Design for Ride Quality – Knowledge Transfer of Advanced Dynamics of Passenger Transportation Systems in Buildings for a Multi-cultural/Multi-discipline R&D Environment

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ABSTRACT

This research study combines two comprehensive research subjects. It aims to make the transfer of complicated technical knowledge regarding the Ride Quality of multi-cabin lift systems from a knowledge provider to a customer as knowledge receiver more efficient and more effective.
These two research subjects together represent a gap in the body of knowledge: Knowledge Transfer (1) of novel technical knowledge (2) for experienced lift engineers, while that technical knowledge was developed by a lift manufacturer in conjunction with the presentation of a totally new concept for the propulsion system of a Passenger Transportation System (PTS).

Both subjects, Machine Dynamics and Knowledge Transfer, are explored in detail.
Machine Dynamics refer to the study of the motion of a system which is influenced by stimulating forces; and the process of transferring knowledge from one person to another is subject of many other research efforts in the wide range of the psychological discipline.

The research study considers novel knowledge about advanced Machine Dynamics of cabins of multi-car Passenger Transportation Systems, and the interaction of Learning Preferences and modern communication channels to propose a state-of-the-art concept for a Distance Learning setting for engineering staff of a global engineering workforce.

The given fundamental business need for a suitable process to hand-over technical information about a Passenger Transportation System to enable a specific customer to elaborate and refine a prototyped lift system to develop it further to a certified product, was the initial sparking idea for the research project.
To clarify the primal difference between information and knowledge, the following comparison helps to prevent further misunderstanding:

Information is defined by a set of structural data of something that is being explored, revised, and processed in a certain context for a better understanding of a specific subject matter.
On the other hand, knowledge is defined as useful information which was gained through a process of gathering experience, conducting training, practical understanding, or a structured learning process. Therein, the awareness of a person as receiver regarding any particular topic is a prerequisite, as e receiver of knowledge needs to ready to take on that knowledge in a Knowledge Transfer process.

Since the area of the relationship of complex (technical) knowledge and the corresponding learning process is underexplored, the initiator and sponsor of this research project, the globally operating lift manufacturer TK Elevator, kicked-off this research activities to enlighten the specific learning or Knowledge Transfer process of Specialists of the Lift Industry. To effectuate that comprehensive research project, the efficient mixed research methodology of causal-comparative & descriptive research was chosen. This selection promised a case-specific and practical approach to the given research topic of Knowledge Transfer.

The project includes a comprehensive analysis of influencing design factors to the perceived performance (noise and vibration) of a lift system, while the second focal area of the research considers concepts of Knowledge Transfer, the substantial examination of higher engineering education principles and the impact of Learning Styles to improve the learning performance of adult learners.
The objectives of the research project are located in the intersection between the Knowledge Transfer process and novel (machine dynamics) knowledge.

In particular, the research study is made up of a blend of research methods:
The critical Literature Review as a common practice, and causal-comparative & descriptive research, which involves the collection of information through questionnaires, interviews or observation, and a general comparison attempt to identify a cause-effect relationship between two or more groups.
Based on subjective observations during engineering training programs which were rolled-out globally, the scope of the research efforts was adapted from a geographic area-specific perspective to the individual approach based on the concept of Learning Preferences independently from the cultural background.
In this connection, different aspects of Social Networking and Social Media were added to the project scope, which in some way stimulated the research project and proved the up-to-dateness of the study.

As a result of the comprehensive and time-consuming research project, important factors for efficient & effective transfer strategies for advanced Machine Dynamics knowledge in an intricate environment were elaborated.
Those complementing factors are put into a compelling perspective and a depending relationship and therewith offer a new concept for effective & efficient contemporary Distance Learning Environments and adult engineering education, under the consideration of much more than just the application of e-learning or latest digital technology.
The research efforts result in a novel Knowledge Transfer model and are highly significant, as the findings demonstrate the clear implication to the future concept design of learning courses to enhance higher engineering education in a multi-cultural/multi-discipline R&D environment.
The research thesis provides a comprehensive analysis of PTS-specific knowledge regarding multi-cabin systems and vibration problems of such

systems on one hand, and a substantial analysis of subject matters around Knowledge Transfer and adult learners on the other hand. These are: Learning Preferences and Psychological Types, Learning Theories, Instructional Design, Learning Environments and learning technologies and the impact of Social Networks.

This present matter of research describes Passenger Transportation Systems in general and specifically multi-cabin systems. It describes the application of linear-motor technology and the uniqueness of its design before it leads over to TK Elevator's MULTI® system. MULTI® is a revolutionary rope-free Passenger Transportation Systems - invented by TK Elevator - that offers multiple cabins to move in two separated shafts and allow a horizontal movement from one shaft to the other shaft. This novel PTS uses magnetic linear-motor technology for the propulsion system.

To explain the design challenges of this rope-free PTS, the thesis defines Ride Quality and adduces Machine Dynamics as the main subject to handle, when it comes to a transfer of knowledge from a knowledge giver (R&D of TK Elevator) to a knowledge receiver (customer).

The aspects of Knowledge Transfer build a group of subject matters around Learning Preferences, its psychological background and the implications of Learning Theories, Learning Environment, Learning Technology, Instructional Design and Social Networks.

After a detail description of all respective research sub-areas, examined through structured questionnaires, survey and interviews, the thesis summarizes all those aspects and suggests a novel nexus that considers all main factors to make the process of Knowledge Transfer successful.

The outcoming and combined results of both aspects of the research study provide a holistic picture about the complexity to prepare, convey, receive and process theoretical and practical content. These results are derived into an overview of components of successful Knowledge Transfer. This includes the proven positive impact of facilitated study groups integrated into the concept of Distance Learning, which became a very notable topic through the Covid-19 pandemic, its consequences, and lock-down effects. Even further, the exposition professes the relationship of Social Networks in connection with Curriculum Strategy, Instructional Design and Learning Infrastructure.

Outlining the relevant issues around Knowledge Transfer of Advanced Dynamics of Passenger Transportation Systems in buildings and a consequent proposal for a distance study set-up for a multi-cultural/multi-discipline R&D environment, this novel approach has game changing potential for appropriate and modern 21st century learning.

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GLOSSARY OF TERMS

AWT	Average Waiting Time
CFD	Computational Fluid Dynamics
CTBUH	Council on Tall Buildings and Urban Habitat
Eur. Ing.	European Engineer
GETpro	Global Engineering Training program
HC	Handling Capacity
ILS	Index of Learning Style
LEIA	Lift and Escalator Industry Association
LMS	Learning Management System
LSQ	Learning Style Questionnaire
MBS	Multi Body System
MBTI	Myers–Briggs Type Indicator
MOOC	Massive Open Online Course
MULTI®	The world’s first rope-free elevator, moving multiple cars in a single shaft vertically and horizontally.
OLE	Open Learning Environment
PTS	Passenger Transportation System
R&D	Research & Development
REF	Research Excellence Framework
RTT	Round Trip Time
STEM	Science, Technology, Engineering and Mathematics

1 INTRODUCTION

1.1 Context of this Research Study

The inducement for this project and research activities was the launch of a new technological conception for Passenger Transportation Systems.
The idea was to use the existing concept of linear motor technology of the Transrapid[1] high-speed monorail system using magnetic levitation for the vertical mode of transportation means in high rise buildings (Barney, 2003).
That technology eliminated ropes, which represent the basic principle of traditional lift systems (Andrew and Kaczmarczyk, 2011), and required a novel car/cabin set-up, a so-called backpack structure. This needed new mathematical simulation models and counter measures to improve noise and vibration of those PTS cabins (Missler *et al*., 2016).
Although the individual components are not new and already utilized in other technical systems, the technical composition or assembly of MULTI® is revolutionary and unique. The obvious uniqueness of MULTI® results of the specific composition of the entire system assembly and the necessary fine-tuning of those parts and sub-assemblies.
With the background knowledge, that the Ride Quality of a PTS cabin is essential for the quality assessment and subjective perception of comfort of a passenger, this present research study investigates the influencing factors and measures to improve Ride Quality.

The existing research is virtually exclusive for roped lift systems and therefore the need for the development of a mathematical model for rope-free lift systems is obvious (Sánchez Crespo *et al.*, 2018).
Although the technological advantages of this novel Passenger Transportation Systems are vast in numbers (for instance: minimization of system footprint, continuous passenger flow, flexibility and design

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[1] The Transrapid system is developed and marketed by Transrapid International, a joint venture of Siemens and thyssenkrupp. The first commercial implementation was completed in 2002 in Shanghai/PRC.

freedom of building design, regenerative system), the pure system investment is much higher when it comes to the comparison with a standard high-rise lift system.

This circumstance forced the innovative lift manufacturer TK Elevator to develop an unusual distribution and licensing concept. The technology itself has been developed, prototyped, tested, and made robust (Löser *et al.*, 2018). The final product at the end must be engineered by competitive licensees around the world.
Keeping in mind, that the technical study is limited to aspects Machine Dynamics of Ride Quality of Passenger Transportations Systems, this approach clearly calls for a professional transfer of knowledge and technology.
Targeting for a global customers or licensees, the transfer process (learning) for the novelty must consider a multi-cultural/multi-discipline R&D environment.

The totally new way of looking at that unique technical system, that contains state-of-the-art components and sub-assemblies but is composed in a unique way, requires a completely new approach of Knowledge Transfer. This fact becomes especially important, as soon as the diversity of local market requirements, engineering knowledge and different ways to grasp information (learning) are being considered:

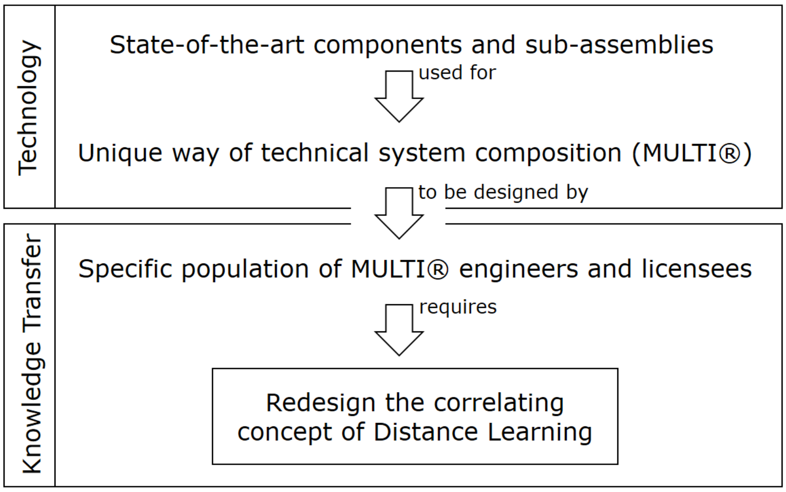

Figure 1 –New way to look at Knowledge Transfer follows unique System Composition of MULTI®

Figure 1 illustrates the need to rethink the concept of Distance Learning of technical topics of the unique assembly of MULTI® to ensure the Knowledge Transfer within a multi-cultural/multi-discipline R&D environment (from the lift manufacturer TK Elevator to and engineering department at a customer side). The system designer decided to use state-of-the-art technical components, which are very well established and have a robust design. These components are available on the market for technical sub-assemblies and find its way into numerous constructions. However, they are assembled in a unique manner, which represents the novelty. For the first time, linear motors are used in a vertical system for passenger transportation purposes. State-of-the-art components for the trajectory control and safety applications are also assembled.

This specific novelty requires new ways for creative thinking and a new way to learn about the technology, as in this specific case, the final design needs to be done by the addressees of the Knowledge Transfer process. These recipients are spread all over the world. For efficiency reasons, the Knowledge Transfer is done in distance, using up-to-date learning Education Technology.

The decentralized company structure of TK Elevator, composed of geographically split Business Areas with strong local governance, is caused by non-natural growth based on mergers & acquisitions activities since the 1970s, and is very unique, in fact. Nonetheless, the corporate parent started to conduct company-wide training in 2012, when they kicked of a R&D Academy with the so-called GETpro initiative.

With GETpro, training started to be conducted with centralized (global) governance, a centralized financial budgeting process and centralized controlling.

The core engineering training curriculum GETpro is primarily designed for the Research and Development (R&D) community of TK Elevator, but it could possibly provide training across other technical staff areas.

Not only that the different experience levels of engineers are taken into account, that set-up allows a constantly good output and alignment to local and global needs.

GETpro follows a modular structure that represents the composition of engineering profession & experience and local regulations (technical).

Each module is defined by learning goals, content and teaching methodology. (Ehrl *et al.*, 2018)

Clearly, the efficient & effective set-up of any corporate learning program is essential, especially when it comes to minimizing the cost and maximizing the productivity of a workforce (Wilke, 2006).

Moreover, the understanding of the learning process has gone through changes. Nowadays various ways how knowledge is being transferred must be taken into account, so for instance the context of the workplace environment.

The Knowledge Transfer process or learning process, which is in scope of this research project, transfers technical knowledge from TK Elevator to a group of engineers at a customer side.

The effectiveness of that Knowledge Transfer process depends on different concepts of which one is the preferred method a person uses to learn or study (Felder and Silverman, 1988), and is matter of effective instructions (aka Instructional Design).

On this basis, this research project builds a connecting link between a learning topic (individual Learning Preferences, Instructional Design and Social Network support) and a technical topic (Machine Dynamics of cabin vibration of rope-free Passenger Transportation Systems).
With extensive research work been done around adult learning and Machine Dynamics, the specific intersection between technical Ride Quality knowledge of PTSs on one hand and the corresponding learning process on the other hand needs a deeper look into.

On the foundation of the novel system design of TK Elevator's Passenger Transportation System MULTI®, the contribution of this research study is the improvement of the learning or Knowledge Transfer process of experienced engineers of the Lift Industry and includes:
The verification of the influencing factors of efficient & effective Knowledge Transfer process of Advanced Dynamics, and the development of an Academic Model of Knowledge Transfer for engineering Specialists of the Lift Industry.

1.2 Aims and Objectives

The overall aim of this research study is to improve the best practice of Knowledge Transfer (for multi-cultural/multi-discipline R&D staff) of issues around novel knowledge in respect to the ride performance of TK Elevator's MULTI® system through an in-depth understanding of the underlying concepts of learning. At the end, a radically new view to an academic Knowledge Transfer model is to be presented.

The discussed Knowledge Transfer process happens between a knowledge provider (in our specific case TK Elevator) and a knowledge receiver aka learner (here: engineering staff of a customer who needs to refine the technical concepts of MULTI®).

The focus question of the study can be condensed to the following:

How to transfer knowledge?

with knowledge defined as a practical or theoretical understanding of a subject. Knowledge is what someone learned, understood or is aware of. In the context of this research study, it is the formal and systematic understanding of something, such as facts or skills, which are transferred through a learning set-up that involves a physical distance between the sender (= teacher) and the receiver (= student) or represents a digital Learning Environment.

The Machine Dynamic content (= facts) that is being transferred has a technical character and involves higher mathematic, kinematics, dynamics, solid mechanics, and acoustics.

The research study conception can be broken down into the following research objectives of this study:

- To determine the key dynamic parameters and interaction that influence Ride Quality of Passenger Transportation Systems.
- To investigate the existing methods of Knowledge Transfer/delivery. (How do people learn and apply learning?)
- To develop an Academic Model for Knowledge Transfer which can be integrated into existing training concepts for lift engineers.
- To test the model and to evaluate its pedagogic impact.
- To predicts the business impact of the model.

1.3 Approach to the Study

With the focus to the project aims, the following strategy with three components has been deployed. That approach includes:

- A critical review of the literature.
- The analysis of two surveys on Learning Preferences and Social Media consumption.
- And the results of specialists' interviews about the set-up of Learning Environments.

The critical Literature Review of plenty of sources includes various subjects, including *Ride Quality, Advanced Vibration Dynamics, multi-car lift systems, Knowledge Transfer, adult learners, engineering education, Learning Theories and Learning Styles, Instructional Design, Social Media, and Learning Technology.*

This structured assembling together, aims to meet the compelling requirements of the UK REF Research Excellence Framework, in particular the criteria of research significance.

With the launched Academic Model for efficient & effective Knowledge Transfer (of complex technical knowledge for a specific professional adult target group), the outcome represents a vital benefit to the learning industry, academia, and higher education. The Academic Model of the final conclusion has the momentousness to potentially change the way universities and higher education faculties prepare their curricula, especially in pandemic times.

Over the period of 18 months, the number of almost 400 survey respondents (the first quantitative query was conducted by 353 respondents and the second quantitative & qualitative query was performed by 40 respondents) and 8 specialists interview participants have been counted. These volunteers included a sample of engineers and students from all over the world, a group of engineering people working in the Lift Industry and Lift Industry Specialists.

The findings based on the analysis of those survey results have been applied to recommend a framework for a concept for the principal set-up of a Distance Learning Environment for lift engineers.
The engineering population of TK Elevator and MULTI® licensees obviously contains of the entire range of engineers with different professions, specific skills, experience level and Learning Style Preferences.
Therefore, a corresponding training curriculum for all learners that guarantees an effective (and efficient) transfer of engineering knowledge becomes indispensable.

The entirety of that R&D environment has been taken into account when the research subsections were structured and designed (please refer to chapters *3.5 Survey with a global Engineering Sample (Research Subsection #1)* to *3.8 The Interviews with Lift Industry Specialists (Research Subsection #4)*.

1.4 Introduction into the Research Methodology

This research study is composed of two research methods: A critical Literature Review and a blend of causal-comparative and descriptive research, which includes qualitative data analysis (interviews) and quantitative & qualitative data analysis (surveys).[2]

For the purpose of this research project, the following terminology is captured accordingly:

- Descriptive research involves the collection of information through data review, surveys, interviews, or observation, and therewith it describes the way things are.

- Causal-comparative research involve a comparison attempt and aims to identify a cause-effect relationship between two or more groups.

Please refer and compare with Cohen *et al*. (2000).

The results from the quantitative & qualitative research aspects (questionnaires/surveys) and the Literature Review were used to specify the structure of the qualitative interviews.

In the descriptive & causal-comparative research part, primary data has been collected through surveys and interviews and subsequently been analysed.

The critical review of the literature considered the analysis of primary, secondary, and tertiary sources.

[2] Please refer and compare to Johnson and Onwuegbuzie (2004) and Terrell (2012)

1.5 The PhD Roadmap

That portrayed basic idea was put into a project roadmap, a graphical high-level toll, that helps to tracking goals and project deliverables presented on a timeline.

The roadmap also serves as a communication tool within the project team at TK Elevator and for the coordination with the supervisors. It provides a bird's eye view of the project without getting into too many details:

A project roadmap generally contains the following aspects:

- Project goals and objectives
- A timeline and schedule
- Milestones and deliverables
- Dependencies

The project roadmap of this present PhD study is shown in Figure 2 on the next page.

TOPICS	DATE	
Paperwork (University of Northampton)		
Proposal	March 2, 2015	Milestone
Registration (enrolment)	November 2014	Project activitiy
Suspension	May 2016 - April 2017	Project activitiy
Transfer	January 2021	Milestone
PhD Thesis writing	April 2020 - August 2021	Project activitiy
PhD Thesis defense (Viva Voce)	March 2022	Milestone
Recommendations for corrections and completion	October 18, 2022	Milestone
Technical research aspects		
Study of technical topics (general Noise & Vibration)	started in March 2015	Project activitiy
Determination of key dynamic parameters that influence ride quality	April 2015 - August 2015	Project activitiy
Develop N&V knowledge (within MULTI project)	ongoing	Project activitiy
Presentation of MULTI prototype in Rottweil	July 2017	Milestone
Educational research aspects		
Research (interviews, surveys, etc.)	various iterations and cycles	Project activitiy
Literature review	March 2015 - August 2021	Project activitiy
Development of academic model	July 2021 - August 2021	Project activitiy
PhD student development program:		
TK Elevator N&V trouble-shooting field support (on site)	April 2015 - April 2016	Project activitiy
How adults learn? (Langevin Learning Services, Atlanta)	March 17th, 2015	Project activitiy
Web-based training (Langevin Learning Services, Atlanta)	May 2015	Project activitiy
Presentations at conferences		
5th Lift Symposium, Northampton	September 2015	Milestone
6th Lift Symposium, Northampton (as co-author)	September 2016	Milestone
7th Lift Symposium, Northampton	September 2017	Milestone
9th Lift Symposium, Northampton	September 2018	Milestone
10th Lift Symposium, Northampton	September 2019	Milestone
6th ATINER Conference, Athens	June 2021	Milestone
Meetings with stakeholders and Supervisory Board of TUoN	about every 6 weeks	General communication
	Milestone	(dark shading)
	Project activitiy	(light shading)
	General communication	(hatched)

Figure 2 –PhD Roadmap

1.6 Structure of this Document

This document is structured into five sections:
Introduction, Literature Review, Research Methodology, Results and Findings, and Conclusions.

The Literature Review summarizes the relevant literature of the topics listed above (please refer to chapter *1.3 Approach to the study*) and therefore builds the groundwork of this study.
Within the Literature Review section, a significant number of chapters are needed to define important topics of the study and to explain the holistic framework of the study.

The Concept Map of this research project (see Figure 3) identifies relations and interdependencies between the individual topics of the study.
A Concept Map is a visual organizer that illustrates suggested relationships between concepts in a hierarchical structure. Thereby this graphical representation of knowledge typically represents ideas and information as boxes or circles, connected with labeled arrows which describe the relationship between concepts with linking phrases.
A Concept Map can help answering the question about the relevance of something and is used by Instructional Designers, technical writers and others to structure knowledge. It typically evolves over the curse of time of a project.
Figure 3 shows the final version of the Concept Map of this research study, which evolved over the curse of time of the research project.
This graphical tool helps to depict the relationship between the pedagogic aspects (the process of Knowledge Transfer in a distance study approach) and the technical aspects (Machine Dynamics) of the project.

In addition to it, the section on the Research Methodology explains the reasons for the selection of the applied research methods of this study.

The section on *Results and Findings* (chapter 4) represents the analysis and reflection of the survey and interview results.

Chapter *5 Conclusions and Further Work* completes the work with a synopsis and lookout for further activities.

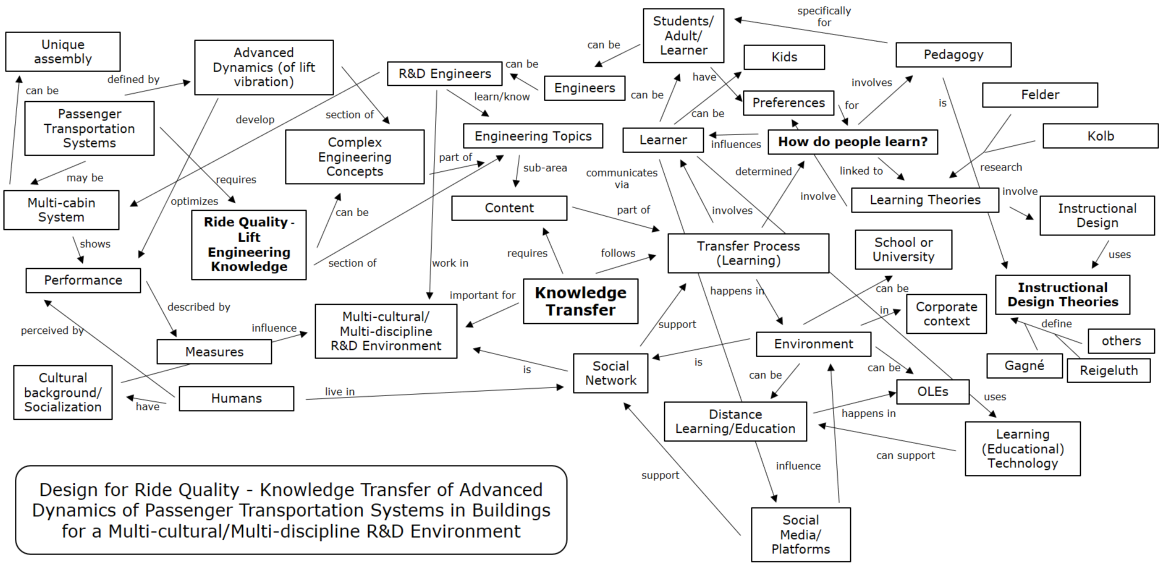

Figure 3 – Concept Map

2 LITERATURE REVIEW

2.1 Preface

This thesis examines the concepts of Distance Learning (Knowledge Transfer) for a global engineering workforce, which is developing a radical new and innovative piece of passenger transportation technology, and hence needs to understand the design-specific advanced Machine Dynamics of Passenger Transportation Systems in buildings.

Know-how or knowledge represents an asset of high value for any organization, and the topic of Knowledge Transfer (not only in organizations) is subject of a huge number of research efforts. For corporate enterprises and organizations, Argote *et al*. (2000) define, that the process of Knowledge Transfer between individuals or groups in an organization is "*affected by the experience of another*".
In other words: Being more than just a problem regarding communication, Knowledge Transfer in organizations is the practical task to transfer knowledge from one part (or individual) of the organization to another.

The concept of (engineering) learning and a Knowledge Transfer of engineering topics is part of a huge number of research studies (Antonova and Csepregi, 2016; Bourne and Mayadas, 2005; Bransford *et al.*, 2000). And as a fundamental basis for that process, the effect of culture to learning results, as initially suspected at an early research stage, was also subject of numerous research projects (Felder and Silverman, 1988; Honey and Mumford, 1986).
All this is described very well in literature, while the interest into the impact of Social Network platforms, which became more and more popular in the 2000s, started with the success of those Social Networking platforms. So did Ellen Hoffman in 2009, when she evaluated "Social Networking Tools for Distance Learning".

It can be deduced from the fact of a huge number of research results, that the subjects that are included in this present research study are explored in depth. However, the intersection between Instructional and Curriculum Strategy, Social Networking and learning infrastructure offers a sufficiently dimensioned research gap, that is worth elaborating.

The idea of this research project arose during the product design phase of the above-mentioned Passenger Transportation System, when licensing concepts to sell the technology worldwide to interested parties were wanted.

So, the sequence of this review of pertinent literature starts with the global megatrend of urbanization, urban development, state-of-the-art and innovative means of vertical transportation, and the application of linear motor technology. Furthermore, literature about Ride Quality of lift systems and Advanced Dynamics of that Ride Quality are discussed.

Beyond that, the Literature Review touches the topics of problem solving and concepts of adult learning, Learning Preferences and individual psychological styles, and Knowledge Transfer.

Finally, on the foundation of learning theories, appropriate literature on Instructional Design, Learning Technology & Learning Environments and the effect of Social Networks, it is examined, how to make the Knowledge Transfer of Advanced Dynamics of Passenger Transportation Systems in buildings for a multi-cultural/multi-discipline R&D environment as efficient and effective as possible.

The technical sub-area of this Literature Review includes literature about ride performance and the general application of cabin vibration to passengers, as this is core area of the research study and the link between the technical system (Passenger Transportation System) and the human being. This Ride Quality (please refer to chapter *2.6 Ride Quality*) was subject of all preparatory technical R&D projects, whereby these development projects are comprised by detail system and component calculations and computations. For the reason of a research connection indeed and the association to those pre-arrangements, this Literature Review on hand doesn't include technical literature on calculation methods or higher mathematics, which are subject of the secondary line of research projects.

2.2 Delimitations and Definitions

2.2.1 Advanced Dynamics

Being the opposite characteristic of *static*, the term Dynamic stands for a stimulated change within a given system.

In his book "*Analytical Mechanics: With an Introduction to Dynamical Systems*", Török (1999) defines dynamics as the "*science of changing systems in a general sense*...".

And the Technical University Delft (2020) describes dynamics as "*a branch of mechanics that deals with physical phenomena of a body or bodies in motion and how forces can be related to motion*." in their outline for an academic online course on Advanced Dynamics.

Moreover Ginsberg (2008) declares engineering dynamics as the subject "*how bodies move under the action of forces*".

In other words, Advanced Dynamics is an important subject of study on the fundamental laws of motion (as reaction to applied forces and stimulation) and looking into analytical tools of dynamics as applied in mechanical engineering.

In engineering and science, the aim of the subject of Advanced Dynamics is the description of dynamic movements of objects to analyze and to detect strong or weak areas applying *"various methods of dynamical analysis",* as written by Greenwood in his book "*Advanced Dynamics*" in 2003.

Their description of dynamical theories includes vectorial and analytical methods, while Balthazar *et al*. (2015) define "*Dynamics and Control of Technical Systems*" as a more general topic.
In their viewpoint, Machine Dynamics refers to an application in science and engineering, which describes linear, non-linear, and chaotic dynamic relationships and the attempt to control consequences and impacts.

Recently, Lemos (2018) ties all that together with a focus on Analytical Mechanics writing about fundamental physical quantities ("*angular momentum and the kinetic energy"*) which need to be considered for the dynamical study. After the application of forces and torques as causes for a specific motion of a rigid body, we are able to calculate obvious problems of the technical system (*"kinematic apparatus"*), while Ginsberg (2008) points out the essential importance of vectors, stating "*almost every quantity of importance in dynamics is vectorial in nature".*
These quantities are oriented in a respective direction and are defined by a specific value. Thereby, the kinematic vector gains substantial relevance as determination of position, velocity and acceleration for kinetic values of force and movement.

When it comes to the consistent and systematic assessment of the behaviour of complex systems and how kinetic and potential energy is involved, mathematical equations help to describe these motions of complex systems.
The needed mathematical methods and practices were developed accordingly with the focus on a precise description of rigid bodies and their predicted motion. At the end, these techniques aim to theoretically anticipate the changes of the rigid body after the application of forces and stimulus.

In Török's words (1999) in his book "*Analytical Mechanics: With an Introduction to Dynamical Systems*": "*In fact, the development of dynamics and mathematics runs parallel*."

In Advanced Dynamics we can model mechanical systems, which are often complex and dynamic, with the support of higher mathematics. And we can derive necessary equations of motions of these modeled complex dynamical systems.
This fundamental mathematical richness caused Lemos (2018) to the statement "*The mathematical apparatus of analytical mechanics is very rich…"* and enables scientists to use and apply a toolset for a huge range of different problem formulations.
This mathematical apparatus is needed for the product development of MULTI® and therefore subject of the future Knowledge Transfer. Different ways to teach mathematics are evaluated and opposed in chapter *3.7 Two Learning Journeys (Research Subsection #3)*.

But it is Ginsberg (2008) who characterizes the capability to model and subsequent analyze complex new systems. He describes the development of mathematical and analytical procedures as necessary qualification for the systematic system analysis of totally new concepts, when it comes to the analysis of kinematics and kinetics principles.

And this competency i.e. was applied by (Arrasate *et al*., 2014), when they proposed a simulation model to describe and analyze the performance in regard to vertical vibrations of an elevator system which is affected by torque ripple generated at the elevator drive system.
These vertical vibrations affect passenger comfort during an elevator travel, and they were subject of a paper, which proved that the "*proposed simulation models can be used as design and analysis tools in the development of high-performance elevator systems*."

The intention of a mathematical model is to describe all important features of a system or rigid body to be able to derive respective equations to predict the behaviour of the system or rigid body. Withal this mathematical model should provide sufficient details on one hand but should be not too complex on the other hand, to allow for better handling.

The whole trick within the engineering science is to develop a mathematical model (for example for a stimulated mechanical system) that is appropriate for the given problem.

This is somehow supported by Rao (2005) who suggests keeping the system description and therewith the modelling of the system as simple as possible.

His statement makes perfect sense but requires a huge mathematical body of knowledge to be able to brighten up the complexity of the topic.

2.2.2 Adult Learners

As described in chapter *2.9 Multi-cultural/Multi-discipline R&D Environments*, multinational organizations are organized more and more in multi-cultural and multi-discipline teams, and this set-up is inhomogeneous and shows many variants and factors, such as for instance

- Age
- Experience
- Gender
- Profession
- Civil status
- Available time, workload and other resources

With this being said, this is pretty much related to the growing number of adult students/learners joining universities. Pelletier (2010) described

that group of adult (university) students as a totally non-homogenous with a long span in its age structure with students aged between 25 years and 75 years. Not surprising, that these students are full-time employees, work part-time or jump between different smaller jobs. Furthermore, they may have kids or other close relatives.
Some of these characteristics are encountered by Hardin (2008), when she described the barriers which adult students are facing. She also differentiates them generally from "*traditional-aged students*".
The main barrier of adult (working) students or learners is obviously the lack of time due to - for instance - family responsibilities. That is valid for all learners, also in our professional context within this research study.

Understandably, that these facts can cause challenges, which can be overcome with a clear and student-focused set-up within an organization such as a university institute or an enterprise organization.
To fulfill the specific needs of an adult student group, the following framework promises an efficient and effective learning result, which is built within the borders of flexible delivery formats, expanded adult-specific advice and services.

Suggested framework for adult students/learners:

- 24/7 access to learning resources
- Consideration of the specific information needs (e.g. support office plus online information)
- User-specific guidance and clear orientation
- Assistance whenever deficiencies (from prior education) occur
- Put adult learners into the centre of action, and consider the special learning needs

Hardin (2008) suggested a ninth principle when she cited the *"Council on Adult and Experiential Learning"*. She endorses the suggested framework indirectly, as those principles are captured for the most part. They are reviewed further in chapters later on.

Basically, Frey supported that idea (2007), when she described the framework for adult learners as university directed and supported learning journey, helping those students to obtain their individual *"educational and career goals*."

2.2.3 How do People learn?

The question *How do people learn?* is subject of numerous publications and research works, and we should probably begin with the understanding for the process of learning, which generally can be described as a sequence order to process experience (Bransford *et al*., 2000).

Abstracted to a bare minimum, learning can also be understood as a simple two-step process which involves information reception and information processing, as outlined by Felder and Silverman (1988) and depicted below.

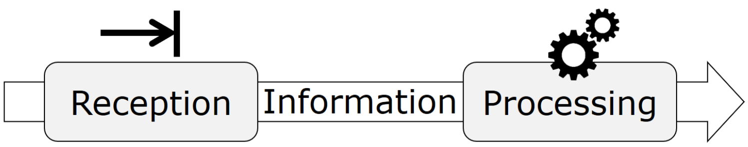

Figure 4 – Learning as two-step Process (Felder and Silverman, 1988)

They describe a two-step process (see Figure 4) which at the end come down to a process output, which is represented by a learned item or an item that is not learned. In the first step (reception) information is

presented to learners who decide to process (learn) the material or not. They may ignore a huge portion of the offered items.
Step two (processing) propounds several different ways to assimilate that information. These different ways to digest the learning food can be a simple memorization, a reflection or following activity or an interaction with others.

This simplified process and the general descriptions about (knowledge) transfer of Bransford *et al*. (2000) represents the underlying learning model of the study design.

Learning itself is topic of numerous research papers, publications, and books. This Literature Review focusses on the aspect of the implication to (adult) pedagogy and distance study/learning.
Other aspects of learning (→ neurobiology, educational psychology, neuropsychology, or experimental psychology) are not part of this Literature Review.

