How to Transfer Complex Knowledge in Distance

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Abstract. This paper outlines some of the issues around knowledge transfer of advanced dynamics of Passenger Transportation Systems in buildings and presents a concept for a distance study set-up for a multi-cultural/multi-discipline R&D environment.

Advanced knowledge regarding vibration control of lightweight cabins of a modern, rope-less Passenger Transportation System forms the basis of a comprehensive research approach to find out how this knowledge can be learned most effectively and most efficiently in a distance learning setting.

The impact of individual learning preferences and modern communication channels, such as Social Networking and Social Media, help to shape the novel concept for a distance learning setting for engineering staff of global engineering workforces.

The presented state-of-the-art knowledge transfer model clearly demonstrates the implications for the future concept design of enhanced learning courses in higher engineering education and has a game-changing potential for appropriate and modern 21st-century learning, which is especially of interest in pandemics and crisis times.

1 INTRODUCTION

The truth of the matter (the initial impulse of the research project) is that it all began with a misperception. Under the impression of numerous sessions as an international trainer, mentor, and advisor for engineering processes and engineering subjects, I reckoned that the way people learn is connected with their cultural background and differs from geographical region to geographical region. With the assignment to ascertain the best method to transfer lift engineering knowledge from the knowledge giver (lift company and inventor of a revolutionary new lift technology) to the knowledge receiver (engineers of a lift company that wants to use that new technology for product design), I proposed a PhD thesis to the University of Northampton (United Kingdom) and started to dig into the research literature. Anyway, after a while, I realised, that my assumption '*people learn differently in country A than in country B'* was an untenable hypothesis, and so I had to rectify my thesis concept.

This paper summarises the research efforts of the research project *Design for Ride Quality – Knowledge Transfer of Advanced Dynamics of Passenger Transportation Systems in Buildings for a Multi-cultural/Multi-discipline R&D Environment* [1], which consolidates around 20,000 data points coming from structured surveys, questionnaires, and interviews, collected over the course of 7 years. It proves the interconnection of four conceptional strategies: Content Curriculum, Social Network, Learning Environment, and Instructional Design. And all that is about technical knowledge, which has been developed to minimise and control the effects of cabin vibration in a rope-less Passenger Transportation System. The paper condenses the results of a PhD research study of 240 pages.

2 THE INTERACTION OF TWO RESEARCH ASPECTS (TECHNOLOGY AND KNOWLEDGE TRANSFER)

2.1 The technological aspects of the research endeavour

2.1.1 The MULTI®

The MULTI® system stands for the future generation of Passenger Transportation Systems for horizontal and vertical transportation. It is a rope-less lift system using linear motor technology that enables multiple cabins to move in a single loop of continuous flow. The system was developed by thyssenkrupp Elevator (now: TK Elevator), and was introduced to the market in June 2017. It offers access to an elevator cabin approximately every 15 - 30 seconds, operating with a maximum speed of 6 m/s. This results in shorter waiting times and improves cabin access in large buildings [2].

It is expected that the technology has huge potential for Passenger Transportation System efficiency by "*saving lots of very valuable space*" and releasing huge potential to rent out expensive floor space of the existing building footprint [3], which is a "*critical factor*" of any Passenger Transportation System [4]. This can be realised as, in such a multi-car lift system, "*two or more cars may move in two elevator shafts independently, always in the same direction in one shaft*". In other words, system cabins move up in one shaft and down in another shaft, while both vertical shafts must have at least two horizontal connections to ensure continuous flow [5].

2.1.2 A rope-less lift and its specifics

The entirety of MULTI®, its technical composition and assembly, is totally new and can be called a showcase of radical technology evolution. Although the individual components and sub-assemblies of the system are already field-tested, the way that it is all being put together and assembled is fundamentally new. To identify the different technical conceptions, Table 1 compares the most important sub-assemblies of MULTI® with sub-assemblies of a conventional lift system. Therefore, technical features that are on par in both systems are not shown.

A system comparison leads to the obvious statement that some principle technical concepts are not applicable to MULTI®: System balancing, pulleys, and traction means. On the other hand, the new multi-car lift system requires a more sophisticated technical conception for certain components. Examples include guide rails with energy transmission, tight guiding functions, and the provision of electromagnetic force.

