))
4. Final version, which is used for WIP

Although this process is somewhat commonized (followed by many PMs in the company), the source of data (the field) is still not part of the process.

Notebooks, Steno Pads & Backs of Napkins

The Brooklyn Bridge was built with a pencil, paper, and a slide rule, and it took many years to complete. Computing power has certainly increased calculating speed, but the source of data about design and build ing is still between the ears and the pen. That said, most jobsite trailers contain gold mines of data on yellow notepads.

These notebooks likely house observations and information that are partially up the path from the taxonomies explained previously. There has been exposure to something (a schedule, an estimate, drawings, etc.), but it has not translated to learning or cross pollinating from experience. However, without access to and from a database of experience, these notebooks become fossils, and the learning is lost with the ink and paper.

Inside the Minds of the Operators

While we can't read a technician's mind or easily capture their insights and knowledge, their exposure is the broadest and deepest; this data source is needed for understanding and managing work in order for industrialization to move forward. A Work Breakdown Structure is a great tool to take a step in getting that insight and knowledge on paper.[7]

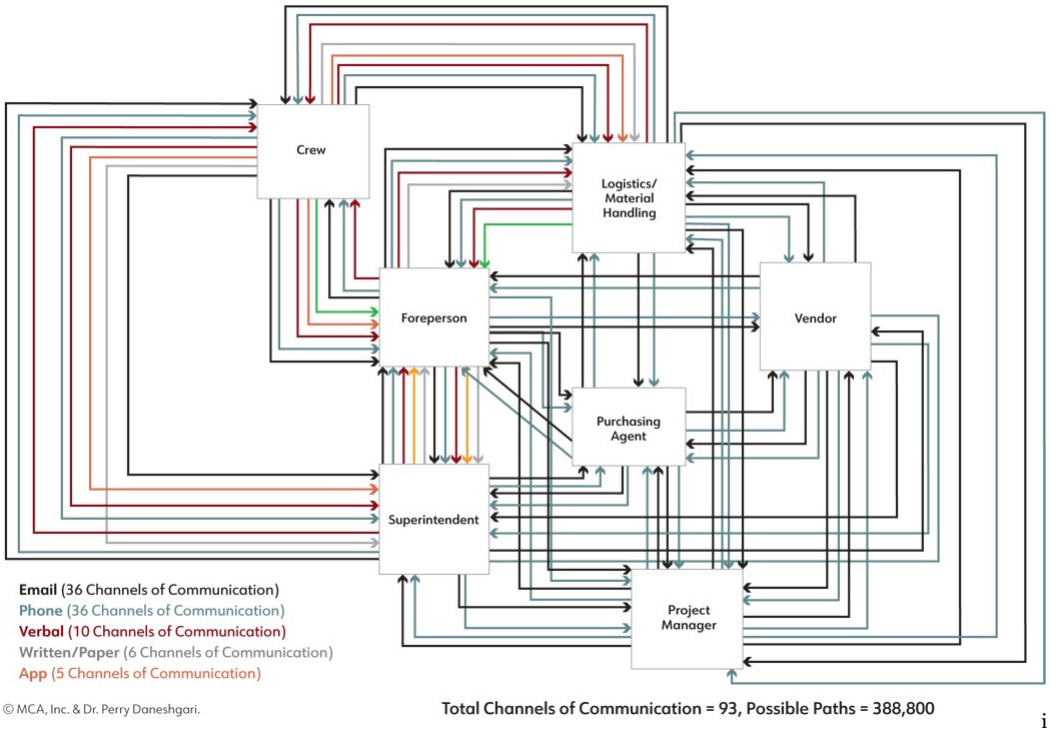
CONNECT THE DOTS FORWARD: THE ROLE OF AI

The sources explained previously are being digitalized using DCI Construction® through the approach of mapping the processes they support, whether tacit or explicit. However, the pathway between the dots may not be optimized.