The concept of learning has to do with three principles:

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

and is also pictured this way by Donovan and Bransford (2004).
To be able to develop necessary competencies and gain desired skills, students should demonstrate a solid given knowledge, understand the conceptional framework of the given context and to structure the skills and knowledge gained in the way that they can utilize it (*"retrieval and application"*).

These are basically other words for a simple depiction of the way we learn:

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

And this pretty much corresponds with the model Kolb introduced and originally published in 1984, when he identified four modes in the learning cycle/process (Kolb, 2014):

- *"Concrete experimentation*
- *Reflection*
- *Abstract conceptualization*
- *Active experimentation"*

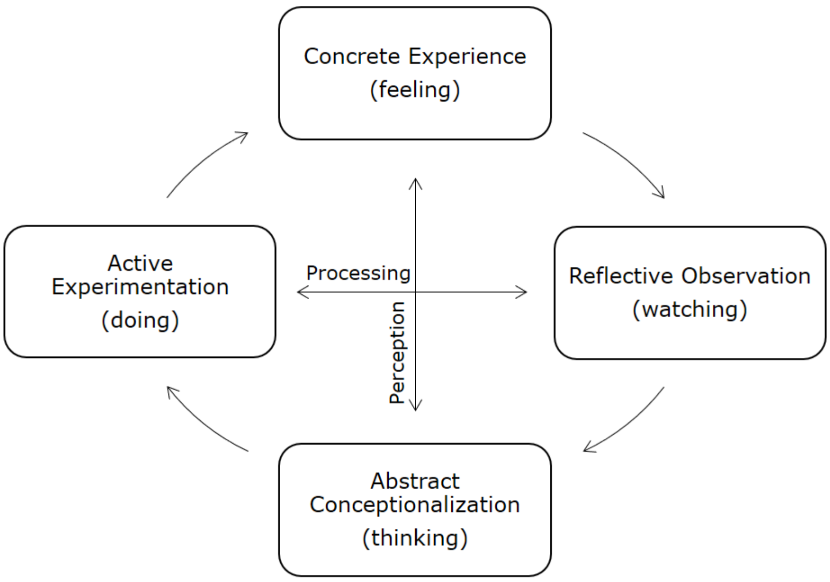

Figure 5 – The Learning Process (Kolb, 2014)

Figure 5 depicts the learning process as a holistic perspective with the learner touching all the bases.

The model illustrates learning of a person as progresses through a four stages cycle:

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

This model of a learning process seems to be a reasonable approach to breakdown the process of learning into further elements, which in consequence should find its way into the conceptional efforts for good practice for a learning set-up.

A more generic approach is depicted by Gross (2010), when he phrases, that "*learning is a hypothetical construct*", which implies the ideally enduring change of the performance or behavior of a human being.
Beyond that, the learning process evidently eludes from a direct observation, but successful learning can be concluded from the detection of recognizable behavior.

With a slightly different viewpoint, Kolb (2014) identifies learning as problem solving and puts it together as problem-based learning (in Higher Education), whilst Engeström (1999) describes a learning cycle as sequence of epistemic actions (see Figure 6),

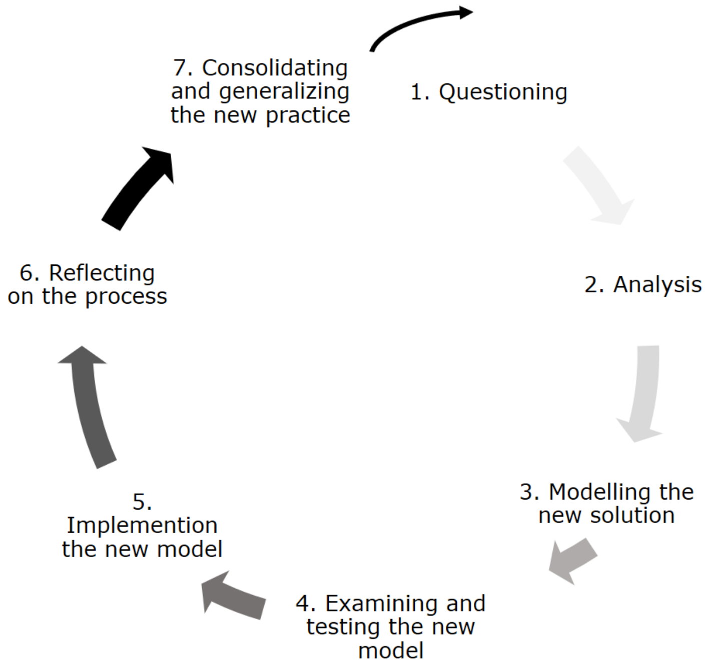

Figure 6 – Sequence of Learning Action (Engeström, 1999)

with the following explanations:

The cycle starts with the "*questioning, criticizing, or rejecting some aspects of the accepted practice and existing wisdom.*"
This initial step is followed by the situation analysis, which involves a transformation of that situation (mentally, discursively, or practically) to examine "*causes or explanatory mechanisms*".
The third cycle step develops a new solution model, while step 4 examines and proves the model regarding limitations, potentials or behavior.
That new model is implemented in step 5 of the cycle, while few conceptional enhancements can still be added to the model. Before the final consolidation and generalization of the model, and the transfer into practice, the entire process is going to be evaluated and assessed.

Dann (2003) manifests statements of other authors in her book "*Promoting assessment as learning – Improving the learning process*", when she states, that learning has a social dimension: Other people play an important role in the learning process, and "*the learner cannot be regarded in isolation from others*."

That leads to a vast deficit, when we take the typical set-up of distance study into account. In a distance study or Distance Learning[3] Environment we have two main differences to a classroom set-up:

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

Distance Learning offers significant advantages, such as for example:

- Easy access and 24/7 availability
- Learning at own pace
- Learning at home
- Saving money and time (no travel needed)

Based on Kolb's Learning Cycle, Engeström's Sequence of Learning Actions, and the implication that learning has a social facet, a simplified model for the transformation process and framework of a model that specifies the components of a new Distance Learning Environment can be derived. This model involves at least the following aspects:

- Importance of a Social Network.
- Access available on different devices.
- Content preparation according to the needs of the user group.

Please refer to chapter *4 Results and Findings* for further information.

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[3] Distance Learning: The way of educating students online. Learning materials are available online or sent via e-mail. Students work from home, not in a classroom.

When it comes to the suitable preparation of content for learners, soon the term Index of Learning Style (ILS) is hailed. The ILS is an instrument developed by Felder and Silverman (1988) and for instance explained for Engineering Education (1988).
Further concepts of Learning Preferences and psychological types are discussed in the chapter *2.10 Learning Preferences and Psychological Types*.

2.3 Passenger Transportation Systems

Urbanization, the process of growth of the number of people living and working in metropolitan areas, is one of the most important megatrends of the century.
This mass migration of populations from rural to urban areas gathered speed over the past decades. While in the beginning of the 19th century about 2% of the global population lived in cities, it is 55% now (in 2017). It is projected that in 2050 that number will increase to 75% (Ritchie and Roser, 2018).
By nature, with limited areal and space, there is only one direction to grow into: Upwards.

In other words… The areal density of life in urban areas requires tall building and hence vertical means of transportation (Burns *et al.*, 2016). This development was made possible and started in the middle of the 19^{th} century, when Elisha Graves Otis made a vertical transportation system for passengers possible in the first place in 1852 with his invention of the safety brake. That sort of vertical transportation system is known today as a lift system in this specific approach.
The term *Vertical Transportation*, also used by Andrew and Kaczmarczyk (2011) in their book "*System Engineering of Elevators*", refers to the complicated process of the movement of people or goods in a building, under the consideration of system specific data (number & location of

shafts, rated load & speed,) and in combination with building circumstances, such as dimensions, access routes and their location in the building or the utilization of building areas.

Certainly not all buildings, and not even in metropolitan areas, are tall buildings. Understandably enough, there are few general categories of buildings, which are determined by its height: low rise, medium rise and high rise.
In this context, we can define low-rise building following Emporis (2020) as enclosed structures with a total architectural height of maximum 35 meters. The entire structure is divided into levels that offer usable space. Unfortunately, this definition leaves medium rise open. But in any way, medium rise buildings build the bridge between low rise and high rise (so-called tall) buildings.

The CTBUH (Council on Tall Buildings and Urban Habitat, 2020) developed the international standards for measuring and defining tall buildings. Therein the number of floor levels seems to be a weak indication for a tall building, as the level height differs from building type and function of a building (for example office building and a residential building).
Well, a building that is more than 50 meters high is typically called a tall building.

With evolving technology and improvements to building supplies and construction materials, even higher buildings were made possible and therefore the skylines grew in height.
The Council on Tall Buildings and Urban Habitat (2020) stated furthermore and classifies two additional tall building sub-groups: Supertall buildings are tall buildings with a height of 300 meters or more, while mega-tall (or ultra-tall) buildings are 600 meters tall or even taller.

Of course, the respective means of vertical transportation in these buildings have to fulfill a number of requirements.
With regard to vertical transportation systems and the application of linear motor technologies, tall (or mega-tall or ultra-tall) buildings, have to address but are not limited to the following technical issues:

- The system configuration concerning the traffic flow within the building, and in some circumstances between buildings.
- The diversity in respect to building capacity of different building use types (e.g.: residential or commercial) and therewith its service functions.
- The incorporation of alternative Passenger Transportation Systems in the building (conventional elevators, escalators or people movers).
- The highest requirements for reliability, safety and passenger evacuation.
- Passenger comfort (changes of air pressure, vibration, vertical and horizontal motions) and travel time.
- The system's propulsion, guide rails, brakes, power consumption, computer control and communication systems.

Noted alike by Gieras *et al*. (2018) with their specific focus to linear motor technology and the application for vertical transportation.

As the purpose of any Passenger Transportation System is the ability to move people around, it is somehow obvious to ask for ideal capacity of such a system.
This ideal system output performance in regard to passenger movement is influenced by the building itself, and thus the efficiency of the circulation of passengers and goods inside a building is affected by the following factors and comparable with Barney and Butcher (2015):

- Building shape
- Specific location of the interior rooms to each other
- Arrangement of main floor spaces in regard to entrances or other equipment to move people
- Importance of the lift journey
- Separation of different kinds of traffic (floor-to-floor or longer shuttle trips)
- The obvious requirement to group alike utilized spaces together
- Potential conflict of vertical and horizontal traffic modes

Hence, the efficiency of the circulation of passengers and goods inside a building depends on a number of diverse factors.

In a broad holistic point of view, the system efficiency (in respect to the movement of people and goods) can be defined as the Handling Capacity (HC), and it is measured in (here for Passenger Transportation Systems) "*number of people per specific period of time"* (Barney and Butcher, 2015). This HC needs to be considered in context with the Round Trip Time (RTT) and Average Waiting Time (AWT).

So, "*in the modern sense, an elevator (or lift) is defined as a conveyance designed to lift people and/or material vertically*." (Strakosch, 2010), while another simplified definition of a lift could be:

> A lift is a box-like device that moves people or goods up and down, from one floor level of a building to another floor level.

Andrew and Kaczmarczyk (2011) define an elevator as "*a permanently installed system, with traction, positive drive or hydraulic drive, serving defined landing levels…",* and add the existence of a lift cabin for passengers or goods, a suspension system (or support by a hydraulic jack) and the reference to a guiding system for cabin and counterweight.

Barney and Butcher (2015) generalize even more when they define the circular flow inside a building as "*movement of people in buildings*". They further describe it as a "*complicated activity*", which is influenced by three factors:

- The operating mode in horizontal and/or vertical direction.
- The type of movement, either a natural movement or supported mechanically.
- The human factor.

The bespoken lift systems are composed of a huge number of sub-assemblies, which make a lift system complete.
The basic lift components include but are not limited to:

- Cabin or car, counterweight
- Hoistway/shaft, guide system, landing doors
- Machine/drive system/motor, sheaves
- Control system/unit
- Safety system (e.g. over speed governor or buffers)

All the above factual descriptions do not consider a human factor, although it is all around moving humans in a building. So obviously, the missing part here seems to be the link to the perception of the quality of a ride in a lift cabin. Consequently, the issue of Ride Quality is investigated in chapter *2.6 Ride Quality*.

2.4 Multi-cabin/car Lift Systems

With the migration of the world's population into cities, and the increasing height of urban buildings, the limitations of the system design of lifts become obvious. One of the biggest problems of the modern lift is the required space for the shaft or hoistway in the building. That inefficiency results in a loss of usable building space (as illustrated in Figure 7), as the floor area occupied by this core that is used for elevators and staircases (and other equipment) does not generate income - in a commercial office building.

Figure 7 shows in principle a depiction of a horizontal cut through a floor of a high-rise building with a total floor area and an occupied area for the building core that contains means for transportation or energy/air/water/etc. supply systems. This figure is a general image; real applications may differ from this generalization and may show different layouts. The principle stays the same: A certain floor areas is pre-occupied and not available for renting.

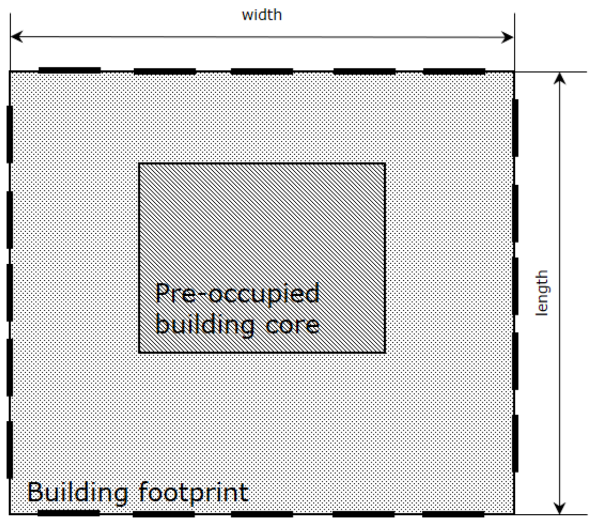


Figure 7 – Building Footprint vs. Core (Illustration)

That problem decreases with technology that allows more than one cabin in the shaft, as simply the number of passengers moving in that hoistway grows.

Passenger Transportation Systems with more than one car in the shaft are named multi-cabin or multi-car systems, and the logical next evolutionary step is a system that moves two lift cabins in one single shaft.

Auvinen (2015) suggests a definition for a multi-car elevator, stating that at least two separate cars move in a shaft at the same time, when they "*operate simultaneously"*. Furthermore, Multi-car lifts do not have cars attached to each other like double-deck systems, which are often used as shuttle systems in high-rise buildings. A multi-car system may have more than one shaft, for instance as overtaking lane or parking space for unused cabins.

All this promises huge potential to improve mobility in tall buildings, because… a multi-car system can…

- Reduce waiting times
- Significantly increase the capacity of a Passenger Transportation System
- Minimize the elevator footprint
- Reduce the elevator weight and moving mass substantially

In their book on *"Linear Synchronous Motors"* Gieras *et al*., (2018) state: "*Rope-less elevators with multiple cars in one shaft may be perceived as practical solution to ultra-tall buildings above 1.000 m."*

They also casually mention the problem of intense consumption of usable space of roped elevator systems and outline, that these conventional systems "*would consume too much space to make such a building financially viable*."

Ergo, TK Elevator, a globally operating lift manufacturer, started looking into the potentialities of multi-car systems…

2.5 The MULTI® System

The global lift business is a market with comparable and similar products, and therefore it is obviously important to shine out of that vender wholeness.

Ionescu and Dumitru (2015) describe innovation to be essential to challenge others within a competitive market situation, such as the global lift business.

With this in mind, TK Elevator developed a piece of revolutionary technology: MULTI®. A lift system without any traction ropes.

And this new technology is about to be brought into the global passenger transportation market.

This rope-less drive technology of MULTI® is promising and seems to break the limits of conventional lift systems and assures higher transportation capacities through a kind of continuous traffic flow according to a large lift manufacturer (thyssenkrupp Elevator AG, 2019). They even talk about a “*new era of mobility in buildings”.*

TK Elevator launched the multi-car technology to optimize traffic in a building, to increase the handling capacity of the building’s lift system, to reduce moving masses and the system footprint. Ergo, they want to break-up “*the constraints imposed by conventional elevators*”.

Moving multiple cars in one single shaft in both directions, vertically and horizontally, allows to think of new ways of people transportation in buildings.

The idea itself, to manage multiple lift cabins in one hoistway, is not new. So for instance Sakita (2008) filed a US patent on “*Elevator system with multiple cars in the same hoistway*”. These design concepts seem kind of limited when traction rope technology is adopted. Those limitations are eliminated in the radically new and distinct system design approach

of the novel Passenger Transportation System MULTI®, which is consisting of standard components but is assembled in unique way:
A unique composition comprising state-of-the-art components.

Although the individual components and sub-assemblies of MULTI® are not new, the way all that is being composed and assembled is radically new and has never been done before in this combination.
Table 1 identifies the technical concepts which are different, comparing MULTI® with a conventional lift system.

The table compares technical conception of MULTI® and a conventional lift system for a number of most important technical applications of a Passenger Transportation Systems. Technical features that are applied in both system concepts are compared with each other.

Example:
Any passenger Transportation System has to have a propulsion system, which is (in a conventional lift system) an electric rotary traction motor and in case of MULTI® a linear motor.

	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 down-time

Table 1 – Conceptions of technical Features of MULTI® vs. Conventional Lift System (selected Items).

Obviously, the following statements can be worked out of that:

- Some fundamental technical concepts are not applicable for the new Passenger Transportation System MULTI®.
  → System balancing, pulleys, traction means
- MULTI® requires an even more complex technical conception for certain components.
  → Guide rails with energy transmission, tight guiding function, provision of electro-magnetic force
- The propulsion systems of MULTI® unifies the technical application of payload and propulsion, whereas in a

conventional lift these applications are allocated to different components and technical concepts.
→ Example: The drive sheave mounted to the shaft of the drive motor (mounted to a machine beam structure) carries the system weight & payload on one side and on the other hand, the drive sheave ensures the necessary traction for the means of traction.

The MULTI® system probably stands for the future generation of Passenger Transportation Systems for horizontal and vertical transportation.
Scott (2016) assumed the potential of the technology regarding Passenger Transportation System efficiency by "*saving lots of very valuable space".* This would considerably reduce the cost caused by the Passenger Transportation Systems, respectively release the potential to earn more money with the existing building footprint.

MULTI®, a totally new Passenger Transportation System is rope-less and uses linear motor technology, which enables multiple cabins move in a single loop of continuous flow.
With a speed of 6 meter per second, this system offers access to an elevator cabin every 15 - 30 seconds.
That results in lower waiting times and ease of access in large buildings (thyssenkrupp Elevator AG, 2019), and thus promises to solve inefficiency problems that result from building space limitations.
With the increased need for more handling capacity availably & anytime and therewith more traffic, the "*critical factor*" of a Passenger Transportation System is obviously the space needed for the system.
(Auvinen, 2015)

With the potential to solve the limitations, this technology has been introduced to the market in June 2017 and represents a brand-new Passenger Transportation System concept.
Siikonen *et al.* (2018) state, that in a multi-car lift system such as MULTI®, *"two or more cars may move in two elevator shafts independently, always in the same direction in one shaft."* Obviously, the system's cabins have to move vertically from one shaft to the other at the bottom or top of the shaft, or even in another designated level.
To put it in another way, cabins move in upward direction in one shaft and in downward direction in another shaft, while both vertical shafts have to have at least two horizontal connections.
A multi-car control system of the lift system "*assigns and dispatches elevator cars to serve landing or destination calls*".

Although the definition of a multi-car system of Siikonen *et al.* seems to be well, the characterization does not describe the whole potential of MULTI®. The scale 1:1 prototype that has been unveiled in the thyssenkrupp test tower in Rottweil/GER on July 22nd, 2017 already shows that the locations to change the shaft are not limited to the bottom and top floor.

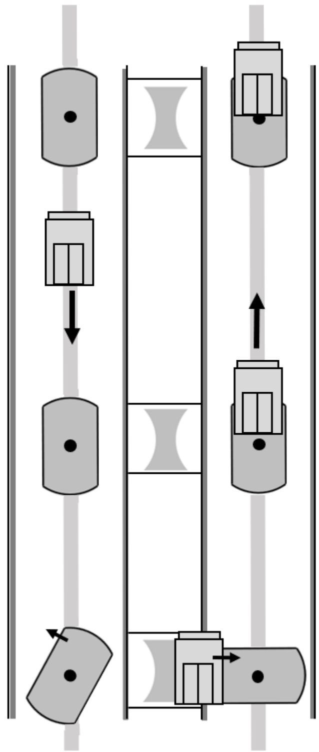


Figure 8 – Schematic of the MULTI® System

Figure 8 is a schematic depiction of the MULTI® Passenger Transportation System. It shows two shafts, one for each of the two vertical directions (up and down). It also shows three exchange stops, where a cabin has the possibility to change from one shaft to the other. This is necessary to ensure that empty cabins are available in any shaft for a passenger call.

In Figure 4, the bottom exchanger is about to move the cabin right into the upward shaft for further use.

On the basis of that prototype, the concept of MULTI® allows the extension from a two-dimensional to a true three-dimensional design configuration. So and Chan (2019) write in their article "*Further study of linear PMSM driven rope-less lifts with consideration of imperfections by simulation*" about the enabling technology of MULTI® which seems to be the first promising rope-less Passenger Transportation System.

The new technology could also offer the direct connection from an underground public transportation station to a final destination of an apartment in a residential building. This has the potential for a new trend of last mile transportation.

They even outline "*MULTI® could be the world's first independent multi-car two-dimensional lift system as developed by a European manufacturer*".

As the focus of this study is on rope-less multicar elevator systems, all further technical aspects regard this specific area of technology under the consideration of the solid fundamental of very well investigated conventional lift systems with one cabin in a shaft. So for example Andrew and Kaczmarczyk (2011), revealing the system composition of parts and sub-assemblies in a lift which intention is, to carry people or haul goods over a desired vertical travel distance with a certain velocity. They also take necessary safety regulations and requirements into consideration in their comprehensive commentary work.
They describe traction elevator systems and focus on the system and safety calculation with a straight and objective engineering viewpoint. In their standard engineering textbook "*System Engineering of Elevators*" they do not have the ride performance in scope.
In addition to the important topic of system safety of a Passenger Transportation System, the system performance in terms of Ride Quality is essential as this happens at the interface between human and machine. Hence, pursuant literature is reviewed in chapter *2.7 Ride Quality*.

To persuade potential customers (Innovators and/or Early Adopters in terms of the Innovation Adoption Lifecycle[4]) that are willing to bring a brand-new Passenger Transportation System into use, detail system analyses and investigations have to be conducted to ensure comparable

[4] Technology Adoption Lifecycle: Sociological model to describe the acceptance of a new product or innovation of defined user groups

Ride Quality results. Based on - but not limited to - the fundamental explorations of "*linear and, mainly, nonlinear dynamics, chaos and control of systems and structures and their applications*" in regard to "*Vibration Problems in Vertical Transportation Systems"* of Balthazar *et al*. (2015), the new rope-less Passenger Transportation System has to be designed with a focus on the best possible Ride Quality.
Missler *et al*. (2017) pick up on that and present a concept of active vibration damping for Passenger Transportation Systems, and a feasible actuator position to reduce the vibrations inside the cabin, which is essential for the passenger, as the journey time increase when buildings grow in height.
With the abovementioned potential to ensure a comfortable and smooth ride in a light-weight multi-car cabin, there are no longer any restrictions in building height and architectural freedom.

As introduced in chapter *2.3 Passenger Transportation Systems*, we can observe, that buildings become higher and higher.
According to the CTBUH (Council on Tall Buildings and Urban Habitat, 2021), the number of buildings with heights beyond 300 m increases from 26 in the year 2000 to 170 in 2019; some of them are taller than 400 m.

But the Ride Quality of a totally new Passenger Transportation System, such as the MULTI®, becomes even more important, as the significantly reduced mass has a huge impact on the ride performance of such a system. The new MULTI® lightweight design includes carbon composites for cabin and doors and shows potential to reduce the cabin weight substantially.
Löser *et al*. (2018) highlight the advantages of the lightweight design of MULTI® including the application of lightweight composite material, such as carbon fiber. Not only the weight of the entire cabin can be reduced by 50%, even further the moving masses of the Passenger

Transportation System will be dramatically reduced by the elimination of ropes and counterweights, which become unnecessary at all through the application of linear motor technology.

Instead of a rope traction system (or hydraulic cylinders), MULTI® is a rope-less Passenger Transportation System and uses linear synchronous motor technology.
A linear synchronous motor is a linear motor in which the mechanical motion is synchronic to the applied magnetic field. That means: The speed of the mechanical system equals the speed of the magnetic field within the linear motor.
According to Gieras *et al*. (2018), the earliest patent concerning an application of linear motors in elevators was granted in 1970, and proposed a system design, which has two linear motors on both sides of the car, moving one single car upwards and downwards in a single shaft.
Linear motors are widely used and find its general application, when not a rotational torque but linear force is needed along a specific length.
Built into the MULTI® system, they enable multiple cars to be incorporated in continuous movement in at least two shafts (bi-directional movement).
The technology was used for the horizontal propulsion in Mass Transportation Systems, such as the thyssenkrupp Transrapid or the so called *Cabinentaxi*[5], a research project developed in the 1970s by a joint venture of Demag und Messerschmitt-Bölkow-Blohm.
So, the application of linear motor technology for vertical transportation means represents a novelty for Passenger Transportation Systems.
The huge potential in regards to improved building efficiency makes this novel application so interesting for architects, investors, developer and building owner.

[5] The *Cabinentaxi* gained series-production readiness in 1981 but has never been brought into the market.

2.6 Ride Quality

Ride Quality is affected by motion and sound quantified using the following parameters:

- Horizontal vibrations [measured in m/s^2]
- Vertical vibrations [with the amplitude measured in m/s^2 and the frequency measured in Hz]
- Acceleration [measured in m/s^2]. Positive acceleration: increase of speed. Negative acceleration: decrease of speed.
- Jerk [measured in m/s^3]. Rate of change of acceleration.
- Sound pressure [measured in Pa] and sound pressure level [measured in dB(A)]
- Tympanic pressure [measured in Pa]. Effect of dynamic change of ear pressure in the middle ear causing discomfort.

A smooth lift travel is a fundamental element of Ride Quality of a lift system, and so Ride Quality in terms of vibrations (horizontal and vertical), acceleration/deceleration and jerk became an important factor for the evaluation of the performance of a lift system.
The subjective perception and sensitivity to motion and sound of passengers travelling in a lift cabin is related to their level of comfort. The dedicated measure for that experienced comfort level is Ride Quality, which is a result of noise and vibration of a running Passenger Transportation System.

To be clear: A Passenger Transportation System that scars passengers will perish in the competitive market. For that reason, Ride Quality of a PTS has full attention and focus during product development and is an essential part of this present research study.

A statement by Pierucci and Frederick (2008), which is obviously valid for all kinds of transportations means, describes the necessity for Ride Quality of a lift system., when they delineate that elevator manufacturers

have to "*provide a very smooth and comfortable ride"* if they want to compete with other market opponents.
Certainly, this requirement represents a core requirement and fundamental characteristic of any given Passenger Transportation System. The potential impact to a human being using the lift is too big to fail.

But it is of special interest, when we consider the ride in a relatively small lift cabin moving in a concrete hoistway.
Without doubt, a smooth ride of any Passenger Transportation System is the fundamental requirement of a passenger entering a lift cabin for a trip (Howkins, 2006).
With *"acceleration, deceleration, jerk and also noise and vibration generated by the elevator systems*" they describe variable experiences that have an impact to the human body of a lift passenger. Needless to say that the passenger's experience is perceived subjectively and "*can also be classified as imaginary"* as there are many potential sources acting on the human body during the trip.

The individual response of a human being influences the perception of a lift ride according to Herrera and Kaczmarczyk (2009) and Howkins (2006), which again seems to be a fact standing to reason. Whereby the overall perception is a subjective feeling based on several different and mean factors. So, it can be questioned whether the elimination or improvement of one factor would make a difference (Tedeschi, 2006).

The obvious question in this context is:

How is the Ride Quality (of the bespoken Passenger Transportation System) affected?

In his research paper "*Achieving Good Ride Quality*", Smith (2006) identified the following primary sources of vibration that affect Ride Quality of a lift cabin:

- Guiding system (faulty guide rails and joints)
- Suspension and compensating ropes
- Torque ripples[6]

which can be complemented by air flow and air gaps, coming from the structural design of the system.

Other researchers, such as Terumichi *et al*. (2003), have their focus to the vibration interactions between the cabin, the guiderail system and the hoist ropes of a conventional lift system, as the system's Ride Quality is especially affected by lateral vibrations.

The following three basic principles to mitigate the effects of noise emission and vibration in mechanical systems can be suggested:

- Prevention. To reduce the strength of the source.
- De-coupling. To interrupt the noise/vibration path.
- Damping. To absorb of the energy of noise/vibration.

To validate the importance of Ride Quality and to link that to the product development of MULTI®, a preparatory project[7] with a subsequent conference paper publication (*Key dynamic parameters that influence Ride Quality of Passenger Transportation Systems*) has been conducted by the author of this thesis in 2015. In that research paper, the abovementioned factors were confirmed.

---

[6] The periodic shift of the output torque.
[7] For the internal purpose of project sponsoring and budgeting reasons accordingly

In the context of MULTI®, Singh *et al*. (2017) looked specifically into aerodynamic drag and piston effects of multi-car lift systems in their research work “*An Analysis of Airflow Effects in Lift Systems*” and applied Computational Fluid Dynamics (CFD) to determine and simulate the aerodynamic effects within these systems.
Although the parameters that affect Ride Quality of a Passenger Transportation System ride are subjective, the Ride Quality of a lift trip can be measured in a precise manner and absolutely objective.

ISO 18738-1 (British Standards Institute, 2012) classifies noise, lateral quaking, acceleration, and jerk as:

- *“Noise/Sound: a weighted sound pressure level measured in [decibels]*
- *Lateral Quaking: a sideways acceleration measured in [m-g]*
- *Acceleration: A rate of acceleration measured on the z-axis velocity and expressed in [m/s²].*
- *Jerk: The rate of change of z-axis acceleration, attribute to lift motion control and expressed in [m/s³].”*

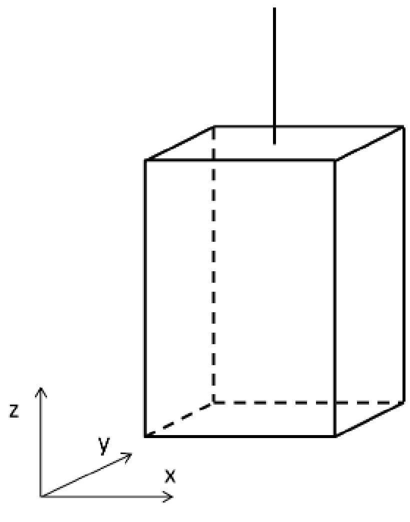


Figure 9 - Arrangement of x-, y- and z-axis

The Figure 9 above depicts the model of a passenger cabin of a roped system with three axes x, y and z, which are orthogonal to each other. The axes x and y have a horizontal direction, while z is vertical.

A number of different measurement devices on the market offer precise measurements instead of subjective perceptions and help R&D engineers and product designers and make it easy to measure and compare Ride Quality according to - for instance - the standard ISO 18738-1 (British Standards Institute, 2012).
The mobile diagnostic system LiftPC® (Henning GmbH & Co. KG) offers the following measurements and diagnoses for PTS, and it enables technicians to observe the Ride Quality and comfort during the ride:

- vibration in 3 axis x, y, z
- sound level
- performance data
- speed
- acceleration, deceleration

Hence, objective evaluation and measuring instead of subjective inspection are the preconditions for a cost-efficient evaluation of design concepts, mock-ups, prototypes, and Passenger Transportation Systems in general.
The mobile diagnostic system LiftPC® is compact, reasonably priced, easy to use and worldwide known. It is the preferred device to be used within the engineering and ride performance aspects of our Knowledge Transfer process.

The importance of these measurement tools was stressed out by Lorsbach (2010) in his "*Analysis of Elevator Ride Quality and Vibration*". Over time, the need to measure the quality of a lift ride became a fundamental requirement to the companies of the Lift Industry. The measurement and even the respective limit values are part of customer specifications nowadays.

That applies to new lift systems and also to modernization projects. Being a substantial criterion for the robustness and overall system quality, these measurements became *"a competitive issue for elevator manufacturing, installation and maintenance companies"*.

Furthermore, the simplification of vibration and sound measurement led to the capability to analyze the performance of system components and sub-assemblies as well ("*the ability to diagnose the function of elevator and escalator system components*").

Whatever the case may be, those Passenger Transportation Systems, which are subject of Ride Quality research studies, such as delivered by Lorsbach (2010) or Nai *et al*. (1994), are conventional lifts using ropes.

Relevant sources of vibration affecting a lift cabin involve the cabin guiding system, ropes (suspension and compensating) and air flow.

Lorsbach (2010)

Generalizing, horizontal vibration is mainly exited by sources located in the lift shaft or lift car, while vertical vibration is caused by system ropes, traction and deflection sheaves, the traction machine, the controller, or the oscillatory instability of the counterweight.

Nai *et al*. (1994) came to the point when they described the direct connection of the motor, sheave, traction ropes and cabin respectively counterweight. Following him, we can interpret this assembly as an interconnection "*of the lift car and the counterweight*".

Because of that, the underlying mathematical models for traction (roped) elevators come to their limits, when rope-less Passenger Transportation Systems are the subject of research (Missler *et al.*, 2016).

With a research focus to MULTI®, he describes his investigated system concept as substitution of the ropes by a linear motor, "*where the active* *elements of the motor are placed inside the lift shaft and the passive elements are placed on the lift*."

With this being said, it becomes necessary to use the concepts of conventional Passenger Transportation Systems and to supplement them with technological models that consider linear motor drive technology (Al-Kodmany, 2015). These rope-less lift systems apply electromagnetic linear motor technology in vertical (and horizontal) direction to move multiple cabins in a loop in both plane directions, vertically and horizontally.

So, to be able to optimize the ride in such a rope-less lift driven by linear motors, it is necessary to develop specific mathematical models and/or simulations of such systems with the aim to develop technical measures to manage system vibration (Kaczmarczyk, 2013; Missler *et al.*, 2017).