The linear motor propulsion systems of MULTI® consolidate the system payload and the system propulsion. In a conventional lift system, payload and system propulsion are split into different technical components. For example, the drive sheave carries the system weight & payload in a conventional lift, and it ensures the necessary traction needed to move the cabin weight.

These considerable conceptual differences require a new and noticeable approach to design, component calculation, and system construction. Justifiably, this novel concept of a Passenger Transportation System needs a different approach to transfer complex knowledge, which is needed to finalize the system design and to customise it for a specific use case.

Table 1 Comparison of technical conceptions of MULTI® vs. conventional lift (selection)

	Technical Conception	
Technical Feature/Application	MULTI®	Conventional Lift System
Car/Cabin	Lightweight structure	Steel frame construction
Propulsion	Linear motor	Electric motor (with rotary movement)
Trajectory control	Magnetic or optical sensors	Overspeed governor
System balancing	not applicable	Counterweight
Guiding system	Guide rails (with additional features)	Guide rails
Cabin doors	Lightweight structure	Sheet metal structure
Tension pulleys	not applicable	Nylon or alloy
Vibration control	Active actuators	Spring-loaded roller guides
Traction means	not applicable	Steel wire ropes or composite belts
Machine room	Typically separate machine room or in shaft head-room	Along the system travel height
Data communication	Wireless	Travelling cable
Energy transfer	Contactless	Travelling cable
Maintenance	Shaft garage	System downtime

2.2 Research background

The initial notion for this research project was the technology launch of a new concept for Passenger Transportation Systems.

The linear motor technology of the Transrapid high-speed monorail train, which was developed and marketed by Transrapid International, a joint venture of Siemens and thyssenkrupp, is used for the vertical mode of transportation in high-rise buildings.

Consequently, this technology eliminates ropes, although these are common practice in a traditional lift system [6]. Furthermore, this new concept requires a novel lift cabin set-up, a so-called backpack structure. This novel backpack concept needs innovative mathematical simulation models and appropriate countermeasures to reduce the vibration and noise of those PTS cabins [7].

The composition of the individual components and sub-assemblies of MULTI® is very unique, although the individual components are established, best-known and already built in other technical systems. So the specific composition of the entire system assembly, including fine-tuning of parts and sub-assemblies, is the uniqueness of MULTI®.

As the ride quality of a PTS cabin is essential for the quality assessment and subjective perception of the comfort of a passenger, the research study looked into the influencing factors and measures to improve ride quality [8]. This technical knowledge is intended to be transferred to customers in a distance learning setup. To make that knowledge transfer efficient and effective, the second aspect of the research study looks into concepts of knowledge transfer aka learning.

2.3 Main aspects of a successful Knowledge Transfer

2.3.1 How do people learn?

Preliminary note: The topic of learning itself is the subject matter of countless research papers and publications. The bespoken research study had its focus on aspects of (adult) pedagogy and distance learning. Other aspects of learning (such as neurobiology, educational psychology, neuropsychology or experimental psychology) were excluded.

The concept of learning has to do with three principles:

- Prior understanding
- Actual and effective knowledge
- Self-monitoring or active learning

To develop the necessary competencies and to gain specific skills, a learner has to demonstrate a comprehensive given knowledge, understand the conceptual framework of the given context and structure the gained skills and knowledge to be able to make use of it ("*retrieval and application*") [9]. This can be depicted more simply to describe the way we learn:

Do something. → Think about and reflect on it. → Share experience with others and apply it to other situations. → Advance.

This matches with a conceptual model introduced and published already in 1984 by David A. Kolb. He identified four learning cycle modes in a learning process [10]:

- Concrete experimentation
- Reflection
- Abstract conceptualisation
- Active experimentation

This concept is depicted in Figure 1 and shows the learning process in a holistic way with the learner touching all the aspects of the process.