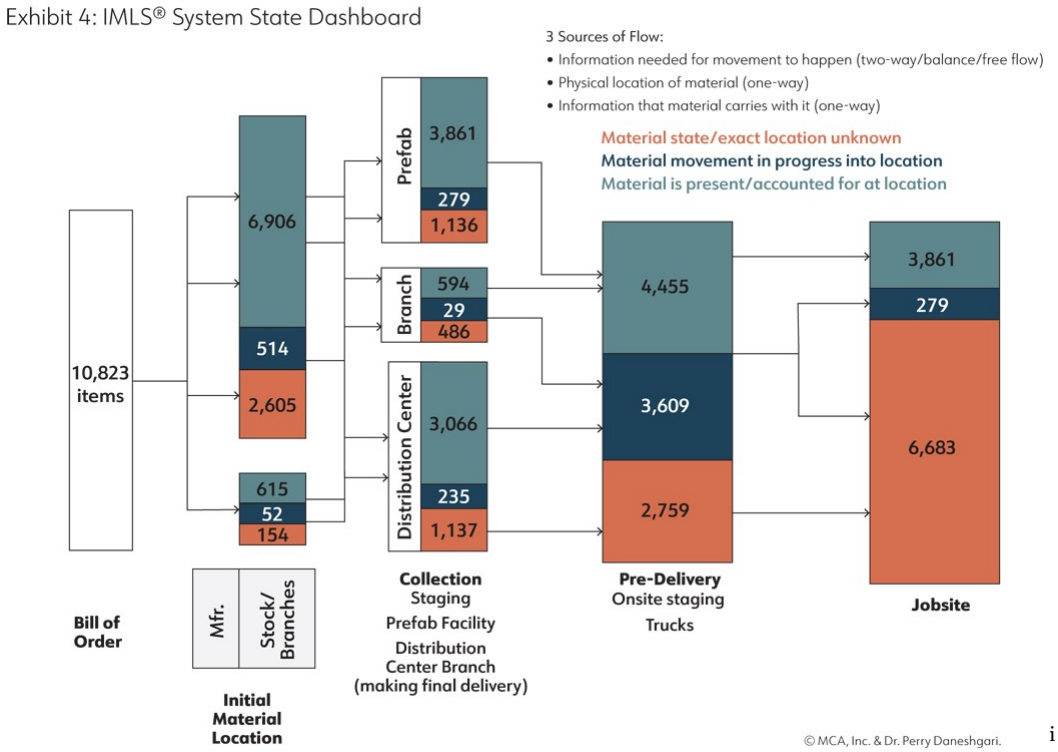
Agile Intelligence™ can be added to the DCI-supported processes to assure they will predict and prevent shortcomings and waste.

For example, Exhibit 3 shows an information flow of a current state material ordering process between a contractor and vendor. This mapping process digitalizes (breaks down the information flow) the process and interconnects the data sources needed (vendor enterprise resource planning system, material requisition forms, material tracking spreadsheets) to achieve it. However, the process itself has not been designed for waste reduction.

Exhibit 3: Sample Material Request Process: Spaghetti Flowchart



The strength of AI in rapid information processing will be added to DCI Construction® and used to model and optimize information and workflow. An example of the pathway is displayed in Exhibit 4, where the data about material availability was used as an early DCI Construction® application to predict and prevent waste at the vendor, prefabrication/ staging, and jobsite locations.



A previous issue of *CFMA Building Profits* conveyed the IMLS® approach that was developed for this application. On the trajectory to the Industrialization of Construction®, these will achieve steps three (lean operations, optimizing explicit processes) and four (modeling and simulation, using data to match physical realities).[8]

Data Quality Is Required During AI Development

Given the strong reliance on data for AI, it is imperative to understand and incorporate data quality as a closed loop in AI. The four areas of data quality must be assured as part of the process for populating and using AI:

- Gathering
- Recording
- Reporting
- Presentation

For example, backing into the presentation of a PM's job cost and financial projections on their job, the following questions should be asked at each stage:

1. Was the data gathered correctly?
    - Are all costs included in the data (including committed costs)?
    - Are the costs up to date (including pricing changes, labor escalations, etc.)?
    - Are the projections accurate to expected behavior (any large purchases missing, labor projections reflecting productivity differential such as with JPAC®)?
2. Was the data recorded correctly?
    - Is everything in the report, or does the PM have some offline spread sheets reflecting change orders or material orders planned but not yet issued as purchase orders?
    - Are allocations and contract provisions applied, such as indirect costs and overhead or retention?
3. Was the data reported correctly?
    - Are items charged to the appropriate cost codes and job?
    - Is the information available timely for a review?
4. Was the data presented correctly?
    - Has the data been reduced and analyzed to show the situation clearly?
    - Is the data represented correctly according to its type (e.g., categorical vs. rankings vs. variables)?
    - Can the numbers and analysis be acted on?

If any of the answers to these questions are “no,” then there is an opportunity for the PM to learn (through exposure) and an opportunity for the company to translate its knowledge to data by assuring the individual PM doesn’t have to tacitly assure the quality.

CONCLUSION

AI’s usefulness must be measured by the outcome of humans’ use of information, not just the existence of the information (intelligence) itself. This article connects the dots among various prior *CFMA Building Profits* articles, but it is only when you, as the reader, put those connections to use that the content can represent intelligence.

Intelligence is not gained artificially; it is through the taxonomy of learning and the taxonomy of creation, which are introduced in this article, starting with exposure, that builds the intelligence. A data-driven approach for interconnecting this learning and creation will help move construction faster on the trajectory of industrialization.

The faster the industry can learn, cross-pollinate, and use a data-based system for accessing the knowledge and wisdom of experience, the faster it can reduce the cost and increase the pace of delivering construction. It took the manufacturing industry one century and the agriculture industry three centuries;[9] construction should be able to get to industrialization faster with Agile Intelligence™.

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Endnotes

*1. Daneshgari, Dr. Perry & Moore, Dr. Heather. “Transforming Construction: AI’s Role in Building the Future.” CFMA Building Profits. November/ December 2023. **cfmabponline.net/cfmabp/11122023/MobilePagedArticle.action?articleId=1938825**.*

*2. Daneshgari, Dr. Perry & Moore, Dr. Heather. “Transforming Construction: AI’s Role in Building the Future.” CFMA Building Profits. November/ December 2023. **cfmabponline.net/cfmabp/11122023/MobilePagedArticle.action?articleId=1938825**.*

*3. Daneshgari, Dr. Perry. “Founder’s Transition: The Time Is Now.” CFMA Building Profits. January/February 2023. **cfmabponline.net/cfmabp/01022023/MobilePagedArticle.action?articleId=1858490**.*

*4. Armstrong, Patricia. “Bloom’s Taxonomy.” Vanderbilt University. **cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy**.*

*5. Daneshgari, Dr. Perry; Moore, Dr. Heather; & Daneshgari, Jennifer. “PMs & CFMs: Increase Information Sharing to Improve Profitability.” CFMA Building Profits. March/April 2021. **cfmabponline.net/cfmabp/20210304/MobilePagedArticle.action?articleId=1669332**.*

*6. Daneshgari, Dr. Perry & Moore, Dr. Heather. “Transforming Construction: AI’s Role in Building the Future.” CFMA Building Profits. November/ December 2023. **cfmabponline.net/cfmabp/11122023/MobilePagedArticle.action?articleId=1938825**.*

*7. Daneshgari, Dr. Perry & Moore, Dr. Heather. “Jobsite to Garage: Changing the Mindset of Prefab & Modular Construction.” CFMA Building Profits. March/April 2020. **cfmabponline.net/cfmabp/20200304/MobilePagedArticle.action?articleId=1656724&temp=140255d6-e3e9-4ec3-b0d4-ae4a13d2038a#articleId1656724**.*

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*9. Moore, Dr. Heather & Parvin, Sydney. “How Industrialized Are You? Measuring Your Company’s Progress.” CFMA Building Profits. November/ December 2021. **cfmabponline.net/cfmabp/11122021/MobilePagedArticle.action?articleId=1743447**.*