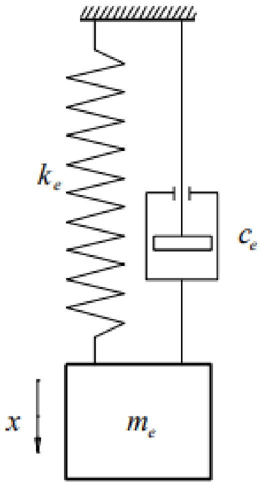


Figure 10 - Simplified Vibration Model

The Figure 10 above graphically describes a simplified model of a conventional passenger transportation assembly of a lift car and counterweight in a 2-dimensional plane (Kaczmarczyk, 2013).
x(t) is considered to be the vertical displacement of the assembly which is represented by an equivalent mass. The mass m_e is suspended on a

spring with the effective constant k_e. The damping within the modelled system is represented by an effective damping constant c_e of a viscous damping element.

The same kind of model works for the bespoken MULTI® system, which is considered to be a Multi Body Systems (MBS), a rigid system experiencing huge rotational and translational displacements.

This approach represents a certain complexity, and the application and development of those Multi Body Systems is linked to engineering mathematics.

Please refer to the parenthesis on the next page for further explanations.

Parenthesis

> The calculation, theoretical handling and application of Multi Body Systems requires a solid mathematical knowledge, especially in regard to differential equations, derivatives and the description of trajectories.
>
> That means in consequence: To ensure that Specialists of the Lift Industry fully understand the concepts behind Multi Body Systems, a certain knowledge of engineering mathematics is a mandatory pre-requisite and absolutely needed.
> When it comes to the transfer of Machine Dynamics knowledge, the topic of engineering mathematics (→ differential equations) needs to be included and considered, as it represents a sort of fundamental lecture.
> For this reason, a research subsection at a later stage of the research project examines the effectiveness and student experience of a mathematical learning journey.
>
> Please refer to chapter *3.7 Research Subsection #3* (Two Learning Journeys) for detail information.

Missler *et al.* (2017) simplified the mathematical model for efficiency reasons and developed a 2D-model, to mathematically & computer-aided process and simulate a backpack cabin design for MULTI® as a representative for a Multi Body System.
The provision of that theoretical knowledge can be classified as Advanced Dynamics knowledge, and it is necessary for the final product design of the novel Passenger Transportation System.

2.7 Leading over from Technology to Pedagogical Aspects

As annotated already in chapter *1.1 Context of this Research Study* and even explained in detail, this research project views into to comprehensive science topics:
Technical aspects around the rope-less Passenger Transportation System MULTI® on one side, and pedagogical aspects around Knowledge Transfer and learning on the other side.

The technical aspects are described in chapters *2.2.1 and 2.3* to *2.6* and involve a certain complexity and the knowledge of a specific group or engineering specialists. This specified body of knowledge is the object of a Knowledge Transfer process which represents the second focus aspect of the research project. That Knowledge Transfer process should be adopted and improved for the specific body of knowledge and a specific group of participants.
Related topics and concepts to that aforesaid Knowledge Transfer process are described in chapters *2.2.2, 2.2.3* and *2.8* to *2.14*.

This research study aims to expose the intersection of subject (Advanced Dynamics) and process (Knowledge Transfer) and is designed to constitute key issues around the optimization of that Knowledge Transfer process, including Instructional Design, Learning Environments and the impact of Social Networks to study groups.
Again, the reason for this specific research perspective and focus is justified by the business need of TK Elevator to transfer knowledge on Advanced Dynamics (of their rope-free Passenger transportation System MULTI®) from their R&D organization to the respective counterpart at a customer’s side, to enable that customer to refine and adopt the system design for a specific use case.

That means, the present research project is situated in the overlay area of the two science topics of Technology and Pedagogy and therein relevant for the uniquely defined user group:

- Process (to improve): Knowledge Transfer
- Object (input item): Advanced Dynamics of Passenger Transportation Systems in buildings
- User group (pre-defined): Multi-cultural/multi-discipline R&D environment

Consequently, the following chapters examine the concepts around the process of Knowledge Transfer and describe inter-relations to Instructional Design, learning theories or Social Networks. Beyond that, the pre-defined user group of a multi-cultural/multi-discipline R&D environment is given a detailed description.

2.8 Knowledge Transfer

The exchange of knowledge (also known as Knowledge Transfer) is a difficult process, not only in a corporate context, as Szulanski has written about (2000), stating that it is not self-evident, that knowledge existing in one part of an organization might not be available for the benefit of another part (e.g.: department) of an organization.
Senaratne and Amaratunga (2008) view Knowledge Transfer as "*the movement of knowledge via some channel from one individual or firm to another*", while the channel is seen as teaching and learning process.

To bring it to a short form: Within an organization, there is a lack of knowledge about the total knowledge of the organization. That means in form of a popular saying: A company doesn't know, what the company knows.

Knowledge represents an important factor for the competitive advantage of organizations. In that regard, Nonaka and Takeuchi (2003) developed a model that considers the creation of knowledge as a dynamic process.

The SECI Model of Knowledge Dimension.

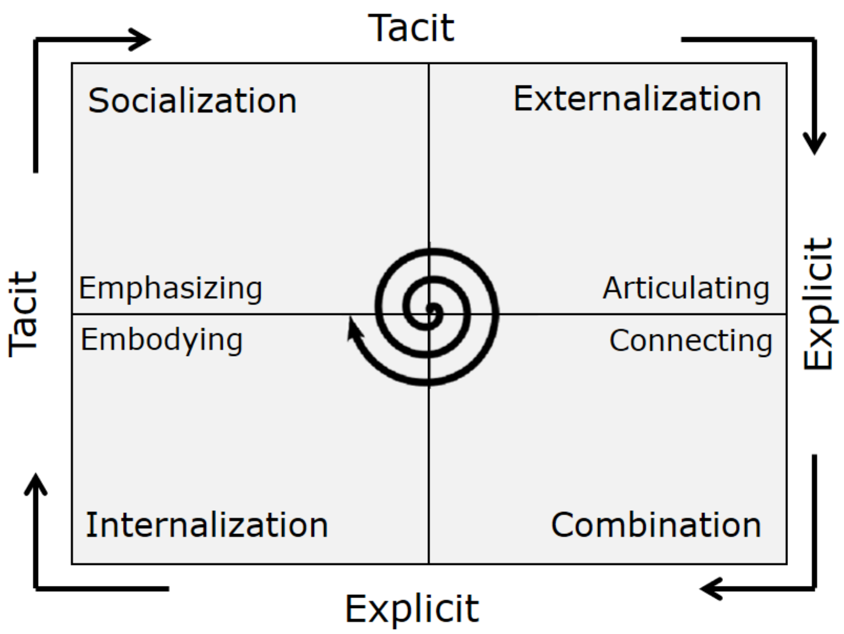


Figure 11 – SECI Model of Knowledge Dimension
(Nonaka and Takeuchi, 2003)

Figure 11 shows that dynamic process model which creates implicit (or tacit) and explicit knowledge in a continuous transformation. Corporate knowledge comes through the successive processes of Externalization, Combination, Internalization and Socialization to a higher organizational level.

The continuous dialogue between tacit and explicit knowledge helps to create new knowledge, and it expands that even further and converts into organizational knowledge.
Farnese *et al*. (2019) summarize Nonaka and Takeuchi in the way that the process of knowledge creation moves around between tacit and

explicit dimension and therein is driven by the interactive interplay "*between individuals, to groups, to the organization as a whole"*.

This internal process might need professional support and moderation to ensure effectiveness and efficiency, with the focus to competitive markets.

In this direction and to tackle that difficult process of Knowledge Transfer (in particular: in the United Kingdom), UK-wide Knowledge Transfer programs are offered to "*helping businesses for the past 40 years to improve their competitiveness and productivity through the better use of knowledge, technology and skills*" (Innovate UK, 2020).

In his book "*Multinational Companies, Knowledge and Technology Transfer",* Sönmez (2013) predicates that Knowledge Transfer mainly involves tacit knowledge, such as expertise know-how, management skills, or technical skills. According to him, the importance of a transfer of knowledge is higher than the importance of a transfer of technology, since Knowledge Transfer involves all, *"technical and organizational skills*."

Having in mind (for the sake of this research project) that the intended technology and Knowledge Transfer to licensees is a fundamental success factor to bring the costly product into the market, the aim of an effective and efficient transfer of knowledge becomes even more important.

In a comprehensive piece of work on institutional learning and Knowledge Transfer, Carayannis *et al.* (2011) define the relationship between knowledge and learning in the following way, stating "*knowledge is the content of learning".*

They outline, that organizations can gain an advantage over their competition, by having specific knowledge within the organization that others don't have and that can't be copied by the competition without efforts.

Learning is acknowledged as the process of acquiring new knowledge in principle, which consequently requires a constant process after to absorb the knowledge within the organization. From there, the new knowledge must be operationalized and to find its way into internal procedures. Learning (aka the process of gaining new knowledge) can be described as the fundamental basis for an always renewing process cycle, which is an essential necessity to persist in a constantly changing world.

Respecting those various definitions for the purpose of this research study, we understand the process of Knowledge Transfer as learning or transformation process.

Antonova and Csepregi (2016) suggest the following model, which shows the important interactions within the learning aka Knowledge Transfer process with supporting IT tools and a knowledge owner and knowledge perceiver as start and end points of the model with an internal Knowledge Transfer process that is described by the sequence of codification, object, and interpretation.

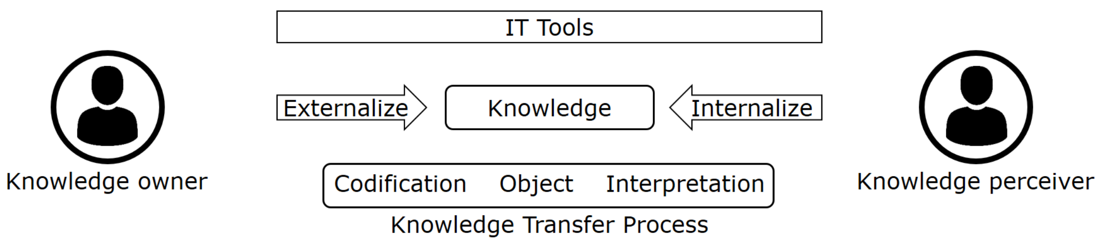


Figure 12 – Knowledge Transfer Model in an organizational Context (Antonova and Csepregi, 2016)

Although this model is simple and very generic indeed, it represents an enhanced black box approach, and builds the foundation of a conception for a new Distance Learning Environment (please refer to chapter *2.2.3 How do People learn?*).

Clarification in own research sense:

Although often assumed and defined as a likely input parameter (of this recent research study), the hypothesis that the cultural background determines the process of Knowledge Transfer is untenable (Joy and Kolb, 2009). They state, "*the impact of culture was only marginally significant*." but found out, that the impact of age and area of profession to the preference of either active or reflective learning is somehow remarkable.

If we put the geographical aspect aside and just focus on different Learning Style Preferences in reference to Distance Learning, a significant tendency to specific dimensions of Learning Styles can be ascertained, as Terrell and Dringus (2000) conclude in their research article on "*The Effect of Learning Style on Student Success in an Online Learning Environment*", expressing, that learning organizations with Distance Learning curricula supported by technology should take the bandwidth of different Learning Preferences into account, when they plan, compile and offer their online courses.

The often-quoted Index of Learning Style somehow pretends the Knowledge Transfer channel, while the supporting technology is the enabling factor for an efficient Knowledge Transfer process.

With the definition Knowledge as the content of Learning, and the need for efficiency and effectiveness of those processes, it is obvious to relate to technology to support that. The aspects of learning technologies are enlightened in chapter *2.13 Learning Environments and Learning Technology*.

Learning Technology is a term that summarizes tools to enhance learning such as information, technological and communication tools, and involves computer-aided learning or multimedia materials enable for distance study or to supplement classroom activities.

Lian (2000) brings the transfer of knowledge and Learning Technology together in her book on "*Knowledge transfer and technology in education*". She believes that learning and multimedia technology brings in new opportunities in education, revealing the potential of technology on one hand, but clearly works out the limits of Learning Technology on the other, when she states, what computers (aka Learning Technology) do or not do.

The following Table 2 shows the capabilities of Learning Technology (computer) and therewith demonstrate that technology can only be an enabling factor, but it can't solve issues between human beings, such as teachers and learners.

"What computers do not do":	"What computers do":
offer opportunities for people to communicate	offer the possibility to connect computers together across the world
offer exploration opportunities	offer the capacity to store and retrieve information at random
allow for creative management of knowledge by learners or teachers	offer the capacity to organize information in many different ways

Table 2 – Capabilities of Learning Technology (Lian, 2000)

With this being stated, the isolation of an uninstructed learning journey with just a piece of Learning Technology is probably not the ideal learning set-up.

This emphasizes the importance of the functioning interaction between instructor and learner, as stated by Dennen *et al*. (2007) writing "*interaction is an important part of learning in general, not just in online environments*."

This is important and has a direct impact to the teaching process, and it should be considered by any instructor. So, instructors should make their expectations clear to the learners, be present in discussions and maintain the communication and contact to the class and individuals.

It is needless to state, that these implications are valid for classroom environments as well as for Distance Learning Environments, which are likely utilized in professional organizations with employees distributed over different countries or even continents.

2.9 Multi-cultural/Multi-discipline R&D Environment

Operating globally in markets, multi-national organizations collaborate more and more in multi-cultural and multi-discipline teams or environments.

The term environment determines the circumstances or conditions by which an individual or a group is surrounded.

Although there are thousands and thousands of companies and organizations which work in a local way (medium-sized companies), there are the global players, who are organized in global teams. These teams typically collect all kinds of nationalities, cultures and disciplines.

In the "*Handbook of Work Group Psychology*" Jackson (1996) defines the term multi-disciplinary teams. These multi-disciplinary teams bundle individuals with different but desired backgrounds together to work on a specific group task. The diversity (of disciplines) is assembled by "*occupational backgrounds and functional areas of expertise"* of the respective team members.

It makes sense to clarify the terms culture and (academic) discipline here briefly:

Culture: Culture, often attributed to a specific country or region, can be defined as all the ways of life of a population that are passed down from generation to generation. As such, it includes the following but is not limited to: Art, beliefs, codes of manners, customs institutions, dress codes, habits, knowledge, language, laws, religion and rituals.

Discipline: An academic discipline is a sub-category of knowledge being taught or/and researched at college, high school, or university. The engineering disciplines can be divided into five main categories (with sub-disciplines of these main disciplines that offer specialized knowledge and skills in a particular subject matter):

- Mechanical Engineering
- Civil Engineering
- Chemical Engineering
- Biomedical Engineering
- Electrical Engineering

The scope of the term diversity can even be widened in this context and include different cultures, which reveals potential to enhance the performance of that team.

Tomek (2011) observes: *"As the world continues to globalize, teams are becoming more and more multicultural".*

This is a self-explanatory statement and self-evident in these times.

Moreover, Doukanari *et al*. (2020) tie all aspects together, when they recently presented the results of their study on "*Multidisciplinary and Multicultural Knowledge Transfer and Sharing in Higher Education Teamworking*".

Apparently multi-national organizations more and more assemble project teams with employees having diverse professional skills and different cultural backgrounds to elaborate solutions for given problems, as they increasingly realize the importance of team collaboration with multi-disciplinary and multi-cultural backgrounds.

This multi-cultural and multi-discipline team composition helps multinational organizations to compete in the global marketplace.

In that context "*higher education strives to equip students with skills to communicate, collaborate and share in diverse environments",* which enables these students to make a next consequent career step.
Doukanari *et al*. (2020)

All this offers a huge potential for an optimization of that implied learning process, when it comes to Knowledge Transfer of complex engineering contexts (Distanont *et al*., 2012), who describes three groups of challenges in "*The Engagement between Knowledge Transfer and Requirements Engineering*".
The consideration of those three factors in reference to the human being help to enhance the Knowledge Transfer process. Therein, the relationships between sender and receiver, motivation or communication styles represent human-oriented factors, while the nature of knowledge to be transferred or different languages are process-oriented factors. The discussed culture diversity is one of the context-oriented factors, outlined in that work.

Those factors are of special interest, as training plays an important role in the building of competencies of employees to perform their jobs in an effective way. Training represents a kind of investment, which helps to reach advantage in market competition (Elnaga and Imran, 2013).
They list a number of benefits employees gain from training in general and mention the increase of job satisfaction, morale, motivation or process efficiencies.
The increased capability to transpose and make use of new technologies may lead to a pay rise, while training could also lead to "*increased innovation in strategies and products"* with motivated and highly skilled staff.
Sufficient and satisfying training program may result in a reduced turn-over rate to the benefit of the employer.

All the above stands for the "*importance of investing in training and development for the sake of improving employee performance*."
(Elnaga and Imran, 2013).

Employee training and opportunities for all staff members to grow and develop the individual skill set is essential and a huge motivation factor. And on the other hand, further education helps to keep the technical staff up-to-date.

The importance of "*learning at the workplace*" is also a topic in the comprehensive collection of building blocks for professional training programs "*theories of learning for the workplace*" (Dochy *et al.*, 2012). It goes even further, as it gives an overview about the most important learning theories and their application to organizational learning and discusses adult learning, workplace learning, informal learning, experiential learning[8] and inter-organizational expansive learning.

Employee learning and training is linked to the success of a company and to the performance and revenue of an organization (Wilke, 2006). He stated, that employees "*reach their full potential*" with the appropriate training.
Which is connected to the necessity of improved efficiency and effectiveness of training (Webster and Hackley, 1997), when they recommend "*successful technology-mediated distance learning courses*".

It is important to balance the correlation of competencies, training needs and the evaluation of training conducted. Well defined and in a balanced relationship to each other, these items result in an efficient & effective training & learning curriculum for a group of people, e.g. employees of an enterprise. This was underlined by Wilke (2006) and Webster and Hackley (1997).

[8] Please refer to Kolb (2014)

Unfortunately, the terms training and education seem to mean the same. And although their implications overlap somehow, they have a different meaning, as it is important to consider the respective context (Masadeh, 2012). He suggests defining and outline those accompanying activities and consequently to specify the learning objectives in all aspects of development human resources.

Condensed to a tangible definition and in the corresponding job-related context this means (but not exclusively for multi-cultural and multi-discipline teams):

- Education: Often taken as a formal academic process
- Training: Focusses on the improvement of skills, knowledge, attitudes and behaviors
- Learning: Wide and general definition of an approach to gain knowledge

2.10 Learning Preferences and Psychological Types

One factor to enhance the learning process is the consideration of the way people perceive information.

The terms Learning Preferences or Learning Styles are commonly used to describe how learners grasp, interpret, organize, conclude about and keep information for future use.

More than 70 models of Learning Styles are identified (Coffield *et al*., 2004), of which some are widely discussed in research and used for further application.

One of the most popular Learning Style models is the VARK inventory (Fleming and Mills, 1992). Their Learning Styles are categorized by a sensory approach:

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

A huge number of other models are reminiscences of the Index of Learning Styles model, introduced by Felder and Silverman in the late 1980s. For instance, Honey and Mumford (1986) developed the Learning Style Questionnaire (LSQ), which is one of several measures of individual Learning Style. Their work corresponds with the probably most widespread measure of individual Learning Styles, which focusses on the way learners process and organize received information.

Felder and Silverman's (1988) Index of Learning Styles (ILS) is an instrument that assesses preferences on four different dimensions sensing/intuiting, visual/verbal, active/reflective and sequential/global, and is based on a self-scoring classification, as shown in Figure 14.

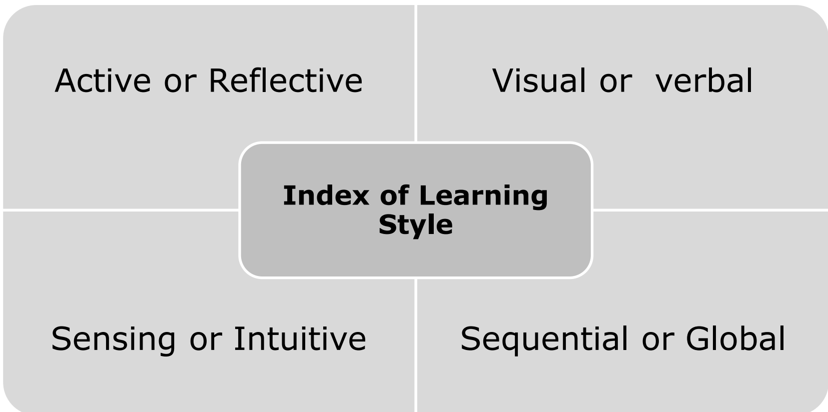


Figure 13 – Index of Learning Style (Felder and Silverman, 1988)

This concept is pretty much in alignment with a concept developed by Honey and Mumford (see Figure 14), who identified four Learning Preferences: Activist, Theorist, Pragmatist and Reflector. That concept is based on the work of Kolb. It describes different Learning Styles and provides - in addition to it - activities that fit to those Learning Styles.

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 put that into practice.
Reflectors are people who learn best when they can observe others and reflect that further.

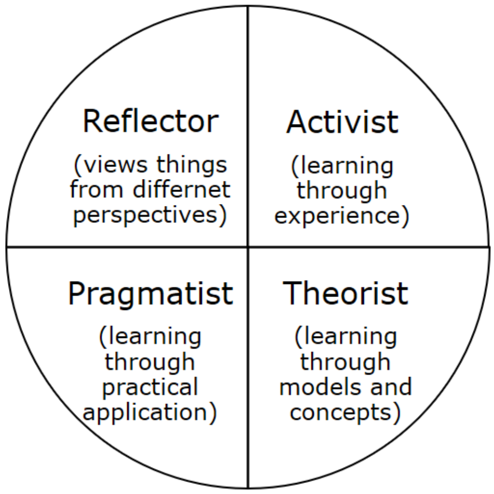


Figure 14 – Learning Preferences (Honey and Mumford)

The Index of Learning Style has been very well investigated and repeatedly examined since decades and integrated into the application of various education fields (Felder, 1996; Felder and Soloman, 2000; Claxton and Murrell, 1987; Stice, 1987).
For example, Cook (2005) looked into the "*Reliability and Validity of Scores from the Index of Learning Styles*", and was able to validate the concept based on 138 sets of data (respondents) collected over a period of 3 years.
While Kolb worked out a guideline that a person would learn through experience, when he referred to the experiential work of Lewin, Piaget and Dewey (2014), who formed a unique perspective on learning and Development.

The ILS theory is supported by other psychological assessments, such as the Myers–Briggs Type Indicator (MBTI).
The MBTI is a self-analysing questionnaire indicating intellectual preferences to describe how people perceive the world and tend to make decisions. This psychological assessment helps you to learn more about yourself. It is not a tool that looks for abnormalities or distinguishes between good or better.

The questionnaire itself consists of four different scales:

Extraversion (E)	–	Introversion (I)
Sensing (S)	–	Intuition (N)
Thinking (T)	–	Feeling (F)
Judging (J)	–	Perceiving (P)

These introduced concepts of Learning Styles and psychological types are very different from each other.
While Fleming and Mills (VARK inventory) use the different ways of sensory information input channels to describe their Learning Styles, Felder and Silverman (Index of Learning Style) categorize that according to the way a learner processes the information. This concept is equals the concept of Honey and Mumford (on Learning Preferences).

That means in consequence that we can look from two perspectives to the underlying concepts of learning: We can define categories for the preferred (and therewith more efficient) entry channel of a set of information that should be processed/learned. Or we can categorize learners according to the way they process that information.
Please refer to *Figure 4 – Learning as two-steps process*.

The Myers-Briggs Type Indicator underlines these concepts with an explaining concept of the rationales behind it. The MBTI attempts to declare the individual and intellectual motive for a certain sensory or procedural preference.
With our focus on the improvement to Knowledge Transfer, the concepts beyond all of these are useful in a hybrid combination and should be taken into account as they imply instructional strategies (see chapter *5 Conclusions and Further Work*).

There are many other different type indicators and Learning Style models existing (Adams *et al.*, 2007). All this should be applied very carefully to avoid the perception of a black-and-white stereotype without the useful consideration of specific learning situations and set-ups, which impacts the individual circumstances of a learner (Adams, 2010).

In addition, Felder (1996) has shown that the Index of Learning Style just plays a tangential role when it comes to the effect to learning results, while the Instructional Design (please refer to chapter *2.12 Instructional Design*) seems to be a more important factor (Reigeluth, 2013), while Newton (2015) casts doubts on this individual Learning Style model with theory as an ineffective technique that detracts students to use other learning techniques.

In other words, the model of individual Learning Styles might help to learn about oneself, but the theory might not help somebody to learn.
Some researcher dig even further into the details of specific characteristics of particular Learning Styles. For instance, when Rogowsky *et al*. (2015) tried to demonstrate a statistically significant relationship between learning preference (here: auditory, visual) and instructional method (here: audiobook, e-text) in their research work and paper on "*Matching learning style to instructional method: Effects on comprehension*" (2015), they could not show that statistical

relationship. Instead, they rather suggest helping students to build "*as much experience with written material as possible to help them build these skills, regardless of their preferred learning style*."

The Index of Learning Styles ILS finds its way to research, and it seems to be a fundamental principle in research hypotheses. The obvious question "*Are there cultural differences in Learning Style?*" was discussed by Joy and Kolb (2009). They proved their hypothesis to some degree. They concluded their study with the statement, that culture has an impact to the decision on the favor for either abstract conceptualization versus concrete experience when it comes to learning preference, while the "*significance of its effect on the preference between active experimentation and reflective observation is marginal*". And they determined furthermore a more significant correlation between the Index of Learning Styles and the area of profession, when they wrote that the impact of professional specialization is a little higher than culture when it comes to the preference for *"abstraction or concreteness"*.

Alalshaikh (2015) confirmed the statement above in his paper on "*Cultural impacts on Distance Learning, Online Learning Styles, and Design*", when he backed up the consistency between Learning Preferences, not between cultures.
He even brings it to the boil, strengthening the importance of the general consideration of culture, stating that teachers and Instructional Designers should work out content for online learning, "*that is culturally appropriate and culturally sensitive.*"

In any way, this shows that it makes sense to consider the model of ILS or other, when it comes to the efficiency and effectiveness of learning.

2.11 Learning Theories

The recent foundation for the discussion on Learning Preferences and Learning Styles is captured by *"Educational Learning Theories"* (Zhou and Brown, 2015; Khalil and Elkhider, 2016)

The main five Educational Learning Theories that should be utilized to improve the environment for learners are:

- Cognitivism
  The way people think. Basic principle: learners can be influenced by both internal and external elements.
- Behaviorism
  How a student behave is based on their interaction with their environment (external forces).
- Constructivism
  Based on their previous experience, students create their own way of learning.
- Humanism
  This theory focusses on the idea of self-actualization (to become the best possible version of oneself).
- Connectivism
  Main principle: People learn and grow when they extend their network and inter-connect.

Whereas Taylor (2004) emphasizes cognitivism, behaviorism and constructivism and as the most popular educational theories applied nowadays, which is probably plausible as these three seem more obvious and evident.

This list may be made up with other theories such as the Situated Learning Theory (Lave and Wenger, 1991), Bloom's Taxonomy (Bloom *et al.*, 1984) or Andragogy, Knowles' Adult Learning Theory (Knowles, 1970). But it is Gagné, who links learning theory with theories of instruction.

Even further, Gagné identified these five domains of learning which impact the process of learning (1977), based on his previous work "*The Conditions of Learning"* (Gagné, 1965).

- Motor skills,
- verbal information,
- intellectual skills,
- cognitive strategies and
- attitudes,

with different internal and external prerequisites (or conditions) that are necessary for each type of learning.
In addition to that, he describes eight kinds of learning, which increase in complexity,

1. Signal learning
2. Stimulus-response learning
3. Chaining
4. Verbal association
5. Discrimination learning
6. Concept learning
7. Rule learning
8. Problem solving

and nine instructional events and corresponding cognitive processes.
Following Gagné, the Table 3 shows those nine instructional events and the respective relationship to the corresponding cognitive processes.
(Hricko, 2008)

For example: The cognitive process of Expectancy is alluded by information on learning objectives provided to the learner.

INSTRUCTIONAL EVENT	COGNITIVE PROCESS
Gaining attention	Reception
Informing learner of objectives	Expectancy
Stimulate recall of prior learning	Retrieval
Presenting stimulus	Selective perception
Providing learning guidance	Semantic encoding
Eliciting performance	Responding
Providing feedback	Reinforcement
Assessing performance	Retrieval
Enhancing retention and transfer	Generalization

Table 3 - Nine instructional Events and corresponding cognitive Processes (Gagné, 1977)

Knowledge Transfer or training implies Instructional Design (also known as instructional system design) and its basic components in itself, with Instructional Design defined as "*a systematic process that is employed to develop education and training programs in a consistent and reliable fashion*" (Reiser and Dempsey, 2012).

How can this be utilized for the present research study?

Here again, the understanding of those concepts and a special sense to balance out the different strategies, seems to be the most auspicious approach.

Gagné delineates five domains of learning which describe the *What*, since the five main Educational Learning Theories (Cognitivism, Behaviorism, Constructivism, Humanism and Connectivism) describe the *How* in learning.

It is again Gagné, who describes the pre-requisites for efficient learning and the suitable definition how to address specific learning type and therewith builds the bridge to Instructional Design of learning, with a kind of a guideline to make learning more efficient.

Having in mind the variety of different explanation attempts around the learning process regarding the receptivity, the processing chain, precondition for learning and the knowledge about the primary importance of specific cognitive processes (with a special focus to Instructional Design), helps to boost learning.

2.12 Instructional Design

The way people learn and grasp information is a matter of the effectiveness of Instructional Design concepts and its underlying Instructional Design strategy.

An Instructional Design strategy is the high-level approach to define, how particular subjects will be taught. It pre-sets the methodologies, techniques, and educational devices for the learners' instruction.
Due to the fact that almost all digital (online) learning events lack an instructor, the importance of Instructional Design strategies became notably important, to ensure that learners use the Learning Environment and learning resources effectively.

While Instructional Design strategies are tools for Instructional Designers to develop an effective course, Instructional Design models are general frameworks to guide the e-learning course design and development process.

Before different Instructional Design models are being discussed, the definition of instruction principles must be considered.

Merrill (2002) identified five principles of instruction that promote learning and increase the effectiveness and efficiency of the learning process:

- (1) The engagement of learners is guaranteed through the use of "*real-world problems*"
- (2) New knowledge is going to be built on the basis of activated or re-activate prior knowledge. This new knowledge needs to be explained to the learners (3).
- (4) The learner directly applies new acquired knowledge, which is integrated into *"the learner's world"* (5).

And it makes sense to implement these principles in different teaching methods (such as classroom training or e-learning) to create effective Learning Environments.

Richey *et al.* outline different definitions of Instructional Design in their book on "*The Instructional Design Knowledge Base: Theory, Research, and Practice*" (2011) and cite Reigeluth with few definitions of Instructional Design which all have different facets.
He defines Instructional Design 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*." (Reigeluth, 1983)
Reigeluth puts it in a nutshell. With the view to a predefined learning goal "*desired changes in student knowledge and skills*", Instructional Design sets the direction for an efficient and effective learning event.
And even further, Instructional Design can be described as a process that starts with learning needs analysis and continues with systematic development of instruction before the learning results are finally evaluated (Reigeluth, 2013).

While there is a number of common Instructional Design models and processes, many of their components are similar, and include the following basics

- Analysis,
- Design & Development and
- Evaluation,

and therewith pretty much represents a usual iterative management method such as the Demin cycle[9] or a typical design process

The foundation for Instructional Design models goes back to the 1960s and following centuries, when Robert Gagné initially described his model of Instructional Design (Gagné, 1977).
Amongst others, Gagné's Model of Instructional Design and the so-called ADDIE model (Analysis, Design, Development, Implementation, Evaluation) are the most common Instructional Design models.
The five phases of the ADDIE model offer a flexible framework to design effective training courses. They stand for:

Analyse, Design, Develop, Implement and Evaluate

and represent a 5-phase process for the development activities to create instructional materials.

- Analyse: Clarify the problem; define the training needs; determine the instructional environment; determine pre-existing knowledge and skills.

[9] Demin cycle or PDCA cycle: Plan Do Check Act

- Design: Define learning objectives; determine instructional strategies to achieve those objectives. Create storyboards and prototypes.
- Develop: Assemble content and incorporate that 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.

Gagné proposes a nine-step model to develop an effective learning program that also offers a holistic viewpoint to the teaching process. His "Events of Instruction" contain the following:

- 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

That is based on the information processing model of cognitive events that occur when adults are presented with various stimuli, and it focusses on the learning results and the specific arrangement of subsequent instructional events to achieve these results or outcomes (Khadjooi *et al*., 2011).

Gagne's theories have been applied to Instructional Designs in a number of subject matter sectors, such as Engineering; Medical Device industry or Healthcare (Khadjooi *et al*., 2011; Woo, 2016).
Kinzie (2005) applied the instructional strategies for a desired change in health behaviour.
In this connection, it is important to understand that his ideas of instruction correspond with so-called "*Conditions of Learning*", which was emphasized also by Driscoll (2005):

- Internal Conditions: prior knowledge available before the instruction
- External Conditions: instructions provided by an instructor (stimuli presented)

To ensure that these Nine Events of Instruction are effective, Bloom's Taxonomy helps to push learners through the basic levels of understanding and recalling new information to be able to apply that new knowledge.
Bloom's Taxonomy splits types of learning into the following levels (Anderson and Krathwohl, 2001):

- *"Remembering - Recall or recognition of an expression.*
- *Comprehension - Understanding of facts. Ability to organize them and bring them into relation.*
- *Application - Deeper understanding. Use/apply information for related problem solving.*
- *Analysing - Break-up information into smaller chunks, organize 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."*

These levels work in a hierarchical order with Evaluation as the highest level of understanding and Remembering as the lowest level.
This categorization is important for the development of learning goals and support Gagné's instructional theory. They help to write the training outline and apply the learning results evaluation method to the group of learners.

In addition to this, it was Kruse, who developed Gagné's ideas even further into the direction of e-learning in his work "*Gagné's Nine Events of Instruction*", when he outlined an example of how the apply the nine events of instruction into an e-learning format (2010). This e-learning format represents a different learning set-up or Learning Environment for Distance Learning.

2.13 Learning Environments and Learning Technology

The classic teaching/learning situation takes place in a classroom, where an instructor is in direct interaction with a student. In the classroom, the instructor can individually consider the different Learning Preferences of any student. With emerging technology, especially the World Wide Web, this instructor-led situation has been supplemented by course content that is available 24/7 and anywhere. Bourne (2005) stated in his paper on "*Online Engineering Education: Studying Anywhere, Anytime*" with a focus on engineering topics:

> "*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…"

This may make the ILS theory for instructor-led situations obsolete, but needs to be considered with a completely different perspective:
Learning with a physical distance between learner/student and instructor/teacher.