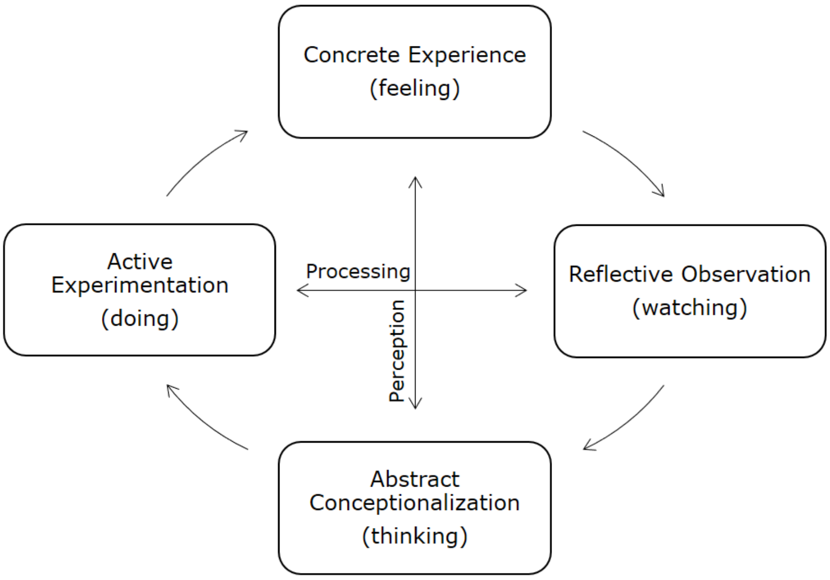

Figure 1 The Learning Process

The model illustrates the learning progress of a person as a walk through a four stages cycle:

1) Having a concrete experience followed by
2) a reflective observation of that experience leading to
3) the conceptualisation (analysis) and generalisations (conclusions). This is then used for
4) active experimentation (testing a hypothesis in future situations), which results in new experiences.

2.3.2 Learning Preferences

The similarity of any conceptual theory of a learning process is the consideration of the way people grasp information. The terms 'learning styles' and 'learning preferences' are used to describe how learners perceive, interpret, organise, conclude about and keep information for future purposes.

There are many models of learning styles, and some of them became popular and are discussed in research work or even developed further for business applications. Out of more than 70 different models of learning styles description, the VARK inventory is widely known and accepted [11]. VARK categorises learning styles by a sensory approach:

- Visual
- Aural
- Verbal [Reading/Writing]
- Kinesthetic

The multitude of existing models of learning styles equal the so-called Index of Learning Styles (ILS) model introduced by Felder and Silverman in the late 1980s [12], such as the Learning Style Questionnaire (LSQ), developed by Honey and Mumford in 1986 [13]. Both works correspond and represent the best-known measure of individual learning styles. Both concepts focus on the way learners process and organise the information they receive.

The *Index of Learning Styles* (ILS) is a tool that evaluates preferences based on a self-scoring assessment on four different dimensions:

- Sensing/intuiting,
- Visual/verbal,
- Active/reflective and
- Equential/global,

while the Learning Style Questionnaire (LSQ) identifies four learning preferences: Activist, Theorist, Pragmatist and Reflector. Please refer to Figure 2.

That means in particular:

- Activists are people who learn best by doing.
- Theorists are people who need models or concepts to be able to learn effectively.
- Pragmatists learn best when they can see and put that into practice.
- Reflectors are people who learn best when they can observe others and reflect that further.

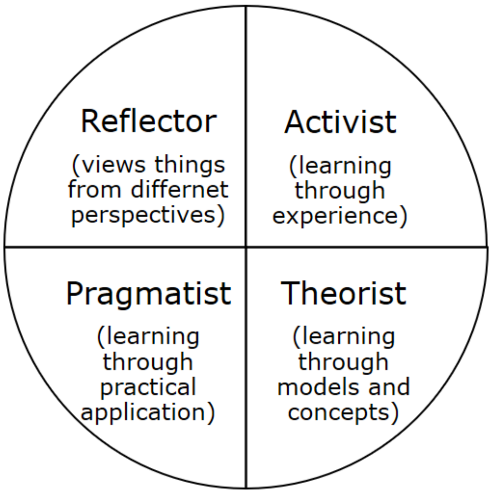

Figure 2 Learning Preferences

2.3.3 Instructional Design

Ideally, the different preferences of learning style as discussed in *Chapter 2.3.2 Learning Preferences* are considered when it comes to the design of a learning event, which is especially important in a distance learning set-up. This Instructional Design strategy, a design procedure model, defines the way particular subjects are taught, and it determines methodologies, techniques, and educational technologies for the instruction of the learners.