With the rise of Learning Technology, that topic became research object of numerous research studies (Chen *et al*., 2002; Kurzman, 2013; Tam, 2000), highlighting different perspectives to the topic, such as attractiveness of Learning Technology, different roll-out formats (MOOC[10] or commercial platforms) or the role of technology to support constructivist Learning Environments.
Wentworth *et al*. (2008) brings it to the point, when he writes: "*The focus of technology in education has shifted over the last decade*."

Education Technologies are tools, equipment and aids that support the learning journey of a student/learner. These technologies include but are not limited to:

- World Wide Web (as enabling system)
- e-learning
- Video casts
- Massive Open Online Course (MOOC)
- Physical simulator training
- Implemented Augmented/Virtual/Mixed Reality
- Micro learning
- Blended learning
- Mobile applications for mobile phones, computers and tablets

[10] MOOC – Massive Open Online Course

- Learning games
- Coaching functionality
- Artificial Intelligence (This technology enables the system to form user-specific learning material, e.g. individual questions.)

And even further Raja and Nagasubramani (2018) discussed these different technologies and the "*positive impact of technology*" on education but pose its negative effects too.

So obviously Distance Learning in its initial set-up, with the student separated from the instructor, has limits, as this set-up lacks the direct communication between both parties.
Sherry (1995) brings it even further and combines technology and environment, when she criticizes "*the latest technologies without dealing with the underlying issues of learner characteristics and needs*" and discusses the "*new roles of teacher, site facilitator, and student in the distance learning process*."

In research and science, the reference term OLE[11] is often used to define it as "*a general design framework to describe environments that support personal sense making via problem contexts enriched with technology tools, resources, and scaffolding*." (Hannafin *et al*., 1999). This indeed is an understandable, sharp description of an established Learning Environment.
The event occurring in these environments is consequently described as Distance Learning.
Distance Learning can be described as an instruction method with instructor and learner being separated in location and/or time that gives responsibility for the own training to the learner (e.g.: content selection, event timing, or choosing a delivery form that suits own preferences).

[11] OLE = Open Learning Environment

Obviously, with solid Instructional Design methodologies, this set-up became even more efficient and therefore popular.

Distance Learning is a sub-set of Open Learning Environments (OLE), which are student-centered frameworks with design principles and activities that support the individual needs (or study preferences) of a learner.
OLEs support self-paced and self-directed learning but offer guidance and supporting resources and strategies to help the individual learner. This learning typically happens in distance with "*courses and support supplied by various distance media such as correspondence although there may be face-to-face elements*".
(Simpson, 2018)

So, several different Distance Learning methods appeared, influenced traditional education and helped to develop mass education and learning content to students with various cultural backgrounds and Learning Style preferences. Bertel and Pate outlined (2010), that teaching methods changed a lot since Distance Learning became popular, which is due to the professionalization of Education Technology. The modern simplicity of Distance Learning attracts people from all over the world and therewith represent a sort of education for the masses. Of course, teaching methods have been adopted to this new concept of learning at any time and any place.

These advantages of digital learning formats over traditional formats was subject of the research work of benchmarking "two distance study approaches" and verifying that (engineering) learners prefer modern e-learning over traditional pdf-document studying. (Please refer to chapter *4.3.5 Benchmarking of two distance study approaches*.)

This is especially important to understand, when it is desired to use Educational Technology within Distance Learning, with Educational Technology defined as deployment of technology (*"technological processes"*) and digital resources to facilitate learning and moreover to enhance the process of learning (Hlynka and Jacobsen, 2009).

Emerging Learning Technology offers a huge potential to maximize learning success, as shown by Abaidoo and Arkorful (2014), who investigated the limitations of IT and Communication Technology for one thing and into its influential potential on the other hand.
With technology and omnipresent knowledge, learning reaches a next level of efficiency. That factor became even more influential with learning on mobile devices "*interwoven with daily life and work*" (Kukulska-Hulme and Traxler, 2005).
Especially mobile devices and smart phones are used to stay connected through Social Media networks, which also have an influence to the success of learning (Fry *et al*., 2008), who outline Social Media or social software as a "*way to engage in a networked discourse over time".*

Selwyn (2012) emphasizes the significance of Social Media for Higher Education, discussing Social Media and new types of learners or learning, to lift the discussion into the next level and trying to find out "*how best to utilize Social Media in appropriate ways*".

Felder and Brent (2016) discover and further point out, that a "*well-designed instructional technology can promote learning in several ways"*:

Proficiently chosen and coherently used Education Technology can enhance learning by providing course content and other applications. Education technologies offers a wide range of different learning formats and help to maintain the active integration of learners. The support through communication technology helps to improve the interaction between students and between student and faculty. It is perhaps needless to state, that (digital) Education Technology enhances to access to media but also opens opportunities for self-assessments through examinations or tests. This is a perfect supplement to the general characteristic of self-pace learning, available anytime and anywhere.

2.14 Social Networks & Social Media

Before discussing the learning implication of Social Networks or Social Media, the term itself needs to be paraphrased:

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.

Correspondingly, Social Media is associated with online social platforms or Social Network sites (Social Media platforms). These platforms provide the "*interaction and communication between users*" and "*allow them to create and share content*" with each other, mainly using mobile devices. (Norman *et al*., 2015)

Based to Greenhow (2011), Social Media offers a "*direct and indirect"* support for the learning initiative, opening new opportunities to relief stress, share ideas, ask for specific help or to maintain the own learning network by the interactive exchange with other learners, students and other fellows.
She developed that idea even further, when she writes that a Social Media network fulfills "*social learning functions within and across informal and formal learning spheres of activity*".

These functions include (Greenhow and Robelia, 2009):

- Support through an active feedback loop to validate own work results.
- Support of the peer or alumni group through the active presence of role model approach ("*managing the ups and downs*").
- Support for study-related assignments.

Social Media helps to connect students, which are spread all over the world and are not together in a classroom set-up:

As people usually study at home, Social Media seem to be a kind of window to the outside world and therefore should be incorporated into the pedagogic concepts of the future Distance Learning courses. On the other hand, it is highly recommended to motivate Distance Learning students to initiate and maintain their own and topic specific communication channels via Social Media.
This is somehow supported by Hoffman (2009), who describes "*social networking as a tool*." Social Media used in Distance Learning offers "*significant advantages*" once technology (for learning and communication), learning objectives and pedagogical demands are compatible and Social Networking tools are prudently applied.

Whereas Aldim and Ulas (2014) assess the effect of a commonly used Social Media network and the potential to "*improve the limitations of education environment through the use of social network tools*".

As shown in chapter *2.10 Learning Preferences and Psychological Types*, Social Media and Social Networks can play an important role to support the individual Learning Preferences of a learner and assist self-paced and self-regulated learning.

Social Media platforms simplify Distance Learning as they stand for well-established and globally accepted tools to virtually live a live within a certain community. It improves the process of building self-confidence and ability to interact with peers and to gain other social competencies "*by accommodating their individual learning styles*".
(Hussain *et al*., 2018)

2.15 Summary

After all the discussions examined in the pedagogic chapters above, the individual factors as listed below seem to exist. They play the major roles in the learning process or Knowledge Transfer process and can be categorized in inner and external factors:

Inner factors:

- Instructional Preferences
- Learning Preferences and Psychological Types
- Information processing Style
- Cognitive personality Style

External factors:

- Learning Environment and Learning Technology
- Instructional Design
- Learning Conditions and Taxonomy
- Social Media

Figure 15 illustrates that and puts the inner and external factors of the Knowledge Transfer process into context with the object (content) of the process, in our case *Knowledge on Ride Quality of Passenger Transportation Systems*.

This illustration reveals the correlation of the two main subjects of this research project: Pedagogy and Technology.
This assembly of different research aspects expresses the complexity of the research project with facets that represent two totally different sciences.
External factors (Learning Environment and Learning Technology, Instructional Design and learning conditions) impact the socially connected learner, while the learner’s performance is affected by inner

factors too (instructional and Learning Preferences, psychological styles or the way, information is processed).

These inner and outer (external) factors specify the effectiveness of the examined Knowledge Transfer of technical knowledge regarding Passenger Transportation Systems

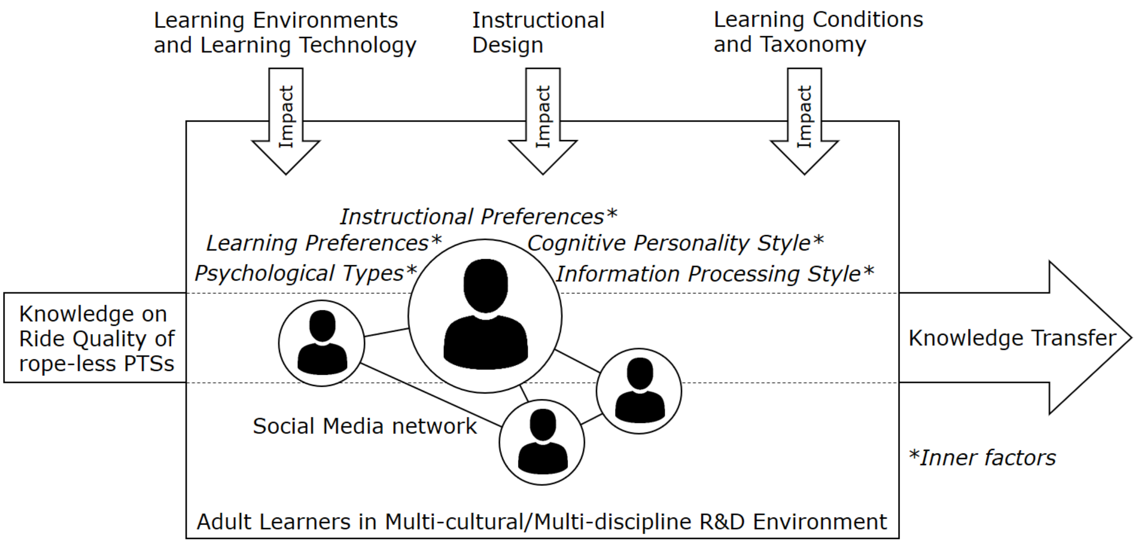


Figure 15 - The Assembly of different Research Study Aspects

and consider the specifics of the investigated cohort of Specialist of the Lift Industry.

With the technological aspects of the research study as outlined in previous chapters, the object of the Knowledge Transfer process is defined (novel Machine Dynamics knowledge), while the aspects of Pedagogy (in reference to Knowledge Transfer) describe the influencing factors of that process. That intersection is framed, and corresponding literature has been reviewed.

The model above builds the foundation for a new concept for Distance Learning, which will be introduced in chapter *5 Conclusions and Further Work*.

3 APPLIED RESEARCH METHODOLOGY

3.1 Circumstances

Essentially, the cause for this research project was the development of a radical new technology for elevators on one hand, and the lack of a well-structured Knowledge Transfer process and the missing training curriculum within the engineering organization of TK Elevator on the other hand.

With the aim to bring the new technological concepts for Passenger Transportation Systems into the global markets, it became necessary to bring the specific knowledge about components, sub-assemblies, and the composition of all that into the contributory engineering workforce.

The engineering (design) workforce within TK Elevator and interested licensees needed to understand the specifics and innovative concept to be able to develop the product and customize to the architectural specifics of a project.

Figure 16 shows the motivational aspects of the research project:

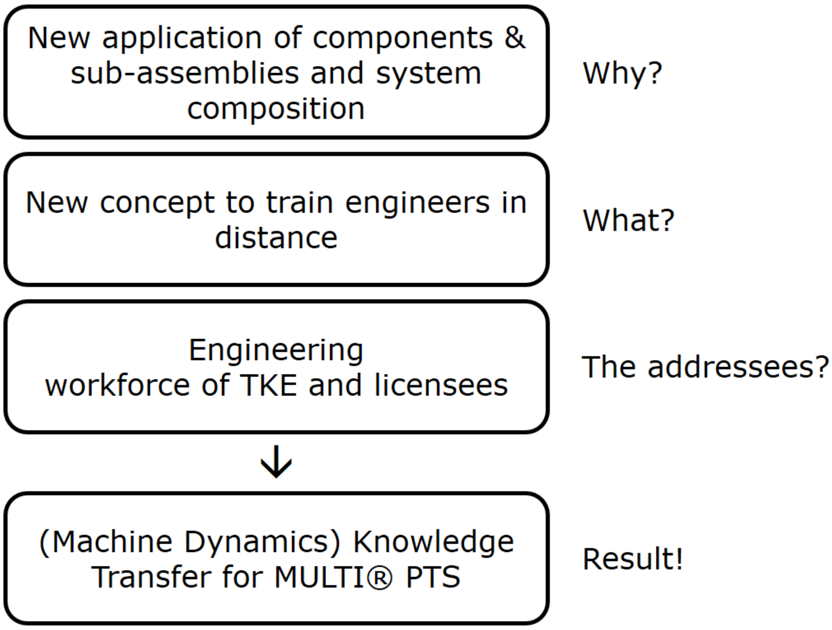


Figure 16 – Motivation for Research Project

- The new application of components & sub-assemblies and system composition requires a new way for the transfer of specific knowledge (training concept).
- The addressee group of the new Distance Learning concept is the global engineering workforce of TK Elevator and its global customers (licensees).
- The direct connection and interplay of stimulus, aim, object, addressee, and justified result makes this research approach matchless.

In 2012, the following story lines were initiated in sequence and completed accordingly, to ensure the transfer of new technology to the global licensees of MULTI®, the revolutionary Passenger Transportation System of TK Elevator:

- Ramp-up and further continuation of a Engineering Training Curriculum: 2012 → ongoing
- Product Design of MULTI® system (after the technology has been developed): 2015 → 2017
- Opening of a dedicated MULTI® test tower facility in Rottweil/GER: 2017
- Research study at the University of Northampton: 2014 → 2021

Especially the experiences during the roll-out of the Engineering Training Curriculum (Ehrl *et al*., 2018) with a variety of subject topics, demonstrated the need for a balanced and structured learning process to exchange knowledge.

The engineering curriculum consisted of the following topics, which were prepared for three global professional experience levels (Junior, Intermediate and Senior):

- Engineering topics (Lift Components, Ride Quality, Trouble Shooting, Machine Dynamics, Material Science, Competition, Patent Applications, etc.)
- Project Management
- Processes (Product Design Process, Failure Mode and Effects Analysis, Life-cycle Analysis, etc.)
- Social Skills (Conflict Management, Communication)
- Software Tools
- Accelerated Programs

The learning outcome of numerous classes conducted between summer 2012 and spring 2015 in engineering locations in South Korea, China, India, Spain, Germany, the U.S. or Brazil resulted in the assumption of the hypothesis, that people learn different in different cultures.
That assumption and unverified hypothesis '*Engineers in Asia and Europe learn in a different way'* was developed further into the general research focus question:

How to transfer knowledge?...

in order to improve best practice and to provide design guidelines for multi-cultural/multi-discipline R&D staff with a special focus to the technology application of multicar rope-less elevator systems.

The section/chapter above explains in detail, what the fundamental justification behind this research project is.
The interpretative approach and belief of this research work, that the specific learning process can be improved after the consideration of

Learning Preferences and other input factors, sets the foundation for the research design. Beyond that and underpinned by the comprehensive Literature Review, the framework of the research work includes a Learning Environment in a broader definition (including Instructional and Curriculum Strategies, Social Networks and Learning Technology).
The Literature Review, which evolved regarding scope and topics over the curse of time, was induced by the basic principles of subject matters beyond the question "How do people learn?". Those enhancements were used to set and review the research direction of the research project and influenced the research methodology.
The initial assumption, that learning results are based on the cultural background of a learner, was indefensible after the first study of relevant literature. And so the research methodology that was primary chosen needed a rescope and new direction into a more mixed setting with a causal-comparative approach and quantitative/qualitative data analyses.

3.2 Research Design

The complexity of the research project is a result of the two different science subjects of it, Machine Dynamics and pedagogy. To identify the inter-dependencies between topics of both aspects, the basic idea of a Concept Map - as initiated in the beginning of the project - was followed and developed over the duration of the research project.

Please refer to the Concept Map as shown in *Chapter 1.6 Structure of this document*, which helps to demonstrate the coherences of the individual topics of the research aspects.
Please refer to *Appendix 6* for a larger depiction of the graphic.

The quintessence and core of this research study on aspects of learning and Knowledge Transfer is based on descriptive & causal-comparative research, and the following methodologies have been chosen for the research project:

- Observations (notion of the hypothesis)
- Literature Review
- Quantitative & qualitative data analyses (questionnaires and surveys)

- Qualitative data analysis (open questions interviews)
- Benchmarking test (customized e-learning vs. standard Distance Learning approach)

This specific research design aims to prove hypotheses on one hand and prove relationships of data on the other hand (causal-comparitive). That approach fits much better to the research setting and seems to be a better approach than a mixed study method, that combines quantitative and qualitative data collection to analyse data in one.
The approach to blend a review of the body of knowledge with quantitative & qualitative data analyses represents the most practicable research design attempt.

The comparative research methodologies help to find out the individual Learning Preferences and Social Media consumption of the user group. These results will give indication for the desired methodology to acquire the technical knowledge (here: Machine Dynamics of vibration and Ride Quality of rope-less lift cars).
Especially the feedback to open questions of the corresponding surveys will be used for the definition of a new learning model that considers a multi-cultural/multi-discipline R&D environment.

3.3 Evidence using Literature Resources

A comprehensive selection of subject topics and literature has been reviewed to create a substantial Literature Review. The sources considered included conference papers, journals, textbooks, standards or norms, articles, and web sources, and involves a huge number of subjects.

That list includes:
Ride Quality, advanced vibration dynamics, multi-car lift systems, Knowledge Transfer, adult learners, engineering education, Learning Theories and psychological styles, Instructional Design, Social Networks, and Social Media, and Learning Technology.

The enormous body of knowledge of related literature proves the relevancy of this research project and emphasizes the efforts been made to elaborate the specific intersection of curriculum and Instructional Strategy, Social Networking, and infrastructure. That means in consequence, that the comprehensive Literature Review is an essential part of the research methodology and is needed to describe the vast level of knowledge.

Within this research project, the pedagogical topics stand in the focus of inherent investigations and efforts. Those aspects, like Learning Theories or Instructional Design are examined in detail over a long period of time, however, the combination of Learning Technology, Social Networking platforms and Learning Theories leaves a certain gap.
While latest research on Instructional Design developed this study area into recent times with emerging (education) technology and learning format that directly use these learning concepts, Learning Theories somehow lack the bridge into today. Learning detached from a stationary event to become a continually journey with access to the comprehensive

knowledge of the world available by a click onto the screen of a mobile phone.
In addition, the traditional groups in classrooms dissolved and disappeared; today we have students and learners sitting in their home environment and learning with own equipment, such as laptop computers or tablets.
Certainly, this changes the way we have to have on learning in general. With the ascending importance of Social Media and Social Networking platforms, another factor of potential relevance comes to light. Social Networking is about to replace traditional communication and the way we hold together.
This research project tries to fill that gap with a novel composition of related topics of Knowledge Transfer: Learning Strategies (curriculum, Instructional Design), Social Networking and Infrastructure (in view of Education Technology).

3.4 Research Aspects of Learning and Knowledge Transfer

Two research methodologies, descriptive & causal-comparative research are applied in this study as hybrid research methods and structured processes that involve individuals and looks "ex post facto" into real situations. This research design is used to look at potential causes for observed differences noticed among groups, or relationships between variables (age, social background, geographical area, etc.) in real life situations. The hybrid descriptive & causal-comparative research aims to identify a cause-effect relationship between two or more observed groups based on up-front observations.
The main reason for the engagement in this descriptive & causal-comparative research is the opportunity to improve the respective actions in the end.

The descriptive & causal-comparative study evaluates the causes of certain occurrences or even non-occurrences. This can be done by the comparison of circumstances associated with observed effects.

There are two methods to explore the cause-and-effect relationship between variables: experimentation and statistical research, with 3 types of descriptive & causal-comparative research: exploration of effects, causes or consequences.

This type of research is complex, as it is necessary to analyse data by comparing averages or using crossbreak tables. And there will always be a kind of uncertainty, as there could be other factors that influence a causal relationship, especially when the research investigates attitudes and motivations of groups of people.

The basic steps of this "after the fact" research methodology:

- Problem formulation
- Selection of the population group of individuals to be studied
- Instrumentation (for example: achievement tests, surveys, questionnaires, interviews, or observational devices)

The fundamental research study design of descriptive & causal-comparative research typically follows these two principles:

- Gather information through data review, surveys, interviews or observation.
- Select a participant group that has the independent variable and select another group of subjects that does not have the independent variable.
- Both groups are compared on the dependent variable thereafter.

Figure 17 depicts the steps involved in standard causal-comparative research, as described above.

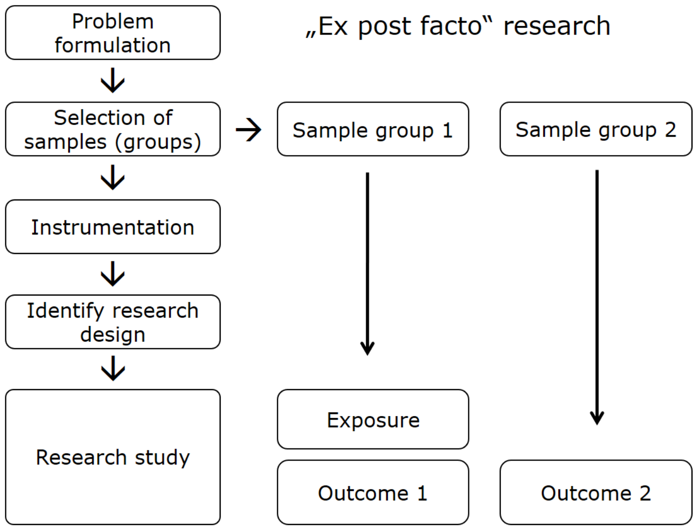


Figure 17 – Steps involved in causal-comparative Research

Causal-comparative research attempts to determine the cause or consequences of differences that already exist among or between groups of individuals. Research is retrospect since both (effect and causes) have already occurred.
Being an accepted methodology for the improvement of educational practices, the causal-comparative technique has been selected for this present research study.

Based on this, Figure 18 demonstrates the inter-dependencies of the sequential descriptive & causal-comparative research elements of the study in hand. That set-up allowed to nail down the problem to its central problem and to counteract accordingly:

How do Specialists of the Lift Industry learn best, when it is about to grasp new technical concepts?

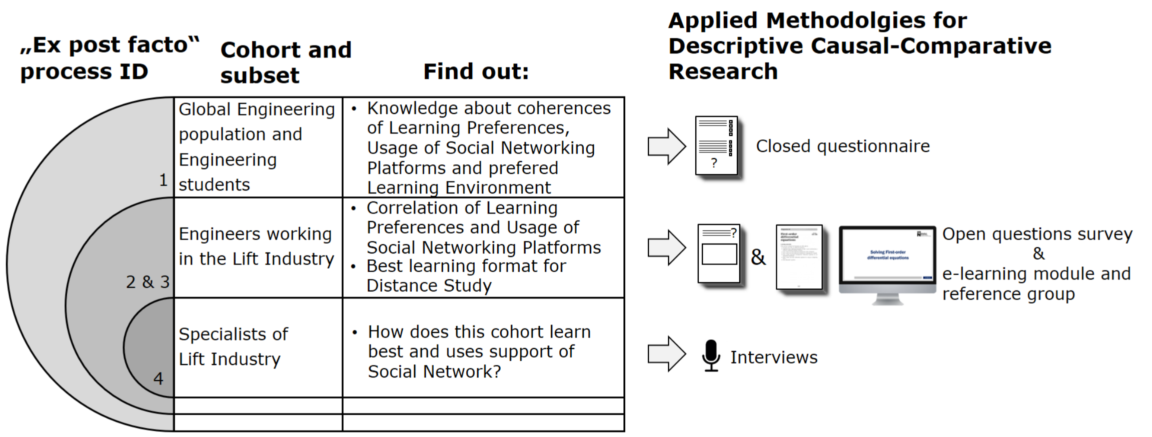


Figure 18 – Interaction of descriptive & causal-comparative Research Elements of this present Study

By comparing two or more groups of individuals, the four closed descriptive & causal-comparative subsections #1 to #4 of the adopted *ex post facto* research design try to identify relationships between variables after an explored event has occurred.
Further details of the present study are explained in the next chapters.

3.5 Survey with a global Engineering Sample (Research Subsection #1)

The first descriptive & causal-comparative research process involved a cohort of 353 engineers and engineering students worldwide and was conducted between October 25th, 2018 and December 31st, 2018.

This first research subsection was designed to reach out to the most widened population, to learn about and work out general Learning Preferences, Learning Environments, Learning Technology and popular Social Media platforms. The reason for this general approach, which intendedly does not represent the targeted sample (Specialists of the Lift Industry), is justified by a statistical rational. To achieve a statistically meaningful result, the size of the examined cohort has to have a certain size.

The different groups to compare came out of the study set-up.

Composition of study participants:

- All levels of professional experience (freshmen → experts)
- All kind of technical profession (electrical, mechanical, software engineers, etc.)
- Different geographical regions
- All gender and age
- All potential participants study or studied an engineering topic that is relevant to lift engineering

The participation was voluntary, and all respondents were noted anonymously using an online survey tool[12], which is supported by the University of Northampton.
The questionnaire with 23 closed questions was structured in 4 sections

1. Learning Preferences:	7 questions
2. Social Media, Devices and Social Network:	7 questions
3. Learning Environment:	4 questions
4. General questions:	5 questions

wherein the number of questions in each section was defined by the categories of Learning Preferences, specifics of the user behaviour of Social Network consumers, potential Learning Environments, general statistical information. The individual extend of each question catalog per section is thereby secondary.
It was intended to discover and evaluate the Learning Preferences of an engineering sample and to figure out differences based on gender, age or cultural background.

[12] www.onlinesurveys.ac.uk

The questions of the Learning Preferences section were preset to specific Learning Preferences already and the respondents just needed to assess their individual characteristics.
Even further, the results of this first approach to a global cohort identified preferred mobile devices to study and to connect to the individual Social Network.
The analysis of the information given by respondents was done with the online survey tool.

3.6 Open Questions for Lift Industry Engineers (Research Subsection #2)

An open questions survey was available for the time of 5 weeks in autumn 2020 (September 23rd, 2020 and October 31st, 2020). In this case, the number of 40 respondents, all voluntary engineers from the Lift Industry, was counted.
The design of the survey followed a different principle, as the questions in respects to Learning Preferences were kept open, and the respondents had to describe their Learning Preferences without being influenced.
This second survey with 23 open questions was structured in 3 sections

1. Learning Preferences:	8 questions
2.1. Learning Environment:	1 question
	1 free text entry field to justify that
2.2. Media/Sources:	1 question
	1 free text entry field to justify that
2.3. Learning Platforms:	1 question
	1 free text entry field to justify that
2.4. Social Media Platforms:	1 question
	1 free text entry field to justify that
3. General questions:	7 questions

All volunteers were invited through the organizing team of the Northampton Lift Symposium, Peters Research Ltd., and LEIA (Lift and Escalator Industry Association).

The general section collected (anonymous) information on gender, age, cultural background, technical profession, and hierarchy level.

The qualitative data analysis of the received information was made with NVivo[13] software.

The design of this survey allowed a deeper analysis of the specific characteristics of the examined cohort but left open some areas and the final verification aspect for the proposed pedagogic model. Those gaps were filled by the fourth subsection of descriptive & causal-comparative research (process #4), the interview round with Specialists of the Lift Industry.

That final research part compares results of the intended cohort (Specialists of the Lift Industry) with research finding of a more general engineering cohort.

3.7 Two Learning Journeys (Research Subsection #3)

A comparing satisfaction survey on two completely different learning journeys was conducted in November and December 2019 with 16 participants split into 2 even cohorts. Volunteers were recruited out of the cohort of Process 1.

A total set of 9 self-assessment statements (to be rated between 1 to 5 stars) using edjet.com and surveymonkey.com was presented. That set included statements on:

- Confidence level about individual knowledge appropriated
- Opportunity to interact with other students

[13] NVivo – A qualitative data analysis software from www.qsrinternational.com

- Enjoyment during learning journey
- Design of the course material
- Amount of multimedia used in course material
- Preference to take the course as e-learning or as standard offline Distance Learning (study pdf files and books)

The intention of this research subsection was the unbiased comparison of two totally different approaches to teach a mathematical concept (step 1) and to justify and finish that by an assignment to prove and underline the perception of the learning journey (step 2). This represents a typical study design of descriptive & causal-comparative research.

Therein, the conclusive assignment fulfilled the following preconditions:

- Directly built on the learned content (here: solving first-order differential equations)
- To stand in context with an engineering problem (here: apply the learned content to the trajectory of the cabin of a Passenger Transportation System). Please refer to *Appendix 5* for further details.

Figure 19 shows the basic set-up of that descriptive & causal-comparative research subsection #3 (Two Learning Journeys), wherein the learning experiences of cohorts A and B are compared to each other.

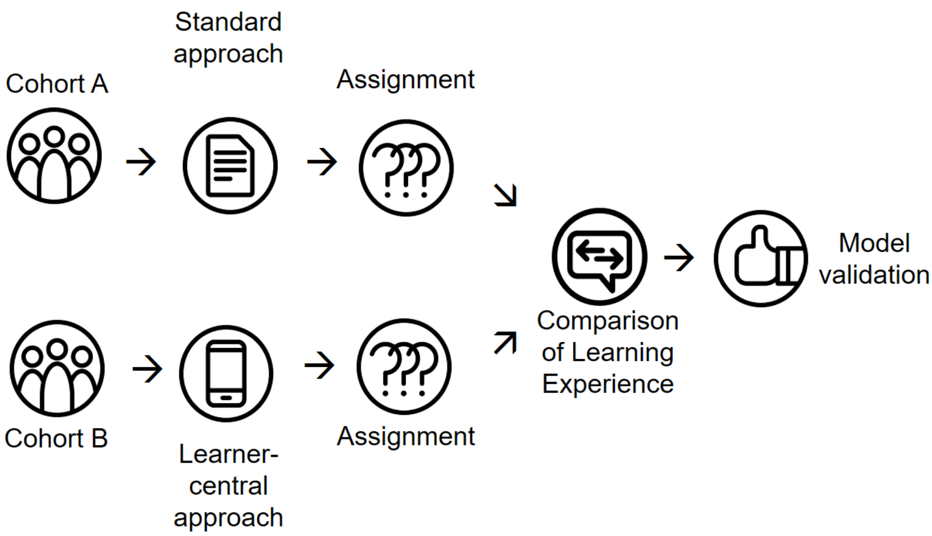


Figure 19 – Process 3 with Cohorts A and B
(e-learning Module and Reference Group)

That subsection built a solid understanding of the expectations of students studying "in distance", and therewith set the future direction for multimedia application in alternative and electronic distance study formats (e-learning, video casts, audio files, simulator, micro learning, blended learning, learning games) to allow for a study anytime, anywhere, at an individual learning pace.

3.8 The Interviews with Lift Industry Specialists (Research Subsection #4)

Eight phone interviews with engineering Specialist of the Lift Industry were conducted in January 2021 to gain an understanding of how Specialists of the Lift Industry want to learn about new technology in a Distance Learning set-up.

The participation of those specialists, who are well-known in the Lift Industry network was voluntary. To maintain the essence of the spoken words for the research, the information was recorded using the Call Recorder[14] app on a mobile phone.

The tape was transcribed using the Call Recorder app and kept confidential on a password-protected computer. All individual identification was removed from the hard copy of the transcript. Participant identity and confidentiality were concealed using coding procedures (in NVivo).

At any time, the volunteers may have requested to see or hear the information collected.

The Lift Industry Specialist participating, represent the average industry population:

- Four experienced lift consultants (located in Europe and North America)
- Four experienced industry representatives (working for globally operating lift system suppliers and located in Europe, China and North America)

[14] Call Recorder – Mobile App developed by BPMobile

4 RESULTS AND FINDINGS

4.1 Prelude

This section represents the findings from the descriptive & causal-comparative research subsections (surveys, questionnaires, and interviews) and tries to reflect the observations and conclusions in a critically way.

Each subsection concludes with a summary of key findings and observations in form of a take-away box and comes along with suggestions for further actions.

It must be noted here that only the findings of the descriptive & causal-comparative research processes of the pedagogic topics and learning aspects in the broader sense are accurately described, but the section abstains from a detail discussion of the technical aspects of rope-free Passenger Transportation Systems and Machine Dynamics of cabin vibration and Ride Quality, which have been developed in research work parallel to this research project, namely:

- Modelling of a rope-free passenger transportation system for active cabin vibration damping (Missler *et al*., 2016)
- Control of actuators for cabin vibration damping of a rope-free passenger transportation system (Missler *et al*., 2017)
- An analysis of airflow effects in lift systems (Singh *et al*., 2017)

The technical aspects represent the content development of knowledge that passes a Knowledge Transfer process and how this is to be learned by others.

So, just the pedagogic aspects are accentuated here, since the focus of this research project was: How is knowledge transferred? How are technical aspects being learned? How have those technical complexities to be taught?

4.2 Key dynamic Parameters that influence Ride Quality of Passenger Transportation Systems

Partial results of the presented work have been published in: Lift and Escalator Symposium, The University of Northampton, CIBSE Lifts Group, LEIA
(Ehrl *et al*., 2015)

<u>Introduction</u>

This initial study investigated the dynamic interaction of the system components of Passenger Transportation Systems (here: lift system) and their influence on Ride Quality and the effect to passengers.

Ride Quality is a measurement for the comfort level experienced by passengers and is intimately associated with their subjective perception and sensitivity to motion and sound, and on the other hand, it is the critical criterion for a PTS manufacturer to determine the subjective and objective quality of any system, either a conventional traction system or a rope-free system.

Please refer to Smith (2008) and Lorsbach (2010).

Figure 20 illustrates the conformity between the two completely different conceptions of a propulsion system of a Passenger transportation System (a conventional lift with suspension ropes and MULTI®). Both axes arrangements follow the same principle: Axes x and y for the horizontal plane and z for the vertical direction.

This fact helps to compare simulation models.

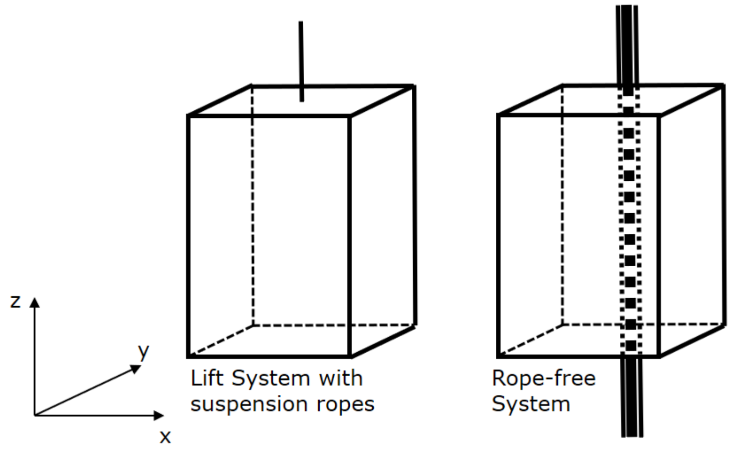


Figure 20 – Arrangement of the x-, y- and z-axis (rope-free Cabin)

The response of the complex structure of a human body to these multiple facets of Ride Quality is different from human to human, as humans are unique in terms of body mass, portion of muscles, physical ability and overall condition. Moreover, everyone has a unique sensitivity for external stimulation.
The influence of noise and vibration to a human body can create various subjective effects, which cause human discomfort in consequence.
At the extreme, when very poor Ride Quality comes together with human over-sensitivity, vibrations can cause stress effects to following physiological areas: Cardio-vascular system, nerves system, muscles, and/or respiratory system.
Therefore, it is common practice in the Lift Industry to stay within certain limits for critical Ride Quality aspects to ensure good Ride Quality, which was elaborated also by Lorsbach in 2010.

This means concerning the cabin inside:
Keep jerk rates under 1.0 m/s^3; keep acceleration rates between 0.8 m/s^2 and 1.6 m/s^2; maintain horizontal vibrations below 0.25 m/s^2; allow maximum limit sound level of 55 dB (A).

Furthermore, a unique person standing inside a lift car interacts with that respective lift car regarding the context of “human-machine”. So, the human becomes part of the dynamic interaction of lift components within the system that is defined by Mass-Damping-Stiffness characteristics.

<u>Components that affect Ride Quality</u>

Unfortunately, the operation of Passenger Transportation Systems is affected by vibrations and associated vibro-acoustic noise, which affects Ride Quality and results in a high level of dynamic stresses in lift components.

Understanding and prediction of vibration phenomena occurring in elevator installations is essential for developing vibration suppression and control strategies in order to design a system which satisfies even demanding Ride Quality criteria.

Vibration sources affecting a lift car involve car guiding system, suspension, compensating ropes (if applicable), building sway and air flow (result in excessive noise and flow-induced vibrations of the car structure). The underlying causes of vibration are diverse, including poorly aligned joints and imperfections of guides, eccentric pulleys and sheaves (if applicable, systematic resonance in the electronic control system, torque ripples, and gear and motor generated vibrations (incl. linear motors).

That variety of sources affect the lift car and – if a passenger travels inside the cabin – the passenger.

Improve Noise and Vibration Performance

The following three basic principles can be applied to mitigate the effects of noise emission and vibration in mechanical systems:

- Prevention → To reduce the strength of the source.
- De-coupling → To interrupt the noise/vibration path.
- Damping → To absorb of the energy of noise/vibration.

The causes of noise and vibration and their effects (responses) can be quantified (please refer to chapter *2.6 Ride Quality*). If the excitation forces are identified, the responses are determined through the application of experimental techniques and/or calculated using analytical techniques and/or computer simulation.

Further Machine Dynamic Research Work being conducted in the Context of this Research:

In conjunction with this research project, further research in regard to the rope-free MULTI® Passenger Transportation System was conducted. Please refer to chapter *4.1 Prelude* for further details.

Although...

The focus of this research study is, how this technical knowledge is being transferred and to be learned by others. Therefore, these complex technical topics are not explained any further.

However, the significance of the Ride Quality topics of the preliminary technical research project MULTI® is obvious and quoted in Key Findings I on the next page.

Key Findings I

- New vibration sources occur due to the new system design, and MULTI ® system-specific Machine Dynamics knowledge is complex but obligatory to understand for the subsequent activities to finish the product design of a customer installation.
- As tests have shown: Actuators offer a sufficient damping mode for rope-free PTS cabins.
- Ride Quality is an essential criterion for the quality of a Passenger Transportation System installation, and well examined by numerous researchers (as elaborated in the Literature Review section of the conference paper quoted).
- Rope-free Passenger Transportation Systems and roped systems both represent a Multi Body System, and thus there are similarities between those models. Rope-free Passenger Transportation Systems need an advanced approach of mathematic modelling and system simulation due to the completely different design principle (back-pack, joist bearing, torsional beams) and bending load cases.
- The study of Multi Body Systems (interconnected rigid or flexible bodies) helps to understand, how mechanical systems behave under the influence of forces.

Implication to the pedagogical part of the research study:

The above-mentioned statements summarize the technical circumstances and importance of *Machine Dynamics of Passenger Transportation Systems in Buildings* in a compact manner. These individual aspects represent the input variable of the Knowledge Transfer process, which is examined in the pedagogical part of the research efforts and are the object of a transfer/learning process and correspond with the asset throughput.

4.3 Pedagogic and Learning Aspects

4.3.1 Improvement of the Learning Environment at an international multi-cultural company through the assessment of relevant methodology and technology goals

Partial results of the presented work have been published in: Lift and Escalator Symposium, The University of Northampton, CIBSE Lifts Group, LEIA
(Ehrl *et al*., 2017)

Introduction

Knowledge development (and Knowledge Transfer after all) of any workforce is important for companies and organizations. Considering, that worldwide knowledge doubles every 18 months (depending on the subject), this purpose becomes even more important (Greenstein, 2012).
In that context and as preparation for the design of the descriptive & causal-comparative research subsections, the opportunity to applying new learning technologies within a multi-disciplinary and multi-cultural environment to improve the efficiency and effectiveness of corporate training was discussed in this research work.
The study is represented by a comprehensive literature research.

Learning

The investigations had its focus on corporate training and therefore principles of adult learning (with a reference to Knowles, 1970) were presumed for multi-disciplinary and multi-cultural work environments:

- Learners need to be engaged.
- Learners need to be able to acquire knowledge.
- Learners must be essentially motivated.

This can be applied regardless of learning format or the presence of Learning Technology.

Concerning the learning event in general, it is important, that the learning goal is directly related to the expectation of the learner to maintain the engagement of an adult learner (personal benefit). This also ensures, that the learner finds it easier to remember what's been learned, and to recall in the future.

The fundamental needs of adult learning are summarized by the Principles of Andragogy, and build the foundation of adult learning programs (Knowles *et al*. 2005):

- Adults must want to learn.
- Adults will only learn, what they think they need to learn.
- Adults learn by doing.
- Adult learning is focused on solving problems.
- The experience an adult has, can affect their learning.
- Adults learn best in an informal situation.
- Adults expect to be considered as an equal partner in the process.

To ensure success in corporate learning, general basics of learning must be considered. These is for instance Bloom's Taxonomy (Bloom *et al*., 1984), which splits types of learning into six levels, or the categorization into four learning types:

- Auditory Learning
- Visual Learning
- Haptic Learning
- Intellectual Learning

The consideration of Bloom's Taxonomy is important for the development of learning goals and learning content and helps to write the training outline.
(Anderson and Krathwohl, 2001)

Training Content

On the assumption that learning is a transformational process with input, process, and output (as result), and with the special focus on corporate training, the process to gain knowledge is essential to prepare the workforce for specific tasks they have to fulfill in a project or at work.
The detail assessment of the learning portfolio of the global SEED campus[15] organization in combination with a benchmarking activity with Volkswagen AG[16] reveals the following topics for professional work environments, but is not limited to:

- Language Skills (especially important in multi-national & global enterprises)
- Craftsman topics (skilled occupation, manual competence)
- Skills in all regard of Information Technology (e.g.: application know-how of a specific software, general skills to be able to operate with computing devices or IT data security)
- So-called Excellence Factors as for example exponential thinking, self-learn/self-reflection competence, customer orientation, data smart, capability to adopt change, responsibility, information scouting & investigation, problem solving, process analysis, design thinking, agile, and user experience

[15] SEED campus – Global learning organization of TK Elevator
[16] Interview conducted with Elsa Szwiec of Volkswagen AG (HR Strategy & Innovation, Digitalisierung, Business 4.0, K-GXB) on April 3rd, 2017

- Soft Skills (e.g.: conflict management, motivation)
- Communication and presentation skills
- General Management Skills (e.g.: instance business models, economics, and project management)

Alternative Learning Formats and the Benefit of modern Training

The far-reaching digitalization of many aspects of daily life is a Mega Trend that also affects the way people live and learn. This implies the opportunity to design training in the most efficient and effective way to ensure a balanced return-on-investment.

Although instructor-led-training or classroom training (training event happening between an instructor or teacher or facilitator and a learner) still represents the majority in corporate training and development programs, there is a shift to teaching & learning alternatives (Kurzman, 2013), which are enabled by evolving technology, the increasing number of mobile devices, the growing share of digital natives, and the fast increase of computational power.

Common alternative forms of training, add-ons and enhancements are listed and defined in Table 4:

Alternative Learning Format, Add-on, Enhancement	Definition
Uncontrolled on-site Training	On-the-job training where the learner gains informal knowledge from co-workers.
e-learning	No clear definition existing. e-learning refers to learning experiences that use technology such as videos or web-based training.
Video Casts	Basically, classroom training that was recorded on video and can be viewed by a learner anytime, anywhere.
Massive Open Online Course (MOOC)	Free online seminars on university level that have a huge number of participants.
Physical Simulator Training	Environment that copies a real-life situation (e.g.: elevator shafts in steel frames that allow group training).
Augmented Reality / Virtual reality / Mixed Reality Training	Immersion of learners into a simulated facility giving them an experience similar to real life. Benefits: The trainee can be placed in simulated environments that would be potentially dangerous to simulate in real life. No need for a simulation facility to undergo the training. Multiple people can be trained at the same time. Different trainees can interact with one another as well as the instructor.
Micro Learning	Smaller chunks of training content, generally available 24/7 via mobile applications to allow access anywhere & anytime.

Table 4 – Alternative Learning Formats

Alternative Learning Format, Add-on, Enhancement	Definition
Blended Learning	Mixed learning formats (e.g.: literature + video tape of a classroom lecture + web-based knowledge control).
Learning Management Systems (LMS)	The latest Learning Management Systems (LMS) combine all facets of training & learning. Amongst the function to manage training events and track learners' progress, these systems offer a comprehensive collection of all kinds of different training types,
Gamification of Learning	This is the educational approach to improve the students' motivation to learn by the application and integration of video game design and game elements into Learning Environments. Goal: To maximize the enjoyment and engagement through the consideration of the specific interests of individual learner groups.
Coaching Functionality	Enabling the opportunity for instant coaching conversation or chat function.
Artificial Intelligence	This technology enables the system to form user-specific learning material, e.g.: individual questions.

Table 4 (continued) – Alternative Learning Formats

This comparison portrays the wide range of technical add-ons and functionalities that can enhance learning. Some of the items listed above have already been developed to a robust state-of-the-art technology (e.g.: video, MOOC, e-learning), while some (for instance Artificial Intelligence) wait for its full implementation into the learning industry.

Not all formats are suitable everywhere and for any intended learning event. So it has to be decided from use case to use case, which format is useful according to user group, learning objectives, transferred content and technical capabilities.

Certainly, good training starts with a good pedagogical concept. But there are a few other factors that influence the success of learning (Doherty, 2017):

- Engaged students (who are motivated, curious and ask good questions).
- Multiple different methods of teaching should be used (individual, collaborative, lecture, group to group, etc.).
- A constant opportunity to practice what has been learned.
- Fun.
- Everyone's different work style has to be accounted for. There are online assessments that can be used to get an idea of different people's working styles so that they can be matched with a suitable training program.
- Expectations of the employee must be made clear initially. But it is also important for the person in charge of training, to know the trainee's expectations.
- Progress check-ins need to be regularly made to an agreed schedule.
- The trainer must consistently ask questions.
- The key to effective training is communication. Knowing the trainee's thoughts throughout the training process will help to adjust the training plan so that the trainee is involved and learns quickly.
- Because of increasing diversity in workplace, it is necessary to put trainees in situations that they would not know in their own culture. This can help to ease an employee when introduced to these situations in the workplace.

The consideration of a good training mix offers benefits that include, but are not limited to:

- Flexibility — The learner can choose time, pace, and place of study. That increases the learners' satisfaction and motivation.
- Efficacy — Easy access to information.
- Social contact — Support relations between learners.
- Cost effective — No need for travel. No need to provide buildings and physical environments.

Key Findings II

- The application of Education Technology helps to improve the efficiency and effectiveness of corporate training.
- Education Technology can supplement classroom training.
- The variety of different Education Technologies is huge and grows permanently. Micro-learning, Gamification or Artificial Intelligence are some headwords to be mentioned in this context.
- The principles of adult learning should be considered for programs for a multi-disciplinary/multi-cultural R&D environment.
- Different content requires different teaching strategy.
- A Coaching functionality to supplementing online courses is a cost-efficient method to keep training going.
- Success factors for successful Learning Environments: Engagement. Variety. Collaboration. Fun. Practice. Diversity.

<u>Implication to or intersection with the technical part (Machine Dynamics) of the research study:</u>

These pedagogical findings around suitable Learning Technology corroborate the need for an extraordinary and customized Learning Environment for the target group of Specialists of the Lift Industry. With their passion and access to technology, the integration of Education Technology that follows the Learning Preferences of the user group is self-explanatory.

…

Key Findings II, continued

…

Suggestions for further actions:

Training must be considered as an ongoing journey, not just a single event. (Please refer to chapter *3.4 Evidence using literature sources*.)

4.3.2 The Optimization of a Learning and Training Portfolio at a Multi-national Lift Manufacturer

The findings of this substantial study were intended to be used to prepare descriptive & causal-comparative research subsection #1 (Survey with a global engineers' sample) and to involve the aspect of Learning Preferences.

The study is being composed of an extensive literature research and the analysis of proprietary information off the SEED campus organization, as the specific focus lies in the area of the improvement of the engineering learning portfolio of a lift manufacturer.

The analysis aimed to define a universal framework for a training portfolio and did not define specific contents for a given business function.

With that in mind, the Competency Model and consequent needs analysis are in the centre of interest in this paper.

An optimized Strategic Learning Curriculum

The expenses for corporate learning curricula to develop internal workforce can be reasonably high, as underlaid by Sönmez, 2013, and Elnaga and Imran, 2013.

To optimize the business investment, the following content aspects and solid structural analysis should be considered, of which some require a feedback loop as shown in Figure 21:

- Competency Model (Skills Matrix)
- Training Needs Analysis
- Evaluation of Training

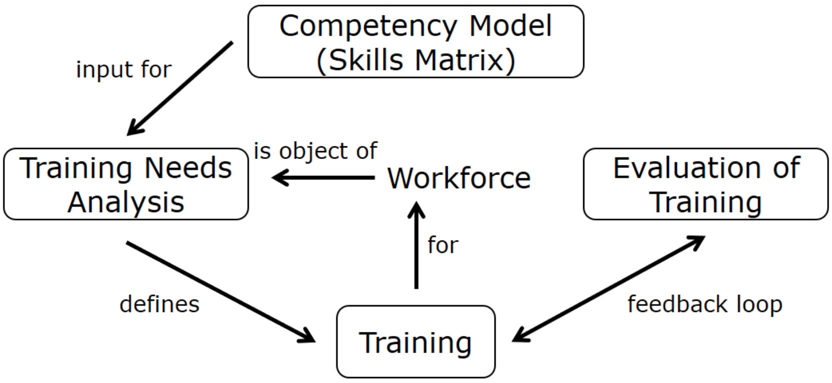


Figure 21 - Correlation of Competencies, Training Needs and Training Evaluation

This Figure 21 shows the correlation of competencies, training needs and the evaluation of training conducted. These relationships are essential for the benefit of an optimized training & learning curriculum for a group of people, e.g., employees of an enterprise.
They cannot be regarded in isolation; they need a holistic consideration.

<u>Competency Model or Skills Matrix</u>

A Competency Model determines tasks and function-specific competency levels, which are descriptions of certain tasks which are required to be performed by an employee).
To be able to qualify employees to perform a specific task (for example: to apply a specific computer program), individual competency profiles are compared with the required competencies.

A Competency Model provides a structured approach to consistently outline competency profiles. In this way, it helps to analyse organizational and position-specific needs, existing capabilities and to derive learning objectives of individual training courses or modules.
The Competency Model and Skills Matrix represent the backbone of a strategic learning curriculum, whether for engineering or other topics. Learning needs, as other important aspect, are analysed thereafter based on business function strategy. So, the needed competencies are defined.

Training Needs Analysis

The purpose of a Training Needs Analysis is the systematic approach to determine training needs and answers the fundamental question: What kind of training needs to be offered?
Based on the business needs and competencies needed, a Training Needs Analysis considers the following aspects:

Training Forms and Cost.

- Training Forms — What training methods fit best to the needs of the learner?
- Cost — How much budget is available to develop and offer a specific measure to a group of learners?

So, a Training Needs Analysis evaluates kinds and volumes of training required by the business functions, taking the different strategic objectives and operational needs into account.

To evaluate whether the skills gap was closed by a training measure or not, the effectiveness of a training measure is assessed.

The following guiding questions help to evaluate the effectiveness of training measures:

- What is the long-term impact of the training measure to the individual learner or group of learners?
- Did the training help to improve abilities and fill skill gaps?
- Do the learners apply what they learned and did their work performance improve?

It seems to be standard within the learning industry to apply the 4-levels of the Kirkpatrick model for the training evaluation (Kirkpatrick and Kirkpatrick, 2016):

- Level 1 – Reaction
  Learners appraise the training regarding their engagement and job relevance.
- Level 2 – Learning
  Learners evaluate the training regarding acquired knowledge, skills, and attitude.

- Level 3 - Behavior
  Learners apply what they have learned during the training back in their jobs.
- Level 4 – Results
  Degree to which the intended/aimed outcomes are demonstrated as a training result.

<u>Key Success Factors</u>

Business relevance, efficiency and effectiveness are the key success factors of any successful learning curriculum.

For that reason, the regular review of the relevance of the content offer with respective stakeholders and customers is mandatory, and should be

conducted before the Training Needs Analysis, as it offers essential input for the Competency Model.
Under notorious cost pressure, the overarching question should be in connection with: How can learning be made more effective and (cost) efficient?

In conjunction with the Training Needs Analysis and the integrated aspect of Training Forms (guiding question: What training methods fit best to the needs of the learner?), the obvious response to that is called Education Technology nowadays, as…

- Mobile devices and mobile applications support and help prepare learner for the next career step.
- Education Technology in the classroom is an effective method to engage with learner of all Learning Styles.
- Education Technology gives learners the opportunity to enhance the interaction and collaboration with their network.
- Education Technology gives teachers the opportunity to develop a digital literacy across all ages and experience levels.
- Integrating Education Technology in Learning & Development helps younger learners to stay engaged.
- Education Technology helps to design digital learning content in short chunks to respect attention span of an individual.
- With Education Technology, the traditional passive learning model breaks up, as classroom or mobile technology changes the role of the teacher into the direction of an encourager, adviser or coach, as already mentioned in chapter *2.13 Learning Environments and Learning Technology*.

Key Findings III

- Education Technology is the key success factor for efficient learning. Education Technology changes the role of the facilitator, enhances the interaction and collaboration within the learners' network, and is an effective method to engage with learners of all Learning Styles. It transforms the learning experience and generates a huge number of new opportunities.
- Business relevance of and Management commitment for the curriculum is essential.
- The coherences between Competency Model or Skills Matrix, Training Needs Analysis and Training Evaluation are the formula for success and represent the backbone of a strategic learning curriculum.

Implication to the technical aspects (Machine Dynamics) of the research study:

The consideration of the already acquired knowledge has highest priority above all, to ensure cooperative efforts and engagement on the part of the Specialists of the Lift Industry.

Suggestions for further actions:

The consideration of a learner-centric approach (for highly skilled engineers of the Lift Industry), 24/7 mobile learning and awareness for different Learning Styles can revolutionize learning and development in Higher Education and enhance the effectiveness & efficiency of Machine Dynamics Knowledge Transfer for Specialists of the Lift Industry.

Especially for the aimed engineering population of Lift Engineering Specialists with a certain passion for technology, the lookout to Education Technology which supports the Knowledge Transfer is promising.

4.3.3 Impact of Learning Style Preferences and Social Media use on the Environment of Distance Learning (#1)

Introduction

Knowledge Transfer has changed over the last decades through permanent scientific innovation and evolving technology, such as typography, personal computers, or the World Wide Web.

These days, in a professional context at a workplace, the acquisition of knowledge (= learning) goes together with the application of that specific knowledge. The effectiveness of that Knowledge Transfer process is a condition of the way a human being receives learning content, and it is believed, that this depends on the Learning Style Preference of an individual.

This research approach (Survey with a global Engineering Sample - Research Subsection #1) evaluated the interaction of Learning Style preferences and modern communication channels (Social Networking and Social Media platforms) and proposes a new concept for efficient and effective Distance Learning transition model in Engineering Education.

The questionnaire

For that reason, a questionnaire to identify the correlation between Learning Style preferences and the usage of Social Networking platforms (in place of the individual need to interact with other learners) was sent to a global student and engineering sample:

- Global R&D workforce of a German Lift manufacturer
- Student force of the University of Northampton, UK
- Student force of Georgia Institute of Technology, U.S.
- Student force of Shanghai-based Tongji University, P.R.C.
- Student force of the University of Stuttgart, GER
- Student force of the University of Applied Science Furtwangen, GER

Those cohorts represent partner universities of TK Elevator and were chosen as potential cohorts for this study, as professorship and/or university staff supported the research project and guaranteed the anonymity of the participants. Furthermore, all universities were/are involved in science projects that are relevant for lift engineering:

- TK Elevator: all engineering activities for hydraulic and traction systems and MULTI® research and product development
- University of Northampton: Study program for MSc Lift Engineering
- Georgia Institute of Technology: Research activities for Lift applications
- Tongji University: Effects of earthquakes to high-rise buildings
- University of Stuttgart: Research on MULTI® trajectory and vibration control
- University of Applied Science Furtwangen: Material Science and Mechanical Engineering

Within the time between October 25th, 2018 and December 31st, 2018, 353 voluntary respondents were counted out of the total potential sample group.

Learning Preferences

Every individual has its own way to receive and process information. The way people grasp information best, when studying, is called Learning Style Preference.

The preference for a certain way to learn may not be unalterable, it rather differs from time to time and depends on specific situations or set-ups. Our learning preference for one or the other maybe strong, moderate, or weak.

Based on various sources and concepts, we can categorize the following types of learners, as outlined in brief in chapter *2.10 Learning Preferences and Psychological Types* and detailed out hereafter with implications to each individual type:

- Visual learners:
  They remember content best when they see for instance pictures, diagrams, flow charts or video sequences.
- Aural learners:
  They gain more out of words and text in written.
- Verbal learners:
  They get most out of sound and spoken explanations.
- Social (active) learners:
  They tend to keep and understand information best by doing something active with it (for example: applying/discussing/ explaining. They tend to enjoy group work and workshops.
- Solitary (reflective) learners
  They prefer working alone (reflection).
- Physical (sensing) learners:
  They tend to like content such as facts and figures.
- Logical (intuitive) learners
  They often prefer to discover possibilities and inter-relationships.
- Sequential (systematic) learners:
  They have a tendency to gain understanding in linear steps (one step is logically following from the previous step).
- Global (random) learners:
  They tend to learn in bigger steps, randomly absorbing content with probably no obvious connections. But finally, they "get it".

The analysis of the respondents shows different shapes of the distribution of the specific degrees of preference for a Learning Style:

Preference of Learning Style	Result of self-assessment
Visual (question 1)	64% to moderate or high degree
Aural and (question 2)	26% to moderate or high degree
Verbal learners (question 3)	50% to moderate or high degree
Physical/sensing learners (question 4)	37% to moderate or high degree
Logical/intuitive learners (question 5)	69% to moderate or high degree
Active learners (question 6)	64% to moderate or high degree

Table 5 - Distribution of the specific Degrees
of Preferences for a Learning Style

Table 5 shows the self-assessment results of the distribution to the specific degrees of Learning Preferences and its percentage and illustrated graphically in Figure 23 below.

Please refer to the concept of Learning Preferences and Learning Styles of Felder and Soloman, 2000.

The questionnaire instructions with pre-formulated statements asked the participants to self-assess their preference for a Learning Style with multiple entries possible.

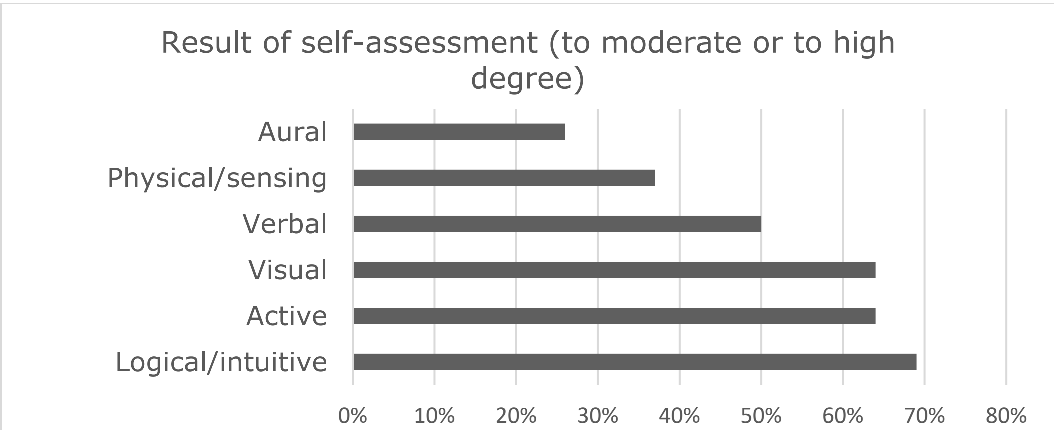


Figure 23 - Distribution of the specific Degrees
of Preferences for a Learning Style (Gantt Chart)

Importance of Social Interaction

Sharma's definition of Social Interaction in "*Fundamentals of sociology*" "*Social interaction is the reciprocal influence human beings exert on each other through inter stimulation and response*." (Sharma, 1996) apparently emphasizes two main conditions of Social Interaction:

Social Contact and Communication.

A Social Interaction is an exchange between two or more individuals and represents the backbone of social life.
In any way, a social interaction or social relation is the way people talk and act with each other and includes interactions in a team, or family and incorporates any relationship between two or more individuals. It is an important source of socialization and characterizes all different types of social relationships.

In our context of teaching & learning, that social interaction works via communication and is a necessity for social contacts. For the social contact, mental proximity is essential, not so much physical, and maybe direct (involve the presence of persons) or indirect (through any means of communication, such as telephone or TV).
Social Media refer to forms of mobile or stationary digital Social Networking platforms involving interactive (human) participation.
Social Media is the entirety of interactive online collaborative channels dedicated to input and shared content coming from the participating community.

Over the past years, various types of Social Networking and Social Media platforms replaced the very well-established one-to-one communication such as face-to-face conversation or telephone calls. The list of Social Networking and Social Media platforms is long and continuously expanding (compare with Greenhow, 2011):

- Facebook, WhatsApp, Instagram, Twitter, LinkedIn, Skype, Weibo, WeChat, Snapchat, Google+, YouTube, etc.

As already shown and proven, Social Media or Social Networking seem to be an obvious tool to communicate up to date in the context of a university environment, which represents a sub-group or distinct society with a specific intention.
The few existing rationales of Social Networking and Social Media to supplement Distance Learning include (Table 6):

Rationale	Description
Create a community	Social Media helps to centralize the knowledge of a specific class, which studies the same topic at the same time, and helps to increase the communicating efficiency (even with the involvement of a professor or teacher).
Continue the conversation	Social Media helps individuals to tap into a study group when classes have been missed or ask questions (addressed to experts).
Organize learning resources	Tools provided within Social Media networks help keeping course content organized and offer ease access to it.
Supplement course materials	Social Media helps identifying additional topic content to amend the initial instruction.

Table 6 – Rationales of Social Networking

Implications to and a proposal for a Distance Learning Transition Model

The quantitative data analysis of the questionnaire feedback allows to make the following statements (directly derived from the quantities of respective characteristic answers) that are also plotted in Figure 23:

- Social Networks are working in the same way with real friends (known in person) or unknown people.
- People are used to study for themselves.
- People like to study at home.
- People like using laptops/tablets or mobile phones to study.
- People are used to reading online sources and prefer video clips.
- People like to recap difficult topics with others.
- Online sources are used for a significant time of the day.
- The most prominent shapes of Learning Style Preferences are visual, logical, and active.

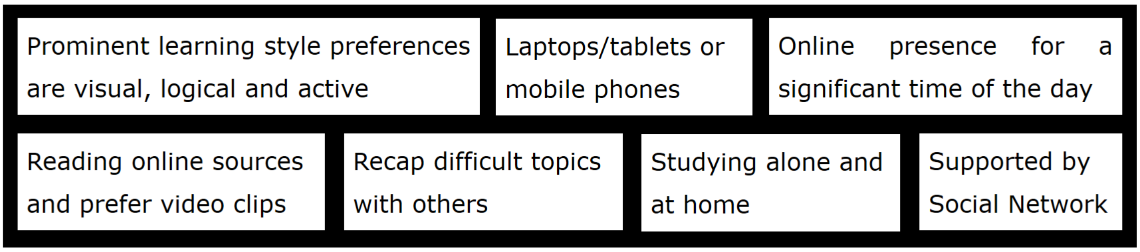


Figure 23 – Aspects of efficient and effective Distance Learning

This builds the foundation for the development and proposal of a new concept for efficient and effective Distance Learning courses in Engineering Education (see Figure 24).

This model of Ehrl *et al.* (2019) captures student needs and takes differences in Learning Preferences into account and considers the following aspects with Social Networking as novelty:

- A Social Network (within each study group) to enable learners to recap difficult topics with others.
- Learning formats have to be responsive to ensure the application via mobile devices and include visual content.
- The learning content should challenge the learners with logical context and should animate them to use other senses actively.

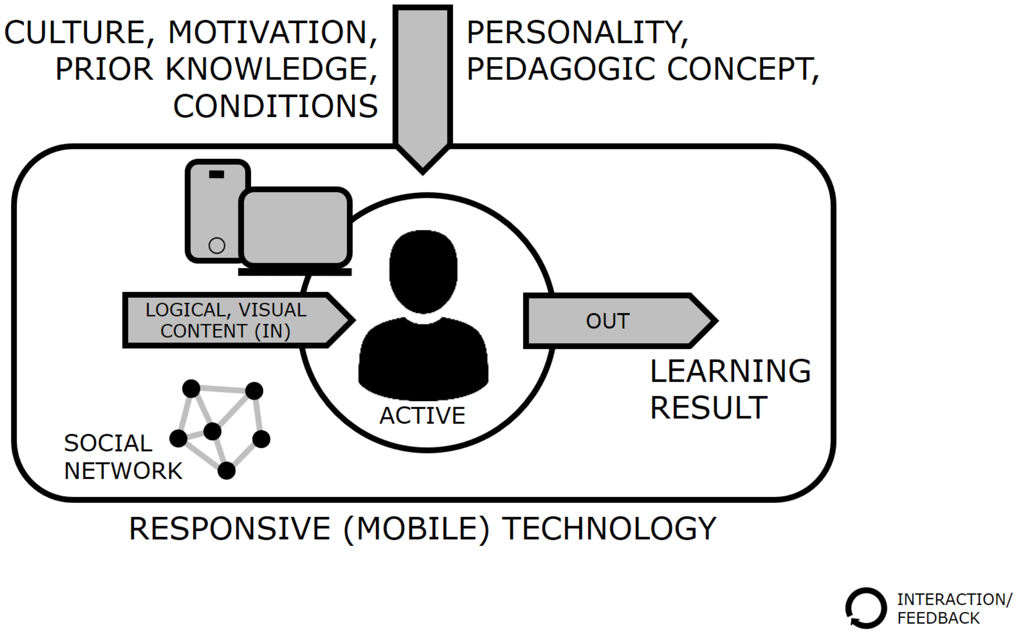


Figure 24 – New Model for Distance Learning

It is also used as input and influencing factor for the conclusive work and development of the novelty as described in chapter *5 Conclusions and Further Work* and already considers important facets of research conducted up to here.

Please refer to the appendix for all results of the research survey.

Key Findings IV

- Social Media can help students to create and maintain a study community to gain the most efficiency and effectiveness out of available study time and to find additional resources to supplement studying.
- There are no significant differences between geographical regions, although assumed initially.
- The number of "real" friends of a Social Network is different in Asia and Western cultures.
- Out of the six (for our Distance Learning context) most relevant Learning Style Preferences, the most common seem to be visual, logical, and active (cohort: mainly global student sample)
- People usually study at home. Therewith Social Networking and Social Media platforms seem to be a kind of window to the outside world.
- It is highly recommended to motivate Distance Learning students to initiate and maintain their own and topic specific communication channels via Social Networking and Social Media platforms.

<u>Interplay with the technical aspects (Machine Dynamics) of the research study:</u>

To overcome the examined hurdles of an isolated home study, the Social Network becomes an important factor when the subject of study is as complicated as it is with new technology around MULTI® and the application of Machine Dynamics topics.

…

Key Findings IV, continued

…
Completely new concepts of Vertical Transportation and new simulations and models can be discussed better and efficiently between Subject Matter Experts using Social Networking platforms. This is even more true, when we take the time-consuming involvement of Specialists of the Lift Industry into account.

4.3.4 Survey on Learning Preferences (#2)

The second subsection of the descriptive & causal-comparative research involved a cohort of 40 volunteers, all engineers from the Lift Industry and invited through the Northampton Lift Symposium, Peters Research Ltd. and LEIA (Lift and Escalator Industry Association) and ran between September 23rd, 2020 and October 31st, 2020.
That sample of 40 volunteers represents the target group of the research activities (engineering Specialists of the Lift Industry), which was tightened over the curse of research subsections.

The online survey with 23 open questions was structured into 3 sections

- Learning Preferences
- Learning Environment, Media, and Sources,
  Learning and Social Networking platforms
- General questions

and unveiled the specific Learning Preferences and Social Networking habits (similar to Norman *et al*., 2015) of engineering Specialists of the Lift Industry.

The qualitative data analysis of Hierarchy Charts (done with NVivo) gave a categorical answer and a very clear indication for the desired technical and framework concepts of a Distance Learning Environment of this cohort.

1. Preferred Learning Environment (of engineering Specialist of the Lift Industry):
   - Home Office or home (most often mentioned)
   - Quiet place (often called)
   - Desk (often called)
   - In comfort (often called)

   Reasoning: No disturbance. Comfortable. Familiar place.

2. Learning platforms (preferred by engineering Specialist of the Lift Industry):
   - YouTube (most often mentioned)
   - Google (often called)
   - University of company platform (often called)

   Reasoning: Easy access. Comprehensive.

3. Media (used by engineering Specialist of the Lift Industry):
   - Books and e-learning (most often mentioned)
   - Handwritten transcripts (often called)
   - Videos (often called)

   Reasoning: Convenient, easy access (electronic media). Used to it (paper and paper books). Ability to underline, comment, add (paper and paper books).