Nearly all online learning events lack an instructor, which makes the Instructional Design strategy even more important to ensure that the learning process works most effectively.

The process of Instructional Design can be defined as "*the process of deciding what methods of instruction are best for bringing about desired changes in student knowledge and skills for a specific course content and a specific student population* [14]." Put into a nutshell with the focus on an intended learning target ("*desired changes in student knowledge and skills*"), the Instructional Design strategy determines the direction and characteristics for an efficient and effective learning event.

Although applied to modern digital/online learning events, the foundation for Instructional Design models was already set in the 1960s and refined respectively and developed further in the following century, when the often-quoted so-called *ADDIE model* was brought to light [15]. The five phases of this *ADDIE model*, which is one of the most common Instructional Design models published, offer an adjustable framework for designing effective training courses. The five phases stand for "*Analysis, Design, Development, Implementation and Evaluation*", and they stand for an iterative 5-phase process to originate and create effective learning material (instructional material). In detail:

- Analyse (to clarify the problem): Define the training needs, determine the instructional environment, and determine pre-existing knowledge and skills.
- Design (to define learning objectives): Determine instructional strategies to achieve those objectives, and create storyboards and prototypes.
- Develop (= assemble content): Incorporate that content into the design of the instructional support materials. Review for quality.
- Implement: Roll out the learning event and monitor its impact.
- Evaluate: Determine whether the learning event delivers the results expected. (This is not trivial!)

This framework can be enhanced and completed with a holistic nine-step model to develop an effective learning program which is named "*Events of Instruction*" [15], containing:

- "*Gaining attention*
- *Informing the learner of the objective*
- *Stimulating recall of prerequisite learning*
- *Presenting the stimulus material*
- *Providing learning guidance*
- *Eliciting the performance*
- *Providing feedback*
- *Assessing the performance*
- *Enhancing retention and transfer*"

If we want to make certain that these *9 Events of Instruction* are effective, we should also consider the familiar Taxonomy of Bloom (*Bloom's Taxonomy*) in an impactful learning design [16]. Therein, learning is split into the following 6 levels in a hierarchical order and rising impact to the effect of learning, with Evaluation as the highest level of understanding and Remembering as the lowest level:

- "*Remembering - Recall or recognition of an expression.*
- *Comprehension - Understanding of facts. Ability to organise them and bring them into relation.*
- *Application - A deeper understanding. Use/apply information for related problem-solving.*
- *Analyzing - Break up information into smaller chunks, organise them and relate them together.*
- *Synthesizing - Ability to structure patterns from given/known information. Develop ideas and critical doubts about the subject.*
- *Evaluating - Ability to take in external information and relate your knowledge to them to make decisions.*"

The functional interaction of the *ADDIE model*, the concept of *9 Events of Instruction* and *Bloom's 6-level Taxonomy*, helps to define realistic learning goals, to write adequate training outlines and finally to apply a reasonable evaluation method for the results of a learning event. When all that is set, we can pick the right piece of Learning Technology to support the process.

2.3.4 Learning Technology

Times are changing. Emerging technology means that more and more teaching/learning situations do not take place in a classroom in the classical way with an instructor who is in direct interaction with students, but are supplemented by course content that is available 24/7 and anywhere. This way of learning at a distance not only moved into the profession of teaching engineering, but as a matter of fact: "*Education at a distance, as provided through correspondence courses and video media, has been largely supplanted by online education as the world`s networking capabilities have become ubiquitous. Studying engineering online from anywhere and at any time has become possible in recent years…*"[17].