4. Social Networking or Social Media platforms (used by engineering Specialist of the Lift Industry):
   - WhatsApp (most often mentioned)
   - LinkedIn (often called)
   - Facebook (often called)

   Reasoning: Fast, easy access. Most common. Exchange.

The different Learning Preferences (of our user group: engineering Specialist of the Lift Industry) were diverse – as expected. However, learning using…

- Pictures, graphics and/or images are preferred by a majority of 75% (to a moderate degree & to a high degree) and even though by 53% to high degree.
  So, this is a Must-have in Distance Learning formats for our user group.

- Sound and music are preferred by a majority of 50% (to a moderate degree & to a high degree) but only by 15% to high degree.
  This is a Can-have in Distance Learning formats for our user group.

- Written elaborations, documents or text are preferred by a majority of 53% (to a moderate degree & to a high degree) and by 25% to high degree.
  Again: A Can-have in Distance Learning formats for our user group.

- Hands on an experiment or physical simulation are preferred by a majority of 68% (to a moderate degree & to a high degree) and to high degree even though by 28%.
  This is another Must-have in Distance Learning formats for our user group.

- Logic, reasoning and/or systems are preferred by a majority of 80% (to a moderate degree & to a high degree) and even though by 50% to high degree.
  Another Must-have in Distance Learning formats for our user group.

- 45% prefer to learn alone (to a moderate degree & to a high degree).
- 53% prefer to learn in a group of people (to a moderate degree & to a high degree).

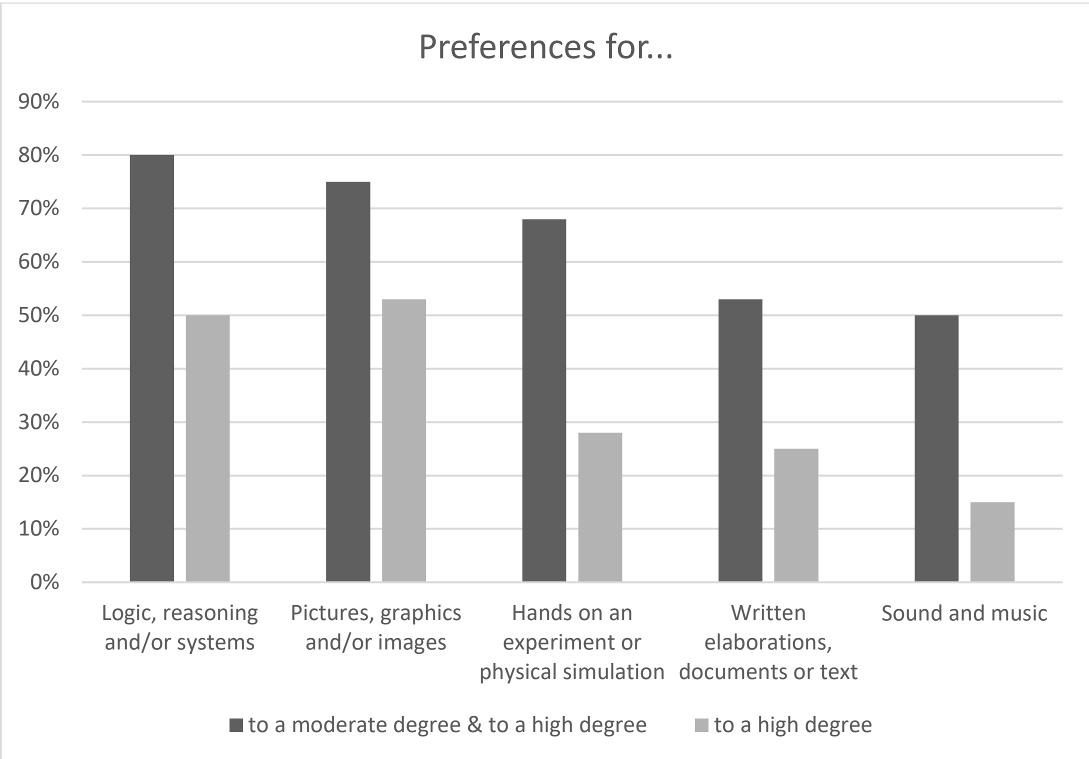


Figure 25 – Learning Preferences of assessed Cohort

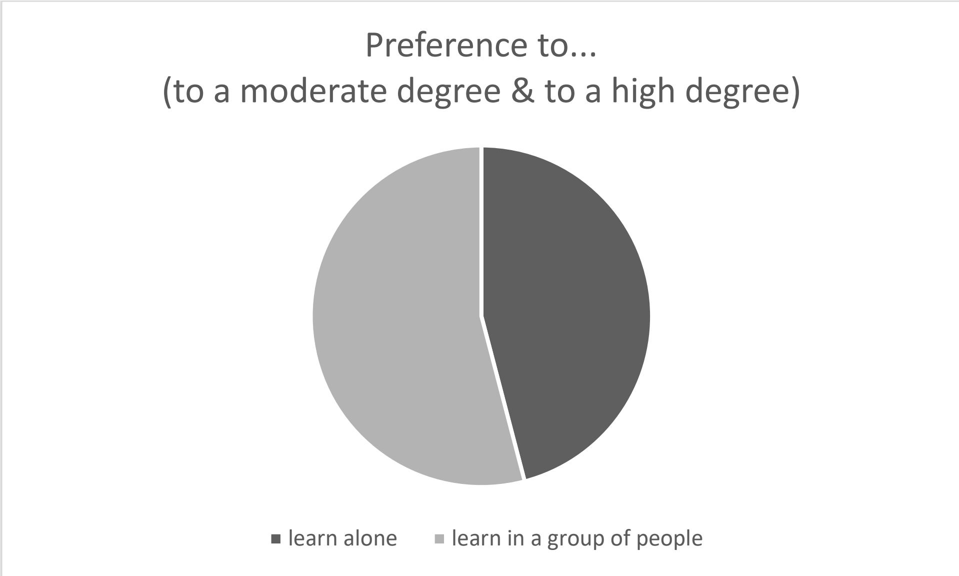


Figure 26 – Preference for Learning Surrounding

Figures 25 and 26 show that distribution by the means of a graphic, whereby Figure 25 uses the categories of Learning Preferences as described in *Chapter 2.10*.

The proportions over 50% (with a distinctness of moderate degree to high degree) express the significance of these preferences and therewith establish the essence for the consideration for future Learning Environments (for Lift Industry Specialists).

In regard to age, gender, profession, hierarchy level, part of the (Lift) industry, geographical region, our cohort represented the mean of the virtual population of a “multi-cultural/multi-discipline R&D environment”. And this answers the research question *How to transfer knowledge?* and corresponds to the research objective *to investigate the existing methods of Knowledge Transfer/delivery*.

Please refer to chapter *1.2 Aims and Objectives*.

Key Findings V

Most common Learning Styles (of Lift Engineering Specialists):

- Visual (Pictures, graphics and/or images)
- Physical (Hands on an experiment or physical simulation)
- Logical (Logic, reasoning and/or systems)

(Learning) preferences in regard to

- Environment: Quiet, comfortable and familiar place
- A Learning Networking Platform: It has to offer ease access and comprehensive content (e.g.: Youtube.com).
- Media: A.) Convenient, easy access (e-learning, videos).
  B.) Ability to underline, comment, add (books, papers, handwritten transcripts).
- A Social Networking platform must be common and speedy, offer ease access and allows to exchange information or data: (e.g.: WhatsApp, LinkedIn)

Suggestions for further actions:
The responses of this survey helped to structure the interview questions of Research Subsection #4 (The Interviews with Lift Industry Specialists).

4.3.5 Benchmarking of two Distance Study Approaches (#3)

Introduction

To gain a better understanding for the application of digital learning formats in a Distance Learning set-up, two short but completely different learning journeys were designed and rolled-out in November and December 2019.

In this case, the research aim was to evaluate differences of the learning experiences of both approaches.

The task picked for this research subsection is associated to the mathematical knowledge of first-order differential equations and therewith it represents an application that is directly related to the aims and objectives of the research study:

The basic mathematical skills (one standard reference source is Stroud and Booth, 2011) to be able to solve differential equations is fundamental for the understanding of problems and concepts in Machine Dynamics (study of system motion after the application of forces to the system). The ability to solving differential equations represent a sort of pre-requisite for Machine Dynamics science that enables engineers to amongst others compute natural or resonant frequencies, calculate positions, velocities and accelerations, or determine forces and moments in mechanical systems or machines.

For the realization of the project, the following software tools were used:

- edjet.com (free e-learning platform to host the e-learning)
- articulate.com/360/storyline (licensed software for creating interactive courses
- surveymonkey.com (free online cloud-based survey software)

Benchmarking Design

The benchmarking consists of the following components (please refer to Figure 27):

1. A standard Distance Learning approach, using an electronic copy of Programme 24 (frames 1 to 14) of the text book "*Engineering Mathematics*" (Stroud and Booth, 2011)

2. An e-learning, which is based on the information of the first standard Distance Learning approach. But this e-learning was designed to fulfill the following characteristics:

    - To guide the learner through the learning journey.
    - The learner should feel, that he is not alone.
    - To motivate the learner to engage with other learners.
    - Built with audio & visual elements.
    - Enablement for breakouts.
    - Has a certain fun factor.

3. Self-assessment of the learning journey

Figure 27 – e-learning vs. standard pdf Reading Task

Figure 27 highlights the differences between the two learning journeys. Journey one is a standard, anachronistic approach of a Distance Learning task using carbon copies or e-copies of book chapters, while journey two follow the approach of an e-learning application customized to the needs of the tested cohort.

The learning outcomes of the chapter on "*first-order differential equations*" were defined as:

- *"Recognize the order of a differential equation*
- *Appreciate that a differential equation of order n can be derived from a function containing n arbitrary constants*
- *Solve certain first-order equations by direct integration*
- *Solve certain first-order equations by separating the variables"*

The cohorts for this research were recruited globally from universities and institutes and from a lift manufacturer (voluntary participation), and represent a sub-group of the cohort of research subsection #1 (Survey with a global Engineering Sample):

- University of Stuttgart, Germany
- Georgia Institute of Technology; U.S.
- Technical University of Clausthal, Germany
- University of Texas at El Paso; U.S.
- Tongji University, P.R.C.
- TK Elevator

This cohort is obviously assembled of different characteristics, some of the volunteers may be Undergrads, some may be young engineers or experienced engineers, and some may even not related to the Lift Industry at all. This is not relevant for this specific subsection #3 for the following reasons:

- Participants have to have a solid knowledge about Higher Mathematics, in particular about Differential Equations (which is a topic that is learned in High School already).
- Participants do not necessarily have to have a lift engineering background, as the task can be understood without that precondition.
- Participants were given all necessary information upfront (of course in different learning formats), and they just needed to follow the instructions or read given information (out of a textbook).
- The research topic in this research subsection #3 (Two Learning Journeys) was independent from the assembly of the examined cohort: Find out the preferred learning journey for a simple mathematical learning item.

16 volunteers participated (anonymously) in the benchmarking and were split into 2 even groups, while both cohorts performed one respective learning journey.

The self-assessment was done immediately after each learning event using the online resource surveymonkey.com. This approach demonstrated a clear picture: The e-learning approach was favored by the test group and the control group.

The Assessment

The self-assessment based on a 1-to-5-star rating (one star means poor; five stars is excellent) showed an explicit result:

Item	Standard	e-learning
Confidence level about individual knowledge grasped	2.75	4.5
Opportunity to interact with other students	1.125	4.28
Feeling being isolated from other students	4.125	1.5
Enjoyment during learning journey	1.75	4.75
Design of the course material	1.125	4.75
Amount of multimedia and photography used in course material	1.0	4.625
Amount of audio used in course material	1.0	4.125
Number of opportunities for interactive learning	1.0	4.5
Preference to take the course as e-learning or as standard offline distance learning (study pdf files and books)	"online" named 7 times, "standard" named 1 time	"online" named 8 times

Table 7 – Results of the Star Rating Assessment

Table 7 summarizes the results of the star rating assessment of two different Distance Learning approaches: The anachronistic approach of a Distance Learning task using carbon copies or e-copies of book chapters vs. an e-learning application.

As shown in Figure 28 (graphical display of the results shown in Table 7), the view of the participants is clear and unambiguous. The expression towards the e-learning approach is obvious and clearly indicates the must-have for Distance Learning Environments.

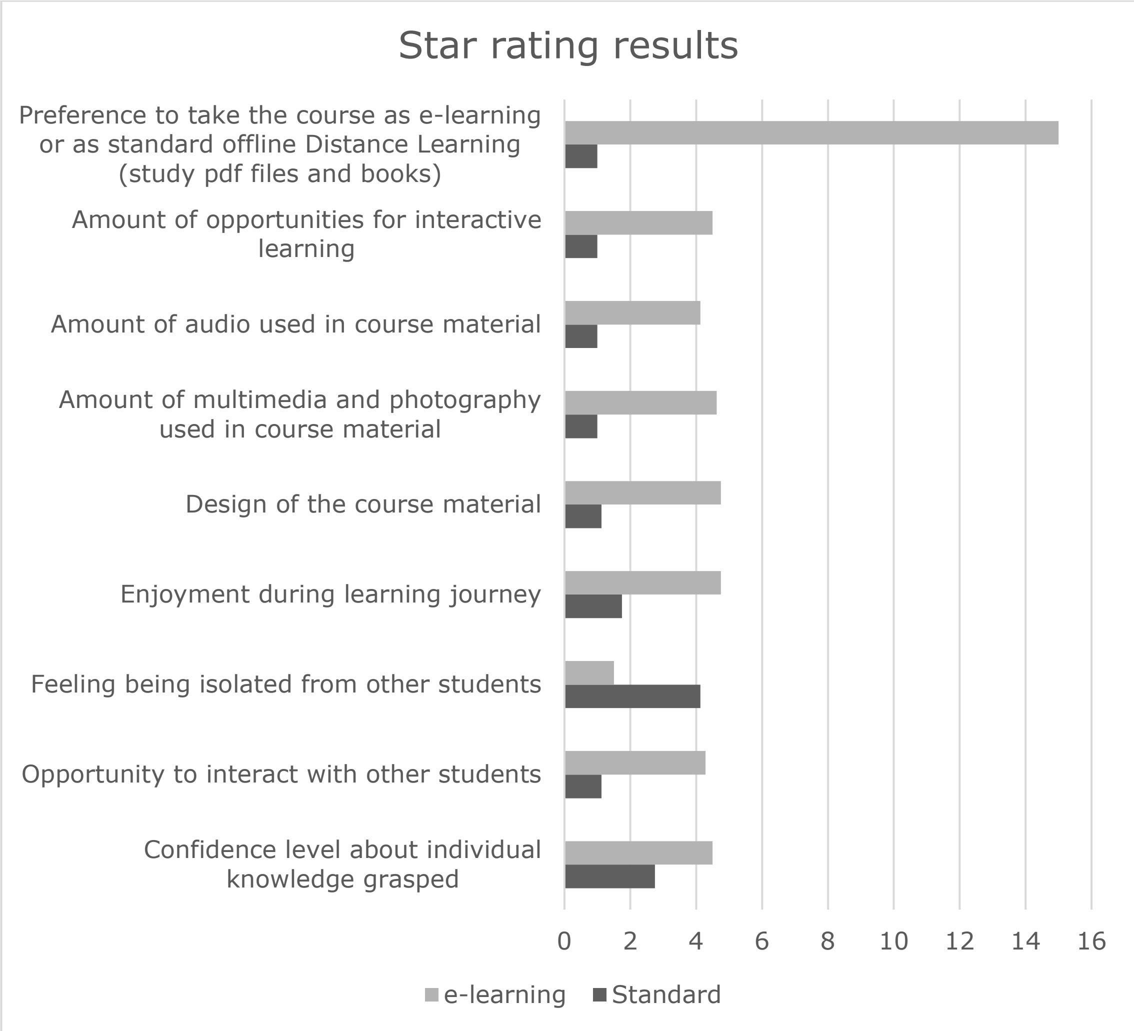


Figure 28 – Star Rating Results

The discussed star rating is an assessment that let customers rate a service or rank attributes on a scale represented with stars (please refer to Figure 29 for Example for Star Rating).

The number of stars can vary, but typically it is five stars. Generally, star rating is used when asking for a general opinion on something and can be found almost everywhere.

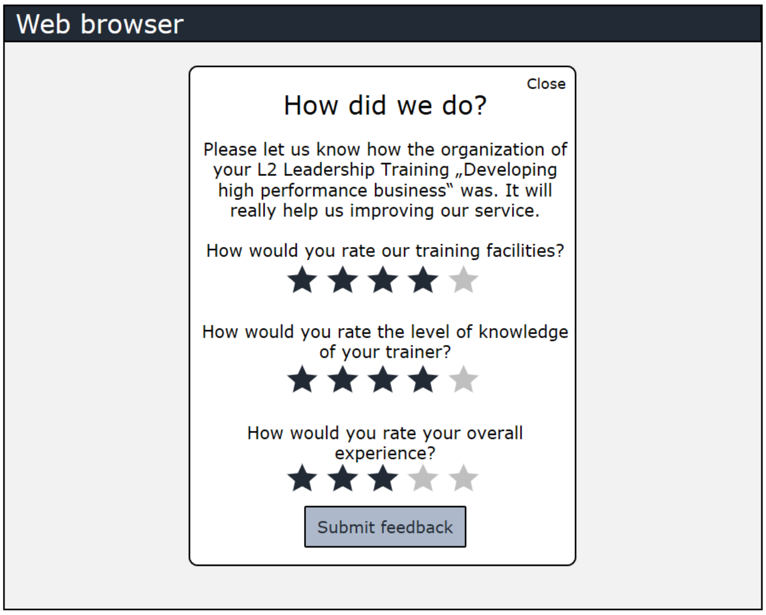


Figure 29 – Examples for Star Ratings

The common 5-star rating is a simple but limited tool, and it has its drawbacks.

It is more precise than a 3-star-rating, but all star ratings suffer from the lack of a negative measure. In that respect, even the very simple thumbs up or thumbs down system forces the customer to make a simple decision.

Also likelihood of skewed data is fairly high. Of all respondents, a significant majority will likely provide a positive rating, lacking competitive alternatives and therewith trying to back up their decision.

With only 16 responses, the results of our small poll are not statistically relevant, but they offer a basic indication, which is sufficient enough for our purpose.

These findings are in alignment with the work of Raja and Nagasubramani (2018) who describe the positive aspects of technology utilized in learning (please refer and compare to chapter 2*.13 Learning Environments and Learning Technology*).

Conclusion

e-learning (and online learning) is more than just a change to the application of technology in learning and teaching. With e-learning we rather redefine how we transmit knowledge and skills.
e-learning became already a sort of the default way to conduct training or to provide education in many areas, and in particular it represents a suitable form of education for Distance Learning populations, regardless of how remote the individual physical locations are.
The benchmarking indicates the success factors of effective digital (Distance Learning) design. To make e-learning successful, the following factors should be considered:

• Activity and relevance	Include tasks in which the learners participate.
• Scenarios	Provide memorable experiences.
• Interactivities	Learning by doing.
• Visuals and animation	Ensure a brilliant appearance of learning.
• Audio	Complement on-screen text.

Buzzetto-More brings it to the point, when she describes her book "*Advanced Principles of Effective e-Learning*" (2007): "*For educators and trainers alike e-learning has become a familiar part of our vernacular that has forever changed our constructs of the class-room, as networked multimedia has been able to extend and redefine the teaching and learning experience*."

The ordinary study clarified the supposition, that digital learning forms have considerable advantages over dated other forms of distance education. The comparison between the traditional reading assignment and the multi-variant e-learning was evident.

Key Findings VI

- To make e-learning successful, the following principles of effective digital (Distance Learning) design should be considered:
    - Activity and relevance
    - Scenario-based
    - Interactivity
    - Visuals and animation effects
    - Audio, to complement on-screen text
- The affordance for individual course-related study groups and group work helps to facilitate the university feeling and prevents learners to feel alone.

4.3.6 Learning Preferences and favored Learning Environment of engineering Specialist of the Lift Industry (#4)

<u>Introduction</u>

To close the loop of the individual research processes or subsections of the present comprehensive research study, a final descriptive & causal-comparative research subsection in form of eight phone interviews with engineering Specialist of the Lift Industry was conducted in early January 2021.

This time, the aim of the process subsection was, to gain understand how Specialists of the Lift Industry want to learn about new technology in a Distance Learning set-up.

According to an aligned Consent Form, the participation of those well-known Lift Industry Specialists was voluntary. All spoken words were recorded and further processed (transcribed) by using the Call Recorder[17] app on a mobile phone. At that time, all individual identification was removed from the hard copy of the transcript to ensure the participant's anonymity and confidentiality during the coding procedures in NVivo software.

Representing the average Lift Industry population pretty well, the eight industry representatives (four experienced lift consultants and four experienced industry representatives who are working for globally operating lift system suppliers) were located around the globe in China, Europe and North America.

<u>The Interviews and the Findings</u>

The findings of this research "*Learning Preferences of Specialists of the Lift Industry and improved Learning Acquisition through Assistance of Social Networking Platforms*" were presented at the 6th Annual International Conference on Engineering Education & Teaching in Athens, Greece in a similar form by Ehrl *et al*. (2021).

The interview questions were derived out of the findings of descriptive & causal-comparative research subsection 2 and structured in 2 parts:

1. Learning Preferences: 2 questions
2. Social Networking and Social Media/platforms: 2 questions

Please refer to *Appendix 4* for all four questions in detail.

The transcripts were coded in NVivo software, and the specific terms and inter-term relations in regard to Learning Preferences, Learning Formats and Learning Content, Social Networking and Social Media were apparent.

[17] Call Recorder – Mobile App developed by BPMobile

Subsequently NVivo software was used for the qualitative data analysis of the interview answers, which means "*for the interpretation of unstructured and semi-structured data*"
(Bazeley and Jackson, 2013)

Raw data in form of 32 answers of 8 interviewees related to 4 questions and the amount of 4058 words had to be processed. The analysis accordingly resulted in 69 codes and 179 references counted. 224 meaningful words with minimum 5 characters and word combinations (e.g.: live + webinar = live webinar) were highlighted after a frequency analysis run with NVivo.

Especially the cleaning of mispronunciation, software typos or filler words, and the analysis and interpretation of the raw data quantity was time-consuming and needed a special attention.
In addition to that, the cognition of appropriate words and meaningful combinations of two or more words to a sensible term was a full-scale task.

Figure 30 represents that process of data clean-up graphically.

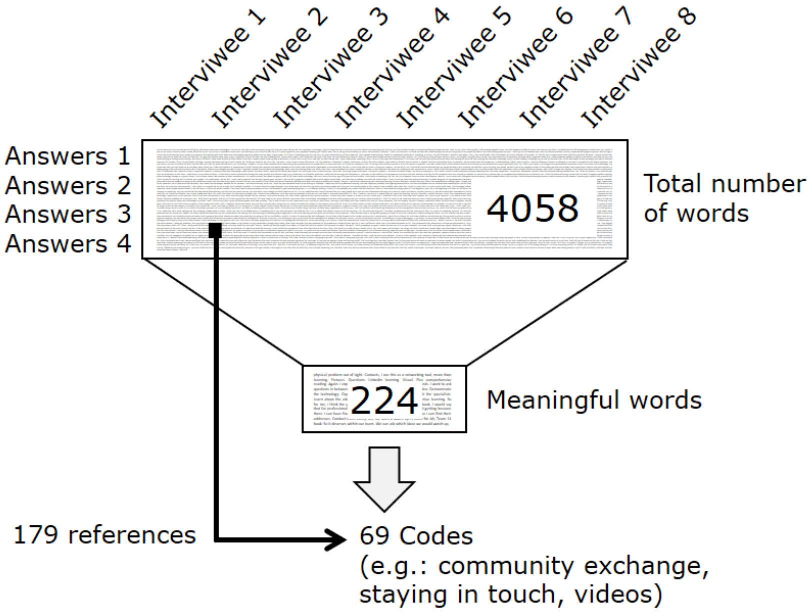


Figure 30 – From raw Data to sensible Data

Amongst others, the visualization functionality of the NVivo 12 software allows the graphical display of the frequency of terms mentioned in texts or answers (codes). These Hierarchy Charts visualize a hierarchy (of mentioned terms or words) in an aggregated way, helping to recognize patterns in the coded data[18].

Figures 31 to 34 show and visualize the markedness of the codes that were named according to the interview answers. Please refer to *Appendix 5b* for a better representation of the charts.

[18] In qualitative research, a code is a word or phrase that captures the essence of a set of data. It represents the analytical process of data categorization.

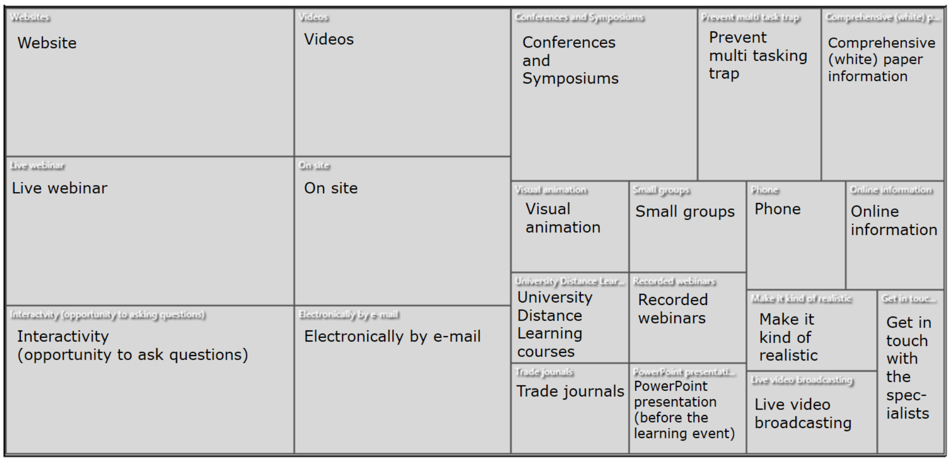


Figure 31 – Hierarchy Chart (coded answers to Question 1)

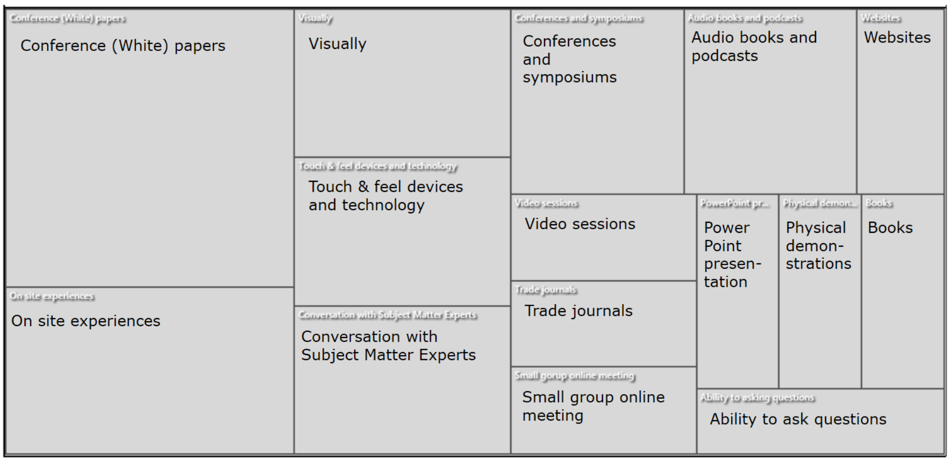


Figure 32 – Hierarchy Chart (coded answers to Question 2)

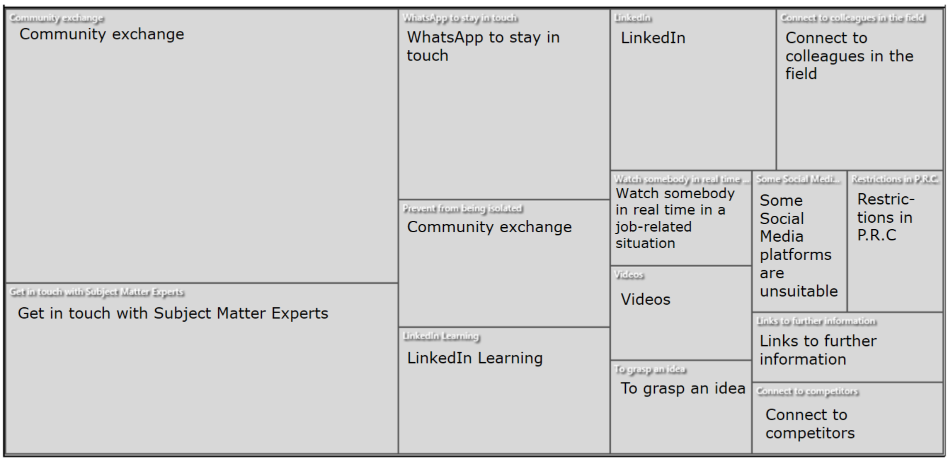


Figure 33 – Hierarchy Chart (coded answers to Question 3)

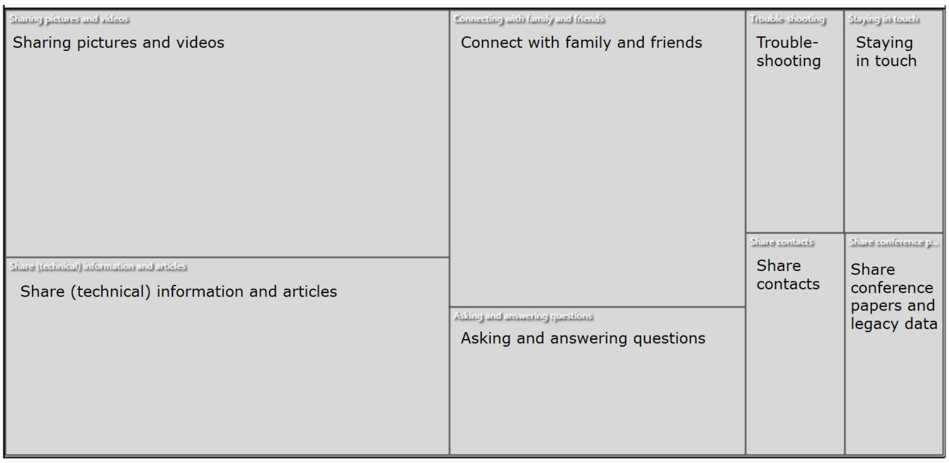


Figure 34 – Hierarchy Chart (coded answers to Question 4)

A subsequent detail analysis based on these results showed the following repertory of relevant words and terms, which were mentioned in varying frequency:

> Interactivity, Sharing, Pictures, Videos, Websites, PowerPoint, Phone, Websites, University Distance Learning Courses Contacts, Post, Trouble Shooting Information Links, WhatsApp, Videos, Visuals, Animations, Video Sessions, Live Demos, Live Webinar, LinkedIn, Small groups, Connecting, Family, Friends, Recorded Webinar, Community, LinkedIn Learning, e-mail, Audiobooks, Tweet, Podcasts, White Papers, Field, Facebook, Integrated, Trade Journals, Find people, Interactive, Conversation, Exchange, Subject Matter Experts, Specialists, On-site, Conferences, Symposiums, Meetings, Practical, Conference Papers, Trade Journals, Books, Sharing, Articles, Legacy Information, Paper copy, Benefits for the customer

These relevant words can be displayed in the Word Cloud[19] as shown in Figure 35.

Figure 35 – Word Cloud (Interviews)

This condensed but rich and comprehensive source of relevant data represents a great and valuable input for the research project. Here, we can read the initial unfiltered voice of the targeted user group, the cohort of international Lift Specialists. Each of the interviewees formulated the answers to the open questions and made statements with own words.
This source builds the grounding for respective aspects of the underlying concept and Distance Learning model.

Especially those notes about preferred media and content (videos, visuals, animations, video sessions, live demos, live webinars, etc.), preferred Social Network channels (WhatsApp, LinkedIn, Facebook) and personal preferences about the way these Specialists of the Lift Industry want to interact with the Learning Environment (interactivity, sharing,

[19] A Word Cloud is a collection of words depicted in different sizes and following the principle, that words appear bigger, the more often they are mentioned within a given text and therefore the more important they are.

posts, connecting, conversation, exchange, integrated, etc.) were very valuable. The cohort finally described in detail the circumstances they need for an effective & efficient Distance Learning Environment. This input is considered for the new *Learning Environment for Lift Industry Specialists* (please refer to Figure 36 at the end of this chapter).

<u>Analysis of Responds and Implications</u>

All interview questions were put into the context of Distance Learning. Anyhow, a couple of the respondents clearly indicated the need for face-to-face meetings, conferences and symposiums, and justified that in the following way:

- Necessity to touch & feel devices and technology on-site.
- Simpler opportunity for interaction with other Subject Matter Experts.

These facts need to be considered as they are an indicator for the Principles of Andragogy, which represents a fundamental basis of adult learning. This is further described in chapter *2.11 Learning Theories* of the Literature Review and was outlined by Knowles *et al*. (2005) and others.

Our group of interviewees mentioned the following terms most often (descending frequency) as answers to question 1.

The following quotes/answers were given to question 1 (In which format or mode would like to receive the information about new technologies and products (e.g.: application of linear motor technology, vibration control measures or lightweight composite materials)?).

An excerpt:

Interviewee 2: "*I want to learn online information. […] From websites, competitors. Supplier information.*"

Interviewee 3: "*…if it's remote learning, is with video explanation and the ability to be able to ask questions. You know, after you watch the video, I think PowerPoint presentations can also be very helpful. [] You want to be comfortable asking questions to make sure that you understand everything.*"

Interviewee 6: "*My preferred method is live webinar. Maybe, you know, someone who is physically giving a presentation and maybe there's a camera on them. So, I know my viewpoint is like, I'm sitting in the audience to make it kind of as realistic as possible. You know, maybe there's some videos included to kind of break up the presentation trying to get some visual. Some visual animation, so that I'm as close to the technology. You know how close you have hands on the other piece. Having that recorded and posted somewhere, that's easily able to be either downloaded or streamed after the fact is crucial to be able to revisit it to jog your memory*."

Condensed and in consideration of a Distance Learning scenario, the following learning formats were preferred:

- Interactive conversation with Subject Matter Experts (17%)
- Live or recorded webinar, broadcasting (14%)
- Videos or visual animation (14%)
- Video sessions and live demos (14%)
- Electronically by e-mail (8%)
- Audio books and podcasts (8%)

On this list, but mentioned distinctly less, are:

- Phone (3%)
- University Distance Learning courses (3%)
- Websites (2%)
- PowerPoint presentation, received before a meeting (2%)

When asked for their preferred sort of information (media) expected in a Distance Learning Environment and considering the individual Learning Preferences, the cohort fairly articulated the following media (answers to question 1):

- Conference Papers, White Papers, Trade Journals (such as Elevator World, Lift Journal, Lift Report magazine), Books (27%)
- PowerPoint presentation (mentioned distinctly less with 4%)

As for instance mentioned by Interviewee 7: "*Okay, that there's a number of ways I would like to receive that information, certainly from the individual making manufacturers. I'd like to receive it in an e-mail format. With an attachment. I'd also like to receive information through the trade journals such as Elevator World. Another good way I could think of receiving this information is, you know, at the Lift Symposium in lectures. I like the distance learning courses that Northampton runs*."

Interviewee 4: "*Video. White papers. Online sessions via video and the opportunity to ask questions and get in touch with the specialists. Learn about the advantages and benefits for the customer. Interactive learning*."

The specific question 2 (How do you prefer to learn respectively expand your subject matter knowledge about the topics mentioned above? Please consider your individual Learning Preferences.) was answered in the following way (extract):

Interviewee 2: "*All from the online website*."

Interviewee 3: "*You know, it was learning from an expert who had done ride quality measurements in person. I rode the elevator. I saw the PMT device and recorded the data. We took data, computer analyse the data that came out of the device. I have to do it myself at least one or two times in order to really get in order to really learn it. I wouldn't feel comfortable being told how to without having hands on something that hands on experience in order to really have it thinking. That's how I learned.*"

Interviewee 4: "*Visual. Plus comprehensive reading. Again. I expect video sessions. And a whitepaper afterwards. I want to ask questions in between*."

Interviewee 6: "*Okay, I think me personally, especially lately what I've been doing a lot of is audio. Either audio books, podcasts, a lot of different ways that I can listen to something, and you know, while I drive while I do other things. I think that has been my preferred method. Of course, if it's something that is the something more complicated or new technical information, I think maybe reviewing a PowerPoint presentation or video. I think that that can be helpful when it's something that's very technical with a lot of details. But if it is a subject that doesn't require visual learning than I do, like audio learning that it has been a preference of mine for learning.*"

Interviewee 7: "*But again, I think symposiums are good. Because its peer reviewed. You know, what you're getting is good information. I also like physical demonstrations of this kind of thing. Also, again I think peer reviewed stuff like Elevator World or the Trade Journals, those sorts of things, where we should be learning. I really do feel that the Lift Symposium is one of the best places*…"

Interviewee 8: "*Well, about right quality? It's very technical, perhaps a webinar with someone going over some more detailed theory and examples. That would be good, that would be the best start. Then intensely, some more papers or a webinar with someone explaining the topic. Or potential new tools or new solutions, then following from there would be some sort of self-reading. Papers*."

Asking for the most valued platforms for Social Networking and Social Media, the following two providers were nominated

- LinkedIn and LinkedIn Learning as Social Media respectively learning platform and
- WhatsApp as Social Networking platform to stay in touch with others

while the Lift Industry Specialists utilize these platforms for the following reasons (answers to question 3):

- Community exchange (29%)
- Get in touch with Subject Matter Experts (16%)
- Connection with family and friends (10%)
- Connection to colleagues in the field (6%)

They answered (after been asked question 3: How do you expect to learn with your Social Network, if Social Networking should support your learning journey?):

Interviewee 5: "*So for me, I think WhatsApp and LinkedIn or Facebook. I would say that for professional learning, the most important probably is LinkedIn, because there I can find people that are involved in something so I can find their addresses. Conduct them easily. And WhatsApp is more for team. So, it works within a team. We can ask, which ideas we would to follow-up...*"

Interviewee 6: "*Well, I think LinkedIn does a great job where people share best practices. They're able to share articles, experiences so on. And there's also LinkedIn Learning is very helpful with their modules that they do*."

Interviewee 7: "*Social Media is something I do. I do it because I have to rather than because I want to. I am in touch with colleagues from the industry with both Facebook and LinkedIn. And also, I do the distance learning courses at Leeds University at the moment. We had a group on Facebook where we all spoke to each other, and if we have a problem, we could talk to each other. Think it's not just about the technical learning. It's about being part of a group because distance learning and can be socially isolated. But I think of the benefit of Social Media use to stay touch with my peer group*."

After been asked question 4 (What kind of information do you typically exchange?), the following answers were recorded:

Interviewee 1: "*It's only high-level information. I do not trust too much the privacy of Social Networks. Not including the controller knowledge, which includes company knowledge on my side on the other side.*

So Social Networking for media exchange, creating awareness, getting in touch, maybe."

Interviewee 4: "*Contacts, I use this as a networking tool, more than learning. Pictures. Questions*."

Interviewee 5: "*I just share some short documents and links on a Social Network. These kinds of things. If you want to share quick information, you can and send pictures or link.*
Then on Facebook again, it's more for me. It's more like for friends and families, not so much professional networking."

Interviewee 6: "*Well, it depends. On LinkedIn I typically share things that are related to the company that I work for. So, I'd like to share articles and then show how it can relate to what we do, how we can help people. So that's what I use LinkedIn for, to share articles.*
Facebook and Instagram to a lesser degree, to share family information, mostly personal information in regard to family, kids, dogs and other events. WhatsApp is mostly just communicating with family, friends and colleagues. And WhatsApp is widely used for sharing some articles or pictures."

Interviewee 8: "*I would say I'm in the basics. Would be sending each other links, interesting articles or information about new products. Sometimes I'm looking for more information, more projects, related information, I might send sketches or project related data. To illustrate the problem, I have at hand*."

Being around on these platforms, they typically share (with 32% mentioned the most):

- Technical information
- Articles
- Conference papers
- Legacy information
- Pictures and videos (professional application as well as in private context)
- Videos or watch somebody in real time in a job-related situation

and (mentioned substantially less):

- Share trouble-shooting information (5%)
- Share contacts (5%)
- Links to further information (3%)

The primal statement and criterion for the usage of a Social Networking platform in the context of Distance Learning, and prominently commented over a reasonable share of the interviewed Lift Industry Specialists' sample (answer to question 3) was: 'To prevent being or feeling alone.'

Conclusion

With the completion of the fourth descriptive & causal-comparative research process subsections and the subsequent qualitative data analysis of the interview answers, the evidence of three aspects of Learning Environments for Distance Studies of (lift cabin vibration) Machine Dynamics content was proven:

1. The justified claim for interactivity (if not face-to-face, through Social Networking and Social Media platforms and the opportunity to interact with others).
2. Audio-visual learning formats supported by the suitable Education Technology, such as videos or visual animation, video sessions, live demos, live webinars, recorded webinars, other broadcasting, audio books or podcasts.
3. Suitable media content with conference papers, white papers, trade journals, books, audio books and podcasts.

Figure 36 (Key findings VII) puts that together graphically and adds further details.

Accordingly, improved knowledge acquisition for Lift Industry specialist is possible when Learning Preferences are considered (including the right choice of media) and a Social Network and right learning infrastructure support the learner.

Key Findings VII

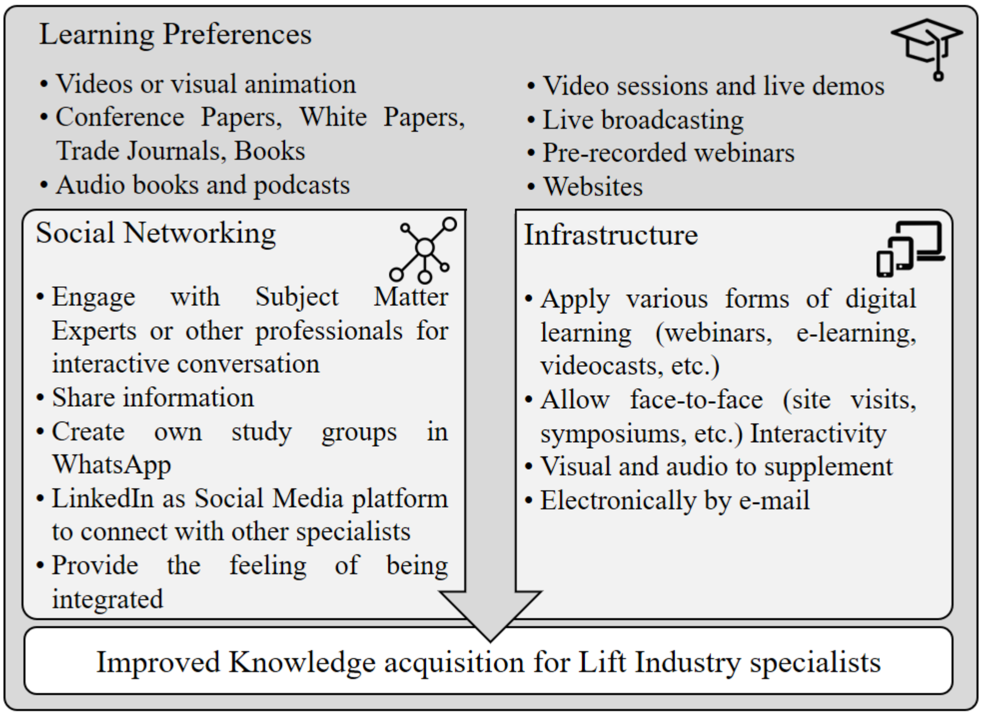


Figure 36 – Learning Environment for Lift Industry Specialists

This model describes the new Learning Environment in the following way:
The foundation for the model is at first the right selection of Learning Technology and media which take the Learning Preferences of the study group into consideration. As shown in Figure 36 above, the allowance of the factors are based on an up-to-date learning infrastructure and supporting Social Network helping to gain an improvement when it comes to the (Machine Dynamics) knowledge acquisition for Specialists of the Lift Industry.

This result is an evident and trend-setting indicator for the future concept work to set-up Distance Learning Environments for Lift Engineering Specialists.

4.4 Business Impact (Business Relevance)

Without a doubt, training organizations are eager to and should measure the business impact of their learning programs. There are certainly some challenges to overcome, as modern Learning Management Systems only offer standardized reports, which unfortunately do not measure an impact. Those reports rather show the following (inconclusive) metrics:

- Number of training registrations
- Training hours delivered
- Completion rates
- Feedback on the training and the trainer
- Assessment results
- Training investment in a given period of time

To measure the business specific impact of learning and furthermore training profitability, a detailed look to the missing link to relevant business metrics must be put into consideration. (Aragón-Sánchez *et al.*, 2003).

This means, the learning metric evaluation has to be combined with the specific business metric evaluation, as focusing on learning metrics alone is not sufficient enough. It is the monitoring of the combined types of data which enables a learning organization to determine the impact of training programs on a specific business.

This is of upmost interest for an organization such as the decentralized company TK Elevator, where quality and budgeting control is complex due to different regional responsibilities combined with a central governance function. When it comes to huge training and Knowledge Transfer investments, it is mandatory to understand the effects to the business. In the case of the Knowledge Transfer process as subject of this research project, there is a need to predefine relevant learning topics upfront to ensure that the right knowledge is being transferred.

How to measure business impact?

One approach to measure the effectiveness of training (training profitability) and the impact of learning on business are the 4 measurements stages Kirkpatrick and Kirkpatrick (2016) suggests in their model of training evaluation:

Level 1: Ascertaining the reaction of the learners

- Objective: Learners find the training relevant, engaging and easy to apply.
- Measurement: Through polls or surveys.

Level 2: Validate whether the training met the learning outcomes

- Objective: Determine whether learning actually happened.
- Measurement: Measured the scores of a summative assessment (feedback)

Level 3: Determine the intended change in the learner behavior

- Objective: Feedback to provide a validation of internalization of learning and the application on the job.
- Measurement: Measured through a poll learners and supervisors) after a certain period.

Level 4: Impact to Key Performance Indicators

- Objective: Determine whether the training created the required value for the business and impacted relevant Key Performance Indicators.
- Measurement: Tracking changes in business metrics that are directly linked to attributes of the training program.

Please refer to chapter *4.3.2 The Optimization of a Learning and Training Portfolio at a Multi-national Lift Manufacturer* for a detailed description of Kirkpatrick's model of training evaluation.

In an aggregated form, this process can be defined in the following way:

> Training leads to Human Resource outcome (skills, knowledge, capabilities, attitude and behavior) which leads to organizational performance.

An example which is specific to our research project is shown below:

Example

1.) Business impact on

1.1) Profitability / Productivity (of internal processes)

Key Performance Indicator:

- Labor hours per product

1.2) Effectiveness / Quality (of a product)

Key Performance Indicator:

- Product/Service quality
- Customer satisfaction
- Reduction of delivery time/completion of service

2.) HR measures

- Training hours taken
- Training cost
- Number of employees trained

Both categories 1.) and 2.) have to be measured and monitored together over time to be able to come to a significant statement of the intended impact to business.

4.5 Discussions and Analysis

The determination of key dynamic parameters and its interaction that influence Ride Quality of Passenger Transportation Systems is left aside in this chapter, as defined prior in chapter *4.1 Prelude*.

Introduction

The purpose of this descriptive & causal-comparative research study was to identify the influencing factors that improve engineering Knowledge Transfer in a Distance Learning set-up, leading to a new pedagogic concept model for engineers of the Lift Industry, and to improve the dynamic performance of vertical (rope-less) Passenger Transportation Systems with the integrated predecessor research study. This technological knowledge corresponds with the throughput of the reviewed Knowledge Transfer process.

This sub-chapter includes a discussion of major findings as related to the literature on Knowledge Transfer in multi-cultural/multi-discipline R&D environments, Learning Preferences, Instructional Design and Social Networking, and what implications may be valuable for use by learning organizations when creating new Distance Learning curricula or academy.

The sub-chapter concludes with a discussion of the limitations of the study and areas for future research.

The entire research thesis concludes with the summarizing and completing chapter *5 Conclusions and Further Work.*

Recap to the initial Research Question and Discussion

This section contains a discussion to help answering the focus research question *How to transfer knowledge in a lift engineering environment?* with these accompanying & associated research objectives of the research study:

- To investigate the existing methods of Knowledge Transfer/delivery. (How do people learn?)
- To develop an Academic Model for Knowledge Transfer which can be integrated into existing training concepts for lift engineers.

The influential factors to improve the engineering Knowledge Transfer in a Distance Learning Environment are multi-dimensional but can be comprised to the following 5 themes:

1.) Education Technology (Infrastructure):

The appropriate utilization of Education Technology nurtures successful learning by introducing engagement, activity, variety, collaboration, fun, diversity and interactive practice.

- It considers the right environment architecture using visuals animation effects and audio, to complement on-screen text.
- The limitless source of evolving Education Technology offers countless gimmicks to make learning successful. In our Distance Learning set-up, a learner, no matter age or experience level, can basically pick the piece of equipment and application which suits him the best.

2.) Business Relevance (Curriculum Strategy):

Scenario-based relevance of learning content and the coherences between Competency Model (Skills Matrix), Training Needs Analysis and

Training Evaluation represent are the essential pillars of a successful strategic learning curriculum.

- The uniqueness of individuals and hence the differences between learners - as emphasized by a Competency Model - has to be incorporated into the Training Needs Analysis. This applies to both, novices and experts, as the founding principle is the same.
- Without a doubt, the connection with the needs or requirements of the driving business application (in our research study context: Machine Dynamics of rope-less Passenger Transportation Systems) is the key to success. A consistent review helps to align and adjust that to ensure business relevance.
- As described in chapter *4.4 Business impact (Business Relevance)*, Key Performance Indicators of the learning organization (e.g.: training hours delivered) and of the business organization (e.g.: product quality) have to be connected and monitored at the same time, as they follow one another.

3.) Psychology of Learning (Instructional Strategy):

Pedagogy and Instructional Design suitable for the specific subject matter, learning situation and learner group is key.

The consideration of relevant Learning Style Preferences (recall: most common Learning Styles of Lift Engineering Specialists: visual, physical, logical) promises effectiveness.

- Although the range of individual Learning Preferences is vast, the examined engineering cohorts (novices and experts) unveil a smaller number of Learning Preferences. This fact may allow the hypothesis, that learners with an engineering background prefer specific ways to learn (Learning Preferences).

- The fundamental principles of Instructional Design must be taken into account to structure the learning framework and to respect learning processes.
- The relevancy of the topic is an important factor in teaching and learning and another a kind of pre-requisite for a successful learning process, as also described in chapter *4.3.1 Improvement of the Learning Environment at an international multi-cultural company through the assessment of relevant methodology and technology goals*. Adult students are eager to learn when they acknowledge the learning content as relevant for them. They need the practical connection to real life problems and topics.
- In regard to the five important factors to improve the engineering Knowledge Transfer in a Distance Learning Environment, this relevancy of topic is included behind the factor Psychology of Learning, and introduced as Principles of Andragogy in chapter *2.11 Learning Theories*.

4.) Social Component (Social Networking):

Taking a social and coaching functionality for the Learning Environment into account, a Social Network can help students to facilitate a university feeling (prevents learners to feel alone), and to create and maintain a study community to gain the most efficiency and effectiveness out of available study time and to find additional resources to supplement studying (relevancy for novices).

- The affordance for individual communication to peers and Subject Matter Experts seems to be specific for experts (of the Lift Industry).
- When the Social Component of Distance Learning is the object of investigation, the differences between novices and expert become obvious. While young professionals use their network to compensate the soleness of Distance Studies, the group of

Lift Industry Specialists uses their respective network to discuss specific issues or to fill a specific knowledge gap.

5.) The right use of media (sub-category beside Infrastructure that comes along functioning as direct user interface):

Used media needs to match the students' Learning Preferences, and has to be convenient, easy to access and offer the ability to underline, comment or add further information.

- While novices (please refer to research subsections #1, #2 and #3) prefer to benefit from video and pictures, it is the group of experts who gains most out of interaction and direct communication with peers and other Subject Matter Experts. The Lift Industry Specialists aim to get in touch with products and components.
- This is interesting and relevant, as this adds another dimension to the requirements of a pedagogic concept for Distance Learning and Knowledge Transfer.

Embedded into the exactly fitting overall business context, some factors relate primarily to the individual learner, some to the Learning Environment, and some are a combination of the successful relationship of both.

All of these factors help contribute to a Learning Environment where engineers of the Lift Industry are challenged and can gather the information and knowledge they need for a certain task.

Interpretation of the Findings

While their specific engineering profession, career specialties and experiences may include variations for each individual attendee of the four research subsections, each of the five common themes were somehow named prominent factors (in three polls and one interview series) for the success of a learning journey.

- Education Technology (Infrastructure)
- Business Relevance (Curriculum Strategy)
- Psychology of Learning (Instructional Strategy)
- Social Component (Social Networking)
- The right use of media

The outcome of the research project proved the importance of the balanced interaction of those factors for successful learning on one side and assembled those together for the first time in this clarity on the other side. This compilation of different points of view onto the process of Knowledge Transfer merge the extensive theories on Learning Theories, psychological types and Instructional Design with the growing basis of Learning Technology and the opportunities given by the utilization of Social Networks in a Learning Environment.

The research findings are a representative illustration of the substantial changes that can be observed in academic, professional education and other Learning Environments. Education Technology to enhance studying anytime and especially as online platform to support and ease learning becomes the normality, and the common learning venue is more and more replaced by the individual home of a student/learner.

Moreover, the impetus of the learner-centric approach of this new normal demands the holistic view as elaborated in this research study.
The factors as mentioned and outlined above are relevant modules and components for the most efficient & effective *Knowledge Transfer of Advanced Dynamics of Passenger Transportation Systems in Buildings for a Multi-cultural/Multi-discipline R&D Environment*.
Each of the above mentioned five influential dimensions of engineering Knowledge Transfer in a Distance Learning Environment have been examined very well with numerous fundamental research work.

The combined entirety and arrangement of principal dependencies are new and assembled to an ensemble that join different facets and success factors. This holistic perspective might establish a new standard for the assessment of Learning Environments and provides key aspects for of contemporary learning of the 21st century, and the results of the research study allow the immediate utilization in a variety of application areas.

5 CONCLUSIONS AND FURTHER WORK

This research study aimed to identify effective transfer strategies for advanced Machine Dynamics knowledge in an intricate environment. Based on a comprehensive Literature Review and the quantitative and qualitative analysis of responses to surveys and interview questions, it can be concluded that there are few important factors to consider when targeting for an efficient & effective Knowledge Transfer.
These factors are complementing each other, and this study puts them into a compelling perspective and a depending relationship. Combined with the radically new application of state-of-the-art technology for an innovative Passenger Transportation System, this research study addresses a specific novelty.

The initial research aim, to *improve the Knowledge Transfer set-up for a multi-cultural/multi-discipline R&D user group for learning issues around ride performance of TK Elevator's MULTI® system*, has been achieved with the development and solid underpinning of novel Academic Model for Knowledge Transfer. And in the process of the research work, the leading focus question of the study "*How to transfer knowledge?*" has been answered in a detailed way. The new Academic Model for Knowledge Transfer (of Machine Dynamics knowledge) defines an enhanced state-of-the-art transfer process, that is trimmed to the needs of the specific user group of Specialists of the Lift Industry.

The novel model of Knowledge Transfer, as the results of the research project, is confirmed by literature. Dann, who emphasized social interaction as premise for learning (2003) and Simpson (2018) who showed different ways to support learners in different learning scenarios and settings describe subareas of the new model. And even further, Antonova and Csepregi (2016) outlined a Knowledge Transfer model in an organizational context and describe the process of Knowledge Transfer as complex and influenced by cultural, social and personal

factors, which is simplified and made easier with the new Academic Model of Knowledge Transfer.
While Khalil and Elkhider (2016) investigated Learning Theories and Instructional Design models to improve the instructional component of learning, which represents a major area of one of the four essential components of the new model.

After the closer examination and associated research activities of subjacent subject areas, the results of this study suggest that there are four guiding factors related to a modern-day Distance Learning Environment to saturate the efficient & effective Knowledge Transfer in a complex professional setting of a multi-cultural/multi-discipline enterprise.

These four guiding factors of Knowledge Transfer for a multi-cultural/multi-discipline R&D environment are:

- Curriculum Strategy
  An effective learning management is aligned to the business and has the full leadership command to ensure business relevancy. It considers the relationship of trainings needs analysis, goals and evaluation.
  Those activities are accompanied by an associated marketing & communication measure.

- Instructional Strategy
  A suitable pedagogy and best-practice Instructional Design adjusted to the specific learners' group is the unalterable foundation for any learning set-up. The awareness for Learning Preferences completes that overarching strategy.
  The provision of effective digital design for Distance Learning including learning scenarios and appropriate media application is self-evident in this context.

- Social Networking (within the specific user group of Specialists of the Lift Industry)
  A Social Network and the responsible utilization of Social Media helps learners to gain most out of the virtual (Distance Learning) environment and to engage with individuals, student groups or other professionals and Subject Matter Experts.
  In addition to that, it can supplement teaching in a traditional classroom environment.

- Infrastructure (for successful cross-company learning)
  The meaningful selection of specific technologies of the entire range of Education Technology and the rational application of particular forms of digital learning help to achieve Knowledge Transfer success.
  It can also allow face-to-face communication and therewith support the Social Component of learning.

The *novel* presentation of Figure 37 combines these four factors and describes them in more detail for a successful Knowledge Transfer of Advanced Dynamics of Passenger Transportation Systems in buildings, referring to the research findings and statements accordingly.
The detail investigations of this research work included various topics which all pay onto the efficiency and effectiveness factor of Distance

Learning for specialist of the Lift Industry. These topics are categorized into four main areas for an improved overview and graphical depiction.
The respective components of this research work are built on each other and complement each other.
The Literature Review and the results of quantitative and qualitative data analyses identified the following topics being relevant for the new Academic Model for Distance Learning for a multi-cultural/multi-discipline R&D environment within the Lift Industry:
Learning content, Learning Theories, problem solving skills, knowledge and Knowledge Transfer process, adult learners as (learning) target group, Learning Preferences, index of Learning Style, psychological types, Instructional Design, Learning Environments, conditions of learning, Learning Technology, Social Networking, justification for training, organizational performance, and training curricula. These topics are subsumed and put into dependencies in the core finding of this research project: *The Set of Components of successful Knowledge Transfer.*

This proprietary model is a *novelty* by all means, and it was developed based on the finding of this research project and consists of 4 main factors which frame the fundamental process of the bespoken and examined Knowledge Transfer, represented by a straight-line input-output process with content as processed object. Please refer to *Appendix 7* for a better (larger) depiction.

The four main framing factors are Curriculum Strategy, Instructional Strategy, Social Networking, and Infrastructure, and they describe the starting points for a successful *Knowledge Transfer (of Advanced Dynamics of Passenger Transportation Systems)*:

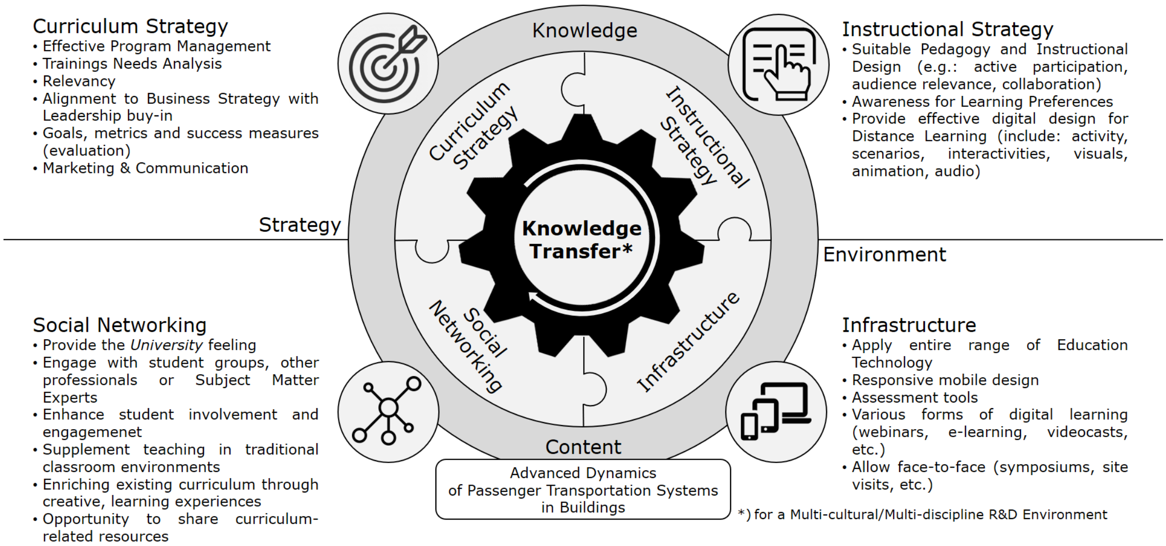


Figure 37 – A novel Set of Components
of successful Knowledge Transfer

Therein applied: Strategy as structured and conceptional input domain (upper half of the graphic). And the domain Infrastructure as supporting environment (bottom half).

If these factors are geared to each other, the presuppositions of a successful Knowledge Transfer are given and promise best results in terms of efficiency and effectiveness.

The balanced characteristics of these four mutual factors are linked to four principle aspects of a Learning Environment:

- Curriculum Strategy → Conceptional factor and alignment to the business
- Instructional Strategy → Conveyance factor
- Social Networking → Human factor
- Infrastructure → Environment and technology factor

and therewith represent the opportunities to influence that Knowledge Transfer process.
The conceptional factor Curriculum Strategy ensures that the training program has a relevancy to the business and impacts it finally. The alignment with a specific business strategy helps the leadership group to buy-in, which – on the other hand – is essential for the acceptance within an enterprise organization and foundation for necessary marketing activities.
Its effective program management is based on a solid training needs analysis and adds up to goals, metrics, and success measures for the evaluation of learning concepts and training measures.
The Instructional Strategy defines the suitable pedagogy and Instructional Design, and therein it takes different Learning Preferences into consideration. It forms the framework for effective digital design for Distance Learning including activities, scenarios, interactivities, visuals, animations, and audio media.

These two are embedded in an Infrastructure that ideally considers the entire range of Education Technology and allows for responsive mobile design. Various forms of digital learning (webinars, e-learning, video casts, etc.) supplement face-to-face events.

That Infrastructure represents the Learning Environment and supports the learner with Social Networking elements to provide a kind of university feeling. The network helps to engage with student groups, other professionals or Subject Matter Experts and enhances the student's involvement and engagement. That combination of Infrastructure and Social Networking has the power to enrich existing curricula through creative, learning experiences.

This orchestration of Learning Theories and Instructional Design theories for effective instruction was emphasized as well by Khalil and Elkhider in 2016.
They discussed the science of learning instructions and related Learning Theories. Their research work proves the evidence of the abovementioned four principal aspects of a Learning Environment and the effectiveness of the systematic approach in that compound, which is even more spanning, as it includes the component of Social Networking. That positive affect of Social Networking for a supportive and collaborative Learning Environment was evaluated by Hoffman (2009).
The specific positive attributes of Social Networking embedded into the learning context are increased learner engagement, increased learner motivation and increased personal interaction of learners.
When composed with tact, the four principal aspects of effective and efficient Distance Learning offer significant advantages, as the following points of view are considered consequently:

- Context of learning
- Learning Environment
- Pedagogical strategies
- Instructional Design
- Social Networking
- Supporting Learning Technology

Thus, this thesis has shown how a good Curriculum Strategy and Instructional Design Strategy combined with a suitable Learning Infrastructure and supported by a functioning Social Network can directly shape the results of the desired Knowledge Transfer of Advanced Dynamics.

With the insights into the latest applications of technology for Passenger Transportation Systems as throughput for an advanced and tailored Knowledge Transfer process for Specialists of the Lift Industry, the findings of this research can directly be used by the distributing organization and customers of the MULTI ® rope-less lift system.

Even further, the findings are already enhanced, processed and prepared in the way that they can find straight entry into adult engineering education in general, especially with a focus to the new normal, studying in distance. It was shown that contemporary learning is more than just the use of digital educational technology.

In conclusion, the practical advantage of the novel Knowledge Transfer model and approach may be a game changer for learning in the 21st century and can help to keep pace with the dynamic changes we face.

<u>Limitations and Further Work</u>

With the best of intentions, this research work investigated a quite small target group, when it came to a "multi-cultural/multi-discipline R&D environment" as user for enhanced Knowledge Transfer process. However, this limitation offers a huge potential for other sub-groups of engineering science, other than Specialists of the Lift Industry.

To verify the results once again, a field test with a test-specific Social Networking tool and a learning platform that runs with artificial

intelligence to proffer learning preference according to the current moment of study to a bigger group of professional engineers.
Designed with senseful data security for the cohorts, these two technical components would have probably given advanced research results.
When it came to the definition of learning topics for the advanced Knowledge Transfer process to verify its efficiency and effectiveness, another factor restricted the verification process. For confidentiality reasons, "real" product data and information was not supposed to be used within the research project; therefore, the research retrenched the scope to general mathematics.

In this study it was apparent that the investigated professional engineers acquire knowledge according to their current situation and available learning sources. For engineering Specialists of the Lift Industry, this often involves the use of internet sources and Social Networks. A study in this area could determine in detail how this information is received and further processed, and how effectively it is kept for further abstraction.
An area that deserves also further investigation is that of temporal change of learning preference, according to a life phase or according to a mood or mental state.

More credibility could be given to this study if other professions than engineering would be incorporated and checked against each other with another causal-comparative study approach.
A deep dive software application based on artificial intelligence, which recognizes different preferences of Learning Style of a specific learner along the learning journey and considers that input with respect to the subsequent content preparation, could be another study of larger scale with the potential to engage an industry partner or a university.

Another aspect to look into is, that existing research work relates to the current and actual assessment of a personal learning preference, which that specific person is likely not aware of. A long-term study, that comprises at least one generational change, would ascertain the personal adjustment of Learning Preferences. A demographic study to evaluate differences in Learning Style Preferences throughout certain stages of life or a career journey and the comparison of different professions, for instance STEM, Social Science and Science or Art would be beneficial. Candidates of different occupational categories and experience levels could answer survey and interview questions over a period of 5 to 10 year to determine if there are large shifts over time in Learning Style Preferences, the preference for certain media or Learning Technologies and the way they communicate with their professional Social Network.

REFERENCES

Abaidoo, N. and Arkorful, V. (2014) Adoption and effective integration of ICT in teaching and learning in higher institutions in Ghana. *International Journal of Education and Research.* **2**(12), pp.411-422.

Adams, J.P., Kaczmarczyk, S., Picton, P. and Demian, P. (2007) Improving problem solving and encouraging creativity in engineering undergraduates, development. *International Conference on Engineering Education ICEE 2007*, Coimbra/Portugal, 2007.

Adams, J.P, Kaczmarczyk, S., Picton, P., and Demian, P. (2010) Problem solving and creativity in engineering: conclusions of a three year project involving reusable learning objects and robots. *Engineering Education*. **5**(2), pp.4-17.

Adams, J.P. (2010) Improving Problem Solving Skills and Developing Creativity in First Year Engineering Undergraduates. PhD. University of Northampton.

Alalshaikh, S. (2015) Cultural impacts on distance learning, online learning styles, and design. *Quarterly Review of Distance Education*. **16**(3), pp.67-75.

Aldim, U.F. and Ulas, M. (2014) The Use of Social Media Elements in Distance Learning. *Journal of Teaching and Education*. **3**(2), pp.233-239.

Al-Kodmany, K. (2015) Tall buildings and elevators: A review of recent technological advances. *Buildings*. **5**(3), pp.1070-1104.

Anderson, L.W. and Krathwohl, D.R. (2001) *A Taxonomy for Learning, Teaching, and Assessing: A revision of Bloom's Taxonomy of Educational Objectives*. New York: Longman.

Andrew, J. and Kaczmarczyk, S. (2011) *Systems engineering of elevators.* Mobile/AL: Elevator World, Inc.

Antonova, A. and Csepregi, A. (2016). How to improve the knowledge transfer models and methods in living labs. *Yearbook of St. Kliment Ohridski University of Sofia, Faculty of Economics and Business Administration*. **14**, pp.5-16.

Aragón-Sánchez, A., Barba-Aragón, I. and Sanz Valle, R. (2003) Effect of training on business results. *International Journal of Human Resource Management*. **14**(6), pp.956-980

Argote, L., Ingram, P., Levine, J.M. and Moreland, R.L. (2000) Knowledge Transfer in Organizations: Learning from the Experience of Others. *Organizational behavior and human decision processes*. **82**(1), pp.1-8.

Arrasate, X., Kaczmarczyk, S., Almandoz, G., Abete, J.M. and Isasa, I. (2014) The modelling, simulation and experimental testing of the dynamic responses of an elevator system. *Mechanical Systems and Signal Processing*. **42**(1), pp.258-282.

Auvinen, M. (2015) Development paths of multi-car elevators. MSc. Aalto University of Espoo.