Naturally, this makes all concepts and theories for instructor-led teaching situations obsolete, and the new teaching/learning situation requires the consideration of a completely different approach. Learning happens with a physical distance between learner and instructor, which obviously has limits as direct communication between learner and instructor is not possible in this distance set-up. This goes even further when combining the learning environment with learning technology, as "*the latest technologies without dealing with the underlying issues of learner characteristics and needs*" emphasise the need to realign the "*new roles of teacher, site facilitator, and student in the distance learning process*." [18].

The so-called education technologies are tools and equipment to support the learning experience of a learner. These technologies include but are not limited to: the World Wide Web (as an enabling system), e-learning, Videos, Massive Open Online Courses (MOOC), Physical Training Simulators, Augmented Reality, Virtual Reality, Mixed Reality, Micro Learning, Blended Learning, mobile applications for mobile phones, computers and tablets, Learning Games, Coaching Functions, and Artificial Intelligence.

The typical set-up of distance study has its deficits when we compare it with a classroom set-up. These deficits are resumed by the following statements considering a distance learning setup:

- Lack of direct interaction (physical separation) between teacher and learner.
- Extended use of learning technology for the communication between teacher and learner.

On the other hand, distance learning offers vast advantages, such as easy access and 24/7 availability, learning at own pace, learning at home, and saving money and time (no travel).

In any case, learning has a social facet [10], requiring a component framework for a new distance learning environment, which at least involves the following basic principles: content preparation according to the needs (learning preference and profession) of the user group, access available on different technical devices, and the importance of a Social Network.

2.3.5 Social Network

What is a Social Network? Literature offers different definitions, and one sharpens that well: "*A Social Network is a social structure built of a set of social individuals (or organizations) which exchange different kinds of information, as well as providing interpersonal (emotional) support*." [1] However, some other similar terms exist that can cause confusion. To enlighten that, the following passage offers further particulars.

The term 'social media' is associated with online tools such as social media platforms or Social Network sites. These platforms provide occasions of "*interaction and communication between users*" and "*allow them to create and share content*" with the community or an individual member of the network. This is done by using mobile devices [19].

With regards to distance learning, social media aka Social Networks provide "*direct and indirect*" support for the learning initiative. It opens up new opportunities to interactively discuss ideas with other learners, students and other fellows, ask for individual or crowd-based help or maintain their own learning network [20]. Even further in a condensed form: Social media network fulfils "*social learning functions within and across informal and formal learning spheres of activity*" [21].

So, social media helps to connect students spread all over the world who are not present in a classroom set-up. And as people usually study at home nowadays, social media is an opportunity to connect with the outside world. This needs to be incorporated into the teaching concepts of effective and efficient distance learning courses and the set-up of learning environments. Through the application of social media, students will be motivated to build and maintain specific communication channels, which compensate for the lack of direct interaction in a classroom, which is being omitted in distance studies. The "*limitations of the education environment through the use of social network tools*" are eliminated or at least improved [22] when we assess the effect of commonly used social media platforms in distance learning set-ups.

Social (online) Networks facilitate distance learning as they represent the global standard or tools to live a virtual life within a certain community. The online network helps to build self-confidence and offers the ability to connect and interwork with their student peer group, and to gain other social qualities "*by accommodating their individual learning styles*" [23].

2.4 The transfer into real life

2.4.1 A transformation of education

Learning at a distance with the utilisation of modern Learning Technology and tools is fundamentally transforming education in a way that has never been seen before. Having more flexibility and more options for learners to access learning material allows both teachers (aka lecturers, professors, tutors, professionals, etc.) and learners to balance learning with other priorities in life. If applied and used well, online or blended learning formats boost the effectiveness of learning.

The following practical examples (academia and industry environment) and adaptations are meant to prove that statement.

2.4.2 Leadership Training for "rising" Talent (example 1)

A first example is the *Leadership Program* for *Young Engineering Talent* at a multi-national enterprise of the Chemical Industry. The concept and design of the 18-month learning journey for engineering staff nominated by their supervisors considers the discussed aspects of Social Networks, Learning Technology, Instructional Design and an aligned Curriculum Strategy of the employer.

The program, which was developed in close cooperation with an international consulting company includes the following facets:

- A tablet computer with access to all electronic learning formats and video conferencing as a giveaway for all participants.
- Different offers of local/global study and discussion groups for specific learning topics of the curriculum such as "*Self-reflection and personal development, Leading business dialogues and storytelling, Making and communicating decisions with self-confidence, Dealing with critical situations in a complex and ambiguous world (VUCA), Being brave and assuming responsibility, Self-marketing and visibility, Business innovation, creative thinking and Design Thinking, Networking and stakeholder management, Solving on regional challenges, Career planning and development*".

- Learner-specific designated and clear learning paths with milestones, deadlines and learning level assessments.
- Access to a self-directed learning platform (here: LinkedIn Learning®) for individual learning needs such as Microsoft Excel Advanced, Microsoft Power BI or Microsoft PowerPoint.

2.4.3 Self-directed learning for an entire workforce (example 2)

Self-directed learning brings benefits to employees of all levels and all professions at a global and decentralised company. The offering of a cost-free learning platform that can be accessed from personal equipment (mobile phones, private tablet computers, etc.) motivates employees to learn whenever and wherever needed.

In the case of example 2, the deployment of LinkedIn Learning® for the entire workforce of an international organisation that produces animal nutrition and other secondary products for further processing, the learning platform is integrated into their own Learning Management System. By doing so, all learning activities can be analysed and evaluated to design specific learning paths and to react to evolving learning needs with customised learning offerings. On the other hand, the user data (e.g. Who accesses the platform? From where? What topics? Duration of the learning event? Search history. Repetitions.) helps to improve the learning offer in general.

This example considers the discussed aspects of Learning Technology, Instructional Design and Learning Preferences.

2.4.4 Engineering Tutoring Program (example 3)

To evaluate the sustainability of knowledge of engineering mathematics of Bachelor Students, a global learning event was developed and executed [1]. Within this exacting piece of work, the pre-discussed aspects of Social Networks, Learning Technology, and Learning Preferences were put into consideration and were adopted accordingly.

A preliminary stage of Artificial Intelligence (semi-automated) was applied to find out the individual momentary preference for the media selection of a learning nudge of an Engineering Tutoring Program for Differential Equations. Based on the selection, the software offered a suitable learning nudge, and, whenever needed, redirected the learner to a study group to discuss a specific question. Even breakout sessions to take the learners' available concentration span into account were built in. Of course, the program ended with a learning level assessment.

2.4.5 Conclusions from practical experiences

The above practical examples of knowledge transfer and learning concepts follow the principles of the proposed alignment of Learning Preferences, Instructional Design, Learning Technology and Social Networks. Based on these examples in academia and industry environments, the following statements can be consolidated as examples of *good practices* in Distance Learning for Engineers. They can be understood as tips to best use what technology offers and were collected as feedback to the respective learning initiatives:

- Distance Learning for Engineers can be made more effective and efficient by using interactive and engaging learning materials, such as videos, animations, simulations or virtual laboratories. This can help students to better understand complex engineering topics.
- Collaborative Learning (study groups, discussion forums, feedback groups, classroom debates) is an effective way to engage students in distance learning. It can help students to develop essential skills (e.g. teamwork or communication).

- To provide feedback and answer potential questions, regular communication between teachers and students is important in a Distance Learning setting. This can be done using e-mail, video conferencing or instant messaging tools, and helps keep learners motivated, on track and engaged with their learning materials.
- Learners have the flexibility to access learning materials at any time and from anywhere.
- The utilisation of virtual classrooms, multimedia content and Augmented Reality applications which help to create an engaging (engineering) learning experience.
- Have specific long-term learning and short-term goals, which are supposed to be *smart* (specific, measurable, achievable, relevant, and time-bound). An established learning routine can provide a structure and helps to organise and manage time efficiently, considering a good balance between study time and relaxation.
- A designated and well-organized space for learning at a distance which is free from distractions can help to condition a learner's mind for learning.

By incorporating these practices into the conceptual aspects of Distance Learning in Engineering, all this can be made more effective and efficient for learners.

3 BASIC PRINCIPLES OF KNOWLEDGE TRANSFER AND OUTLOOK

The unique aspects of Learning Preferences, Instructional Design, Learning Technology and Social Networks together with the suitable content (learning curriculum) build the cornerstones of a new academic framework of successful (efficient and effective) Knowledge Transfer. This is shown in Figure 3, and it illustrates the functional interaction and synergy of these absolutely necessary components of Knowledge Transfer that were developed in conjunction with the development of specific Machine Dynamic knowledge that appeals to minimise the vibration of cabins of rope-less Passenger Transportation System MULTI®.

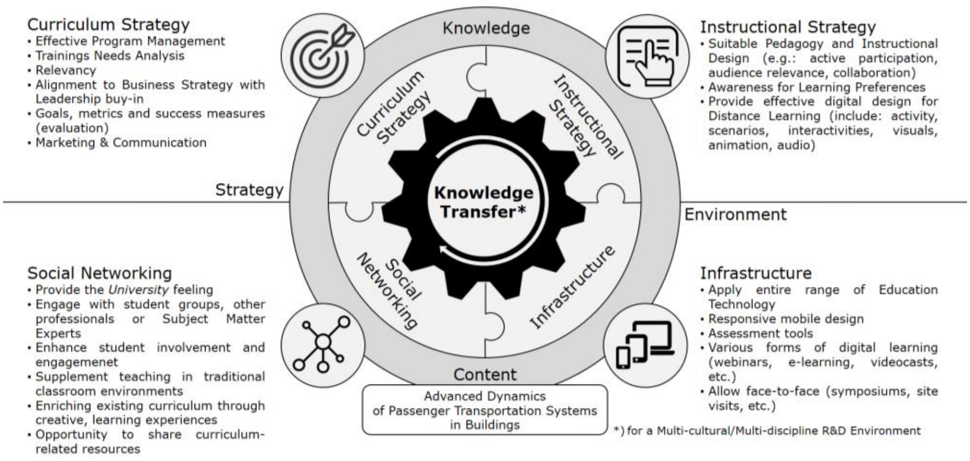

Figure 3 Components of a successful Knowledge Transfer

The model, although originated with a focus on a specific population of engineering specialists in the Lift Industry, can be considered a guiding principle for any set-up of a Knowledge Transfer to students or learners at a distance. The directive may be the case for universities, high schools or other learning situations of adult learners. It lends itself as a source of inspiration for teachers, tutors and learning professionals.

Especially with regard to the impact and consequences of Covid-19, the model offers huge potential for future application, as more and more learning takes place in the virtual world with learners studying in their private environments or even in public spaces. And it is apparent that this new way to learn and transfer knowledge calls for a decent level of success.

When it comes to the crucial aspect of Learning Preferences, which has an impact on Learning Technology, Instructional Strategy (please refer to Figure 3) and Social Networking, the evolving technology of *Artificial Intelligence* can help to enhance the learning experience.

Future learning units such as online study paths, online lectures or online qualification measures can be made reasonably priced but made-to-measure for all learners through Artificial Intelligence, as computer technology and software can load learner-individual learning opportunities according to a specific shape of learning preferences, which may change over the course of the day and over the decades of personal development. This may be implemented through computer and camera observations, comparisons of mouse click response times or the consideration of browser search histories.

"*Tell me and I forget. Teach me and I remember. Involve me and I learn.*"

Benjamin Franklin (1706 - 1790)

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BIOGRAPHICAL DETAILS

Dr Thomas Ehrl has a degree in Mechanical Engineering and graduated from The University of Northampton in 2021 with a PhD title. In his PhD thesis, he enlightens the interrelated complexity of Distance Learning and demonstrates a way to transfer sophisticated engineering knowledge at a distance in the most efficient and most effective way.

In his engineering career, which started back in 1994, he worked in different work environments, such as Plant Technology, Medical Device Industry, Steel Milling and the Lift Industry (Thyssenkrupp Elevator AG from 2008 to 2019).

Dr Thomas Ehrl enjoys long nature walks with his labrador dog Sally. He maintains and rides his classic British motorcycle *BSA A10 Super Rocket*, built in 1958. In his free time, he loves to cook for his family and friends, works as a Business Coach and travels with his wife and dog in his tiny caravan.