Balthazar, J.M., Gonçalves, P.B., Kaczmarczyk, S., Fenili, A., Silveira, M. and Navarro, I.H. (2015) *Dynamics and Control of Technical Systems (Applied Mechanics and Materials)*. Trans Tech Publications Inc.

Barney, G. (2003) Vertical transportation in tall buildings. *Elevator World*. **51**(5), pp.66-75.

Barney, G. and Butcher, K. (2015) *Transportation systems in buildings: CIBSE Guide D.* 5th ed. London: CIBSE.

Bazeley, P. and Jackson, K. (2013) *Qualitative data analysis with NVivo*. SAGE Publications Limited.

Bertel, J. and Pate, C. (2010) *Distance learning. Encyclopedia of cross-cultural school psychology*. 1st ed. Springer.

Bloom, B.S., Krathwohl, D.R. and Masia, B.B. (1984) *Bloom taxonomy of educational objectives*. Allyn and Bacon. Pearson Education.

Bourne, J., Harris, D. and Mayadas, F. (2005) Online engineering education: Learning anywhere, anytime. *Journal of Engineering Education*. **94**(1), pp.131-146.

Bransford, J.D., Brown, A.L. and Cocking R.R. (2000) *How people learn: Brain, mind, experience, and school: Expanded edition.* Washington D.C.: National Academies Press.

British Standards Institute (2012) *Measurement of ride quality. Lifts (elevators)*. BS ISO 18738-1. Milton Keynes: BSI.

Burns, P., O'Brian, C. and Wild, J. (2016) Improving vertical transportation design for a dense vertical urban environment. In: CTBUH Conference, Shenzhen/Guangzhou/Hong Kong, 2016

Buzzetto-More, N.A. (2007) *Advanced principles of effective e-learning*, Santa Rose, California: Informing Science.

Carayannis, E.G., Pirzadeh, A. and Popescu, D. (2011) *Institutional Learning and Knowledge Transfer Across Epistemic Communities*. New York: Springer Science & Business Media.

Chen, Y., Lou, H. and Luo, W. (2002) Distance Learning Technology Adoption: A Motivation Perspective. *Journal of Computer Information Systems.* **42**(2), pp.38-43.

Claxton, C.S. and Murrell, P.H. (1987) *Learning Styles: Implications for Improving Educational Practices*. Higher Education Report No. 4. Texas: ASHE-ERIC.

Coffield, F., Moseley, D., Hall, E. and Ecclestone, K. (2004) *Learning styles and pedagogy in post-16 learning: A systematic and critical review*. London: Learning and Skills Development Agency.

Cohen, L., Manion, L. and Morrison, K. (2000) *Research methods in education*. 8th ed. London: Routledge.

Cook, D.A. (2005) Reliability and Validity of Scores from the Index of Learning Styles. *Academic Medicine*. **80**(10), pp.97-101.

Council on Tall Buildings and Urban Habitat (2020) Tall building criteria*.* *CTBUH* [online]. Available from: https://www.ctbuh.org/resource/height [Accessed 10 March 2021].

Council on Tall Buildings and Urban Habitat (2021) Tallest buildings. *CTBUH database* [online]. Available from: https://www.skyscrapercenter.com/buildings [Accessed 19 October 2021].

Dann, R. (2003) *Promoting assessment as learning improving the learning process*. 1st ed. London: RoutledgeFalmer.

Dennen, V.P., Aubteen Darabi, A. and Smith, L.J. (2007) Instructor–Learner Interaction in Online Courses: The relative perceived importance of particular instructor actions on performance and satisfaction. *Distance Education*. **28**(1), pp.65-79.

Distanont, A., Haapasalo, H., Vaananen, M. and Lehto, J. (2012) The engagement between knowledge transfer and requirements engineering. *International Journal of Management, Knowledge and Learning*. **1**(2), pp.131-156.

Dochy, F., Gijbels, D., Segers, M. and van den Bossche, P. (2012) *Theories of learning for the workplace building blocks for training and professional development programmes*. Abingdon/Oxon: Routledge.

Doherty, B. (2017) *Tips for teaching adult students* [online]. Available from: https://www.facultyfocus.com/topic/articles/effective-teaching-strategies/ [Accessed 4 August 2021].

Donovan, M.S. and Bransford, J.D (2004) *How students learn: History, mathematics, and science in the classroom*. Washington D.C.: National Academies Press.

Doukanari, E., Ktoridou, D. and Epaminonda, E. (2020) Multidisciplinary and Multicultural Knowledge Transfer and Sharing in Higher Education Teamworking. In: *IEEE Global Engineering Education Conference (EDUCON): proceedings of a conference, Porto/Portugal, 2020.*

Driscoll, M.P. (2005) *Psychology of Learning for Instruction*. 2nd ed. Boston: Allyn & Bacon.

Ehrl, T., Smith, R. and Kaczmarczyk, S. (2015) Key dynamic parameters that influence Ride Quality of Passenger Transportation Systems. In: *5th Lift and Escalator Symposium, The University of Northampton, CIBSE Lifts Group, LEIA: proceedings of a conference, Northampton/UK, 2015.*

Ehrl, T., Adams, J.P., Kaczmarczyk, S. and Meier, B. (2017) Improvement of the Learning Environment at an international multicultural company through the assessment of relevant methodology and technology goals. In: *7th Lift and Escalator Symposium, The University of Northampton, CIBSE Lifts Group, LEIA: proceedings of a conference, Northampton/UK, 2017.*

Ehrl, T., Kaczmarczyk, S., Adams, J.P. and Meier, B. (2018) The Optimization of a Learning and Training Portfolio at a Multi-national Lift Manufacturer. In: *9th Lift and Escalator Symposium, The University of Northampton, CIBSE Lifts Group, LEIA: proceedings of a conference, Northampton/UK, 2018.*

Ehrl, T., Kaczmarczyk, S., Adams, J.P. and Meier, B. (2019) Impact of Learning Style Preferences and Social Media Use on the Environment of Distance Learning for Engineers in the Vertical Transportation Industry. In: *10th Lift and Escalator Symposium, The University of Northampton, CIBSE Lifts Group, LEIA: proceedings of a conference, Northampton/UK. 2019.*

Ehrl, T., Kaczmarczyk, S. and Adams, J.P. (2021) Learning Preferences of Specialists of the Lift Industry and improved Learning Acquisition through Assistance of Social Networking Platforms. In: *6th Annual*

International Conference on Engineering Education & Teaching, Athens Institute for Education and Research, Athens/Greece, 2021.

Elnaga, A. and Imran, A. (2013) The effect of training on employee performance. *European journal of Business and Management*. **5**(4), pp.137-147.

Emporis International (2020) Emporis Standards. *Emporis* [online]. Available from: https://www.emporis.com/building/standards [Accessed 19 October 2021].

Engeström, Y. (1999) Innovative learning in work teams: Analyzing cycles of knowledge creation in practice. In: Engeström, Y., Mietinnen, R., Punamäki, R.L. (eds.) *Perspectives on Activity Theory*. 1st ed. Cambridge: Cambridge University Press, pp.377-406.

Farnese, M.L., Barbieri, B., Chirumbolo, A. and Patriotta, G. (2019) Managing knowledge in organizations: A Nonaka's SECI model operationalization. *Frontiers in Psychology*. **10**(2730), pp.1-15.

Felder, R.M. (1996) Matters of style. *American Society of Engineering education ASEE prism*. **6**(4), pp.18-23.

Felder, R.M. and Brent, R. (2016) *Teaching and learning STEM: A practical guide*. 1st ed. San Francisco: John Wiley & Sons.

Felder, R.M. and Silverman, L.K. (1988) Learning and Teaching Styles in Engineering Education. *Engineering Education*. **78**(7), pp.674-681

Felder, R.M. and Soloman, B.A. (2000) *Learning styles and strategies*. Module 3: The Middle/Work Phase of Supervision, North Carolina State University, pp.1-4.

Fleming, N.D. & Mills, C. (1992) Not Another Inventory, Rather a Catalyst for Reflection. *To improve the academy*. **11**(1), pp.137–155.

Frey, R. (2007) *Helping Adults Learners Succeed: Tools for Two-Year Colleges*. Council for Adult and Experiential Learning. Chicago, Illinois.

Fry, H., Ketteridge, S. and Marshall, S. (2008) *A handbook for teaching and learning in higher education: Enhancing academic practice*. 3rd ed. New York: Routledge.

Gagné, R.M. (1965) *The conditions of learning*. 1st ed. New York: Holt, Rinehart and Winston.

Gagné, R.M. (1977) *The conditions of learning*. 3rd ed. New York: Holt, Rinehart and Winston.

Gieras, J.F., Piech, Z.J. and Tomczuk, B. (2018) *Linear Synchronous Motors* 2nd ed. Boca Raton: CRC Press.

Ginsberg, J. (2008) *Engineering dynamics*. 1st ed. Cambridge: Cambridge University Press.

Greenhow, C. (2011) Online social networks and learning. *On the Horizon*. **19**(1), pp.4-12.

Greenhow, C. and Robelia, B. (2009) Old communication, new literacies: Social network sites as social learning resources. *Journal of Computer-Mediated Communication*. **14**(4), pp.1130-1161.

Greenstein, L. M. (2012) *Assessing 21st century skills: A guide to evaluating mastery and authentic learning*. Corwin Press.

Greenwood, D.T. (2003) *Advanced Dynamics*. 1st ed. Cambridge: Cambridge University Press.

Gross, R. (2010) *Psychology: The Science of Mind and Behaviour*. 6th ed. United Kingdom: Hachette.

Hannafin, M., Land, S. and Oliver, K. (1999) Open Learning Environments: Foundations, methods, and models. In: Reigeluth, C.M. (editor) *Instructional-design theories and models: A new paradigm of instructional theory*. 2nd ed. London: Routledge, pp.115-140.

Hardin, C.J. (2008) Adult students in higher education: A portrait of transitions. *New directions for higher education*. **2008**(144), pp.49-57.

Herrera, I. and Kaczmarczyk, S. (2009) The assessment of vibration absorption capacity of elevator's passengers. J*ournal of Physics: Conference Series*. **181**(012081), pp.1-8.

Hlynka, D. and Jacobsen, M. (2009) What is educational technology, anyway? A commentary on the new AECT definition of the field. *Canadian Journal of Learning and Technology*. **35**(2)

Hoffman, E. (2009) Evaluating social networking tools for distance learning. In: *Proceedings of TCC Online Conference, Hawaii, 2009.* Hawaii: TCC.

Honey, P. and Mumford, A. (1986) *Using your learning styles*. 2nd ed. Maidenhead: Peter Honey Publications Ltd.

Howkins R. E. (2006) Elevator Ride Quality. In: *Elevcon Conference: proceedings of a conference, Helsinki/Finland, 2006.*

Hricko, M. (2008) Gagné's Nine Events of Instruction. In: Tomei, L.A. (editor) *Encyclopedia of Information Technology Curriculum Integration*. IGI Global, pp.353-356.

Hussain, I., Cakir, O. and Candeger, Ü. (2018) Social Media as a Learning Technology for University Students. *International Journal of Instruction*. **11**(2), pp.281-296.

Innovate UK (2020) Knowledge Transfer Partnerships. *Innovate UK* [online]. Available from: http://ktp.innovateuk.org/ [Accessed 19 October 2021].

Ionescu, A. and Dumitru, N.R. (2015) The role of innovation in creating the company's competitive advantage. *Ecoforum Journal*. **4**(1), pp.99-104.

Jackson, S.E. (1996) The consequences of diversity in multidisciplinary work teams. In: West, M.A. (editor) *Handbook of work group psychology*. John Wiley & Sons Ltd., pp.53-75.

Johnson, R.B. and Onwuegbuzie, A.J. (2004) Mixed methods research: A research paradigm whose time has come. *Educational Researcher*. **33**(7), pp.14-26.

Joy, S. and Kolb, D.A. (2009) Are there cultural differences in Learning Style? *International Journal of Intercultural Relations*. **33**(1), pp.69-85.

Kaczmarczyk, S. (2013) Vibration Problems in Lift and Escalator Systems: Analysis Techniques and Mitigation Strategies. In: *Proceedings of the 3rd Symposium on Lift and Escalator Technologies, Northampton/UK, 2013.*

Khadjooi, K., Rostami, K. and Ishaq, S. (2011) How to use Gagne's model of instructional design in teaching psychomotor skills. *Gastroenterology and Hepatology from bed to bench*. **4**(3), pp.116-119.

Khalil, M.K. and Elkhider, I.A. (2016) Applying learning theories and instructional design models for effective instruction. *Advances in Physiology Education*. **40**(2), pp.147-156.

Kinzie, M.B. (2005) Instructional design strategies for health behavior change. *Patient Education and Counseling*. **56**(1), pp.3-15.

Kirkpatrick, J.D. and Kirkpatrick, W.K. (2016) *Kirkpatrick's four levels of training evaluation*. Alexandria/USA: Association for Talent Development.

Knowles, M.S. (1970) *The modern principle of adult education: Andragogy versus pedagogy*. New York: Cambridge Books.

Knowles, M.S., Holton, E. and Swanson, R. (2005) *The adult learner: The definitive classic in adult education and human resource developmen*t. 6th ed. Amsterdam, Oxford: Elsevier.

Kolb, D.A. (2014) *Experiential Learning: Experience as the Source of Learning and Development*. 2nd ed. Upper Saddle River/USA: Pearson.

Kruse, K. (2010) Gagné's Nine Events of Instruction: An introduction. *e-learningguru.com* [online]. Available from:

http://www.kvccdocs.com/teaching-online/teaching-online/nine-events.pdf [Accessed 19 October 2021].

Kukulska-Hulme, A. and Traxler, J. (2005) *Mobile Learning: A handbook for educators and trainers*. London: Routledge.

Kurzman, P.A. (2013) The Evolution of Distance Learning and Online Education. *Journal of Teaching in Social Work*. **33**(4/5), pp.331-338.

Lave, J. and Wenger, E. (1991) *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

Lemos, N.A. (2018) *Analytical Mechanics*. Cambridge: Cambridge University Press.

Lian, A. (2000) Knowledge Transfer and Technology in Education: Toward a complete Learning Environment. *Journal of Educational Technology & Society*. **3**(3), pp.13-26.

Löser, F., Appunn, R., Frantzheld, J. and Jetter, M. (2018). MULTI®-rope-less elevator demonstrator at test tower Rottweil. *Transportation Systems and Technology.* **4**(3), pp.80-89.

Lorsbach, G.P. (2010) Analysis of elevator ride quality and vibration. *Elevator world*. **51**(6), pp.154-162.

Masadeh, M. (2012) Training, education, development and learning: what is the difference? *European Scientific Journal*. **8**(10), pp.62-68.

Merrill, M.D. (2002) First principles of instruction. *Educational Technology Research and Development*. **50**(3), pp.43-59.

Missler, J., Ehrl, T., Meier, B., Kaczmarczyk, S. and Sawodny, O. (2016) Modelling of a rope-free passenger transportation system for active cabin vibration damping. In: *6th Lift and Escalator Symposium, The University of Northampton, CIBSE Lifts Group, LEIA: proceedings of a conference, Northampton/UK, 2016.*

Missler, J., Ehrl, T., Meier, B., Kaczmarczyk, S. and Sawodny, O. (2017) Control of actuators for cabin vibration damping of a rope-free passenger transportation system. In: *7th Lift and Escalator Symposium, The University of Northampton, CIBSE Lifts Group, LEIA: proceedings of a conference, Northampton/UK, 2017.*

Nai, K., Forsythe, W. and RM Goodall, R.M. (1994) Vibration reduction techniques for high speed passenger elevators. In: *International Conference on Control and Applications: proceedings of a conference, Glasgow/Scotland, 1994.*

Newton, P.M. (2015) The learning styles myth is thriving in higher education. *Frontiers in Psychology*. **6**(1908), pp.1-5.

Nonaka, I. and Toyama, R. (2003) The knowledge-creating theory revisited: knowledge creation as a synthesizing process. *Knowledge Management Research & Practice*. **1**(1), pp.95-110.

Norman, H., Nordin, N., Din, R., Ally, M. and Dogan, H. (2015) Exploring the roles of social participation in mobile social media learning: A social network analysis. *International Review of Research in Open and Distributed Learning*. **16**(4), pp.205-224.

Pelletier, S.G. (2010) Success for adult students. *Public Purpose*. **12**, pp.2-6.

Pierucci, M. and Frederick, M. (2008) Ride quality and noise in high speed elevators. *Journal of the Acoustical Society of America*. **123**(5), pp.3247-3247.

Raja, R. and Nagasubramani, P.C. (2018) Impact of modern technology in education. *Journal of Applied and Advanced Research*. **3**(1), pp.33-35.

Rao, S.S. (2005) *Mechanical Vibrations*. 4th ed. Upper Saddle River: Pearson Education, Inc.

Reigeluth, C.M. (1983) *Instructional-design theories and models: An overview of their current status*. London: Lawrence Erlbaum Associates

Reigeluth, C.M. (2013) *Instructional-design theories and models: A new paradigm of instructional theory*. New York: Routledge.

Reiser, R.A. and Dempsey, J.V. (2012) *Trends and issues in Instructional Design and Technology*. Boston: Pearson.

Richey, R. (2011) *The instructional design knowledge base: Theory, Research and Practice*. New York: Routledge

Ritchie, H. and Roser, M. (2018) Urbanization. *Our world in data* [online]. Available from: https://ourworldindata.org/urbanization?source=content_type%3Areact%7Cfirst_level_url%3Aarticle%7Csection%3Amain_content%7Cbutton%3Abody_link [Accessed 28 December 2020].

Rogowsky, B.A., Calhoun, B.M. and Tallal, P. (2015) Matching learning style to instructional method: Effects on comprehension. *Journal of Educational Psychology*. **107**(1), pp.64-78.

Sakita, M. (2008) *Elevator system with multiple cars in the same hoistway*. United States Patent. Patent No. US 7,357,226 B2

Sánchez Crespo, R., Kaczmarczyk, S., Picton, P., Su, H. and Jetter, M. (2018) Modelling and Simulation of a high-rise elevator system to predict the dynamic interactions between its components. *International Journal of Mechanical Sciences*. **137**(2018), pp.24-45.

Selwyn, N. (2012) Social Media in Higher Education. *The Europa World of Learning*. **1**(3), pp.1-10.

Senaratne, S. and Amaratunga, R. (2008) A knowledge transfer perspective on research and teaching in higher education. In: *CIB International Conference on Building Education and Research: proceedings of a conference, Sri Lanka, 2008.*

Scott A. (January 2016). Are we ready for the ropeless lift? *CIBSE JOURNAL* [online]. Available from: http://www.cibsejournal.com/technical/engineers-cut-lose-as-ropeless-lifts-enter-space-race/ [Accessed 19 January 2020].

Sharma, R.K. (1996) *Fundamentals of Sociology*. New Delhi: Atlantic Publishers & Distributors.

Sherry, L. (1995) Issues in distance learning. *International Journal of Educational Telecommunications*. **1**(4), pp.337-365.

Siikonen, M.-L., Sorsa, J. and Alasentie, P. (2018) *Managing elevator cars in a multi-car elevator shaft system*. United States Patent Application. Patent Application No. 16/268.08

Simpson, O. (2018) *Supporting Students in online, open and distance learning*. 2nd ed. Oxon: RoutledgeFalmer.

Singh, N., Kaczmarczyk, S. and Ehrl, T. (2017) An analysis of airflow effects in lift systems". In: *7th Lift and Escalator Symposium, The University of Northampton, CIBSE Lifts Group, LEIA: proceedings of a conference, Northampton/UK, 2017.*

Smith, R. (2006) Achieving Good Ride Quality. In: *Symposium on the Mechanics of Slender Structures. The University of Northampton: proceedings of a conference, Northampton/UK, 2006.*

So, A. and Chan, W. (2019) Further study of linear PMSM driven rope-less lifts with consideration of imperfections by simulation. *Building Services Engineering Research & Technology*. **40**(6), pp.682-697.

Sönmez, A. (2013) *Multinational Companies, Knowledge and Technology Transfer*. Heidelberg: Springer International Publishing.

Stice, J.E. (1987) Using Kolb's Learning Cycle to Improve Student Learning. *Engineering Education*. **77**(5), pp.291-296.

Strakosch, G.R. (2010) *Vertical Transportation Handbook*. 4th ed. Hoboken: John Wiley & Sons.

Stroud, K.A. and Booth, D.J. (2011) *Advanced Engineering Mathematics*. 5th ed. Basingstoke: Palgrave Macmillan

Szulanski, G. (2000) The process of knowledge transfer: A diachronic analysis of stickiness. *Organizational behavior and human decision processes*. **82**(1), pp.9-27.

Tam, M. (2000) Constructivism, Instructional Design, and Technology: Implications for Transforming Distance Learning. *Journal of Educational Technology & Society*. **3**(2), pp.50-60.

Taylor, L. (2004) *Educational theories and instructional design models. Their place in simulation*. Nursing Education and Research, Southern Health.

Technical University Delft (2020) Advanced Dynamics. *TU Delft* [online]. Available from: https://online-learning.tudelft.nl/courses/advanced-dynamics/ [Accessed 18 September 2020].

Tedeschi, L.O. (2006) Assessment of the adequacy of mathematical models. *Agricultural Systems***. 89**(2/3), pp.225-247.

Terrell, S.R. (2012) Mixed-Methods Research Methodologies. *The Qualitative Report*. **17**(1), pp.254-280.

Terrell, S. R. and Dringus, L. (2000) An investigation of the effect of learning style on student success in an online learning environment. *Journal of Educational Technology Systems*. **28**(3), pp.231-238.

Terumichi, Y., Kaczmarczyk, S., Turner, S., Yoshizawa, M. and Ostachowicz, W.M. (2003) Modelling, simulation and analysis techniques in the prediction of non-stationary vibration response of hoist ropes in lift systems. *Materials Science Forum.* **440–441**, pp.497-504.

thyssenkrupp Elevator AG (2019) MULTI® - A new era of urban mobility. *thyssenkrupp Elevator AG* [online]. Available from: https://multi.thyssenkrupp-elevator.com/ [Accessed 19 January 2020].

Tomek, S. (2011) Developing a multicultural, cross-generational, and multidisciplinary team: An introduction for civil engineers. *Leadership and Management in Engineering*. **11**(2), pp.191-196.

Török, J.S. (1999) *Analytical Mechanics: With an Introduction to Dynamical Systems*. New York: John Wiley & Sons.

Webster, J. and Hackley, P. (1997) Teaching effectiveness in technology-mediated distance learning. *Academy of Management Journal*. **40**(6), pp.1282-1309.

Wentworth, N., Graham, C.R. and Tripp, T. (2008) Development of Teaching and Technology Integration. *Focus on Pedagogy*. **25**(1/2), pp.64-80.

Wilke, J.D. (2006). The importance of employee training. *Jacksonville Business Journal*. **9**(1).

Woo, W.H. (2016) Using Gagné's instructional model in phlebotomy education. Advances in Medical Education and Practice. **7**, pp.511-516.

Zhou, M. and Brown, D. (2015) *Educational Learning Theories*. 2nd ed. Education Open Textbooks.

APPENDICIES

Appendix 1a: Questionnaire 1 (#1)

1. Based on your own assessment, how do you learn best?
Please read through the listed descriptions and pick the one, which describes your learning preference best.

1.1 I am a visual learner. (Example: I prefer using pictures, images and/or spacial understanding.)
Possible answers: Not at all, To little degree, To some degree, To moderate degree, To high degree.

1.2 I am an aural learner. (Example: I prefer using sound and music.)
Possible answers: Not at all, To little degree, To some degree, To moderate degree, To high degree.

1.3 I am a verbal learner. (Example: I prefer using words, both in speech and/or writing.)
Possible answers: Not at all, To little degree, To some degree, To moderate degree, To high degree.

1.4 I am a physical learner. (Example: I prefer using my body, hands and/or sense of touch.)
Possible answers: Not at all, To little degree, To some degree, To moderate degree, To high degree.

1.5 I am a logical learner. (Example: I prefer using logic, reasoning and/or systems.)
Possible answers: Not at all, To little degree, To some degree, To moderate degree, To high degree.

1.6 I am a solitary learner. (Example: I prefer to work alone and use self-study.)
Possible answers: Not at all, To little degree, To some degree, To moderate degree, To high degree.

1.7 I am a social learner. (Example: I prefer to learn in groups or with other people.)
Possible answers: Not at all, To little degree, To some degree, To moderate degree, To high degree.

2. Your individual usage of online Social Networking, Internet & Media

Please read through the listed descriptions and pick the one, which describes you best. Check all that apply.

2.1 In a normal week, how likely do you use Social Networking websites (such as Google+, Facebook, LinkedIn, MySpace, Bebo, Twitter, WhatsApp or others)
Possible answers: Extremely likely, Very likely, Moderately likely, Slightly likely, Not at all.

2.2 In a normal week, how much time do you spend using Social Networking websites per day?
Possible answers: 0-1, 1-2, 2-3, 3-4, more than 4.

2.3 How many of your Social Network "friends" have you met in person?
Possible answers: All of them, Most of them, About half of them, A few of them, None of them.

2.4 Which of the following devices do you use to connect to the internet?

Possible answers: Laptop, desktop, tablet, smart phone

2.5 Where are you mostly, when you use the internet to access online learning sources for your studies?
Possible answers: Outside, Home, Café or friend’s home, Library, At work, Other

2.6 How many hours do you spend online on a normal day?
Possible answers: 0-1, 1-2, 2-3, 3-4, more than 4.

2.7 For your study or learning activities: Which online media or sources do you work with?
Possible answers: Digital research academic articles or eBooks, Take online academic classes, eLearning, Videos, Printed books or print media, None of them.

3. Your preferred Learning Environment

3.1 How do you learn best in a classroom?
Possible answers:
When I can actively bring in my ideas or when I present something.
When I just listen and make notes.

3.2 You learned a longer time for a specific exam and today you made it through. What would you do thereafter to reward yourself?
Possible answers:
You enjoy the silence at home on your sofa.
You meet friends that you have not met for a longer time.

3.3 When I have to understand something, it helps me to …
Possible answers:
… talk to someone.

… think about it by myself.

3.4 Imagine a situation in which you can choose, whether you do your oral exam in a group or individually.

Possible answers:

You prefer an individual exam, because you want to be in the centre of an event.

You choose the group exam, because you don’t like to be in the centre of attention.

4. General information

4.1 How old are you?

Possible answers: 20-29, 30-39, 40-49, 50 and above. Prefer not to say.

4.2 What is your gender?

Possible answers: Female, male, diverse. Prefer not to say.

4.3 What is your technical profession?

Possible answers: Mechanical, Electrical, Software, other

4.4 In which geographical region do you live?

Possible answers: Europe, North America, South America, Asia, Australia, Africa

4.5 In which geographical region were you born?

Possible answers: Europe, North America, South America, Asia, Australia, Africa

Appendix 1b: Results of Questionnaire 1 (#1)

Jisc Online surveys

Learning Styles and Media Consumption, rev

Showing 353 of 353 responses

Showing **all** responses

Showing **all** questions

Response rate: 353%

1 "I prefer using pictures, images and/or spacial understanding." Please read through the listed options and pick the one, which describes you best.

Rank value	Option	Count
1	Not at all.	13
2	To little degree.	18
3	To some degree.	95
4	To moderate degree.	127
5	To high degree.	100

Mean rank	3.8
Variance	1.05
Standard Deviation	1.02
Lower Quartile	3
Upper Quartile	5

2 "I prefer using sound and music." Please read through the listed options and pick the one, which describes you best.

Rank value	Option	Count
1	Not at all.	64
2	To little degree.	95
3	To some degree.	104
4	To moderate degree.	72
5	To high degree.	18

Mean rank	2.67
Variance	1.3
Standard Deviation	1.14
Lower Quartile	2
Upper Quartile	4

3 "I prefer using words, both in speech and/or writing." Please read through the listed options and pick the one, which describes you best.

Rank value	Option	Count
1	Not at all.	12
2	To little degree.	48
3	To some degree.	116
4	To moderate degree.	115
5	To high degree.	62

Mean rank	3.47
Variance	1.08
Standard Deviation	1.04
Lower Quartile	3
Upper Quartile	4

4 "I prefer using my body, hands and/or sense of touch." Please read through the listed options and pick the one, which describes you best.

Rank value	Option	Count
1	Not at all.	53
2	To little degree.	67
3	To some degree.	103
4	To moderate degree.	92
5	To high degree.	38

Mean rank	2.99
Variance	1.48
Standard Deviation	1.22
Lower Quartile	2
Upper Quartile	4

5 "I prefer using logic, reasoning and/or systems." Please read through the listed options and pick the one, which describes you best.

Rank value	Option	Count
1	Not at all.	10
2	To little degree.	17
3	To some degree.	81
4	To moderate degree.	111
5	To high degree.	134

Mean rank	3.97
Variance	1.06
Standard Deviation	1.03
Lower Quartile	3
Upper Quartile	5

6 "I prefer trying out and experiencing new things." Please read through the listed options and pick the one, which describes you best.

Rank value	Option	Count
1	Not at all.	11
2	To little degree.	24
3	To some degree.	91
4	To moderate degree.	127
5	To high degree.	99

Mean rank	3.79
Variance	1.05
Standard Deviation	1.03
Lower Quartile	3.0
Upper Quartile	5.0

7 Based on your own assessment, how do you learn best? Please read through the listed descriptions and pick the one, which describes your learning preference best.

Rank value	Option	Count
1	I prefer to work alone and use self-study.	159
2	I prefer to learn in groups or with other people.	194

Mean rank	1.55
Variance	0.25
Standard Deviation	0.5
Lower Quartile	1
Upper Quartile	2

8 In a normal week, how likely do you use social networking websites (such as Google+, Facebook, LinkedIn, MySpace, Bebo, Twitter, Whatsapp or others)?

Rank value	Option	Count
1	Extremely likely	81
2	Very likely	89
3	Moderately likely	114
4	Slightly likely	60
5	Not at all	9

Mean rank	2.51
Variance	1.2
Standard Deviation	1.1
Lower Quartile	2
Upper Quartile	3

9 In a normal week, how much time do you spend using social networking websites per day?

Rank value	Option	Count
1	0 - 1 hour	113
2	1 - 2 hours	127
3	2 - 3 hours	62
4	3 - 4 hours	26
5	More than 4 hours	25

Mean rank	2.22
Variance	1.38
Standard Deviation	1.18
Lower Quartile	1
Upper Quartile	3

10 How many of your social network "friends" have you met in person?

Rank value	Option	Count
1	All of them	75
2	Most of them	100
3	About half of them	51
4	A few of them	76
5	None of them	51

Mean rank	2.8
Variance	1.88
Standard Deviation	1.37
Lower Quartile	2
Upper Quartile	4

11 Which of the following devices do you use to connect to the internet?

Rank value	Option	Count
1	Laptop	211
2	Desktop	107
3	Tablet	77
4	Smart phone	290

Mean rank	2.65
Variance	1.69
Standard Deviation	1.3
Lower Quartile	1
Upper Quartile	4

12 Where are you mostly, when you use the internet to access online learning sources for your studies? Please pick maximum 2 answers.

Rank value	Option	Count
1	Outside	41
2	Home	303
3	Café or friend's home	33
4	Library	72
5	At work	133
6	Other	25

Mean rank	3.05
Variance	2.13
Standard Deviation	1.46
Lower Quartile	2.0
Upper Quartile	5.0

13 How many hours do you spend online on a normal day?

Rank value	Option	Count
1	0 - 1	37
2	1 - 2	119
3	2 - 3	83
4	3 - 4	49
5	More than 4	61

Mean rank	2.94
Variance	1.6
Standard Deviation	1.27
Lower Quartile	2
Upper Quartile	4

14 For your study or learning activities: Which online media or sources do you work with?

Rank value	Option	Count
1	Digital research academic articles or eBooks	206
2	Take online academic classes	72
3	eLearning	124
4	Videos	194
5	Printed books or print media	191
6	Other	35

Mean rank	3.24
Variance	2.58
Standard Deviation	1.61
Lower Quartile	1.25

15 How do you learn best in a classroom?

Rank value	Option	Count
1	When I can actively bring in my ideas or when I present something.	207
2	When I just listen and make notes.	146

Mean rank	1.41
Variance	0.24
Standard Deviation	0.49
Lower Quartile	1
Upper Quartile	2

16 You learned a longer time for a specific exam and today you made it through. What would you do thereafter to reward yourself?

Rank value	Option	Count
1	You enjoy the silence at home on your sofa.	182
2	You meet friends that you have not met for a longer time.	171

Mean rank	1.48
Variance	0.25
Standard Deviation	0.5
Lower Quartile	1
Upper Quartile	2

17 When I have to understand something, it helps me to ...

Rank value	Option	Count
1	... talk to someone.	213
2	... think about it by myself.	140

Mean rank	1.4
Variance	0.24
Standard Deviation	0.49
Lower Quartile	1
Upper Quartile	2

18 Imagine a situation in which you can choose, whether you do your oral exam in a group or individually.

Rank value	Option	Count
1	You prefer an individual exam, because you want to be in the center of an event.	163
2	You choose the group exam, because you don't like to be in the center of attention.	190

Mean rank	1.54
Variance	0.25
Standard Deviation	0.5
Lower Quartile	1
Upper Quartile	2

19 How old are you?

Rank value	Option	Count
1	20-29	155
2	30-39	128
3	40-49	44
4	50 and above	20
5	Prefer not to say	6

Mean rank	1.85
Variance	0.92
Standard Deviation	0.96
Lower Quartile	1
Upper Quartile	2

20 What is your gender?

Rank value	Option	Count
1	Female	83
2	Male	261
3	Diverse	3
4	Prefer not to say	6

Mean rank	1.81
Variance	0.27
Standard Deviation	0.52
Lower Quartile	2
Upper Quartile	2

21 What is your technical profession? (Please select the option below that comes closest to your actual profession.)

Rank value	Option	Count
1	Mechanical Engineering	189
2	Electrical Engineering	54
3	Software Engineering	24
4	Civil Engineering or Architecture	5
5	Materials Science	3
6	Chemical or Pharmaceutical Engineering	2
7	Process or Manufacturing Engineering	7
8	Other	41
9	No technical profession	28

Mean rank	2.96
Variance	8.47
Standard Deviation	2.91
Lower Quartile	1
Upper Quartile	3

22 In which geographical region do you live?

Rank value	Option	Count
1	Europe	132
2	North America	29
3	South America	4
4	Asia	185
5	Africa	0
6	Australia	0

Mean rank	2.69
Variance	2.02
Standard Deviation	1.42
Lower Quartile	1.0
Upper Quartile	4.0

23 In which geographical region were you born?

Rank value	Option	Count
1	Europe	126
2	North America	26
3	South America	3
4	Asia	193
5	Africa	3
6	Australia	0

Mean rank	2.77
Variance	2.04
Standard Deviation	1.43
Lower Quartile	1.0
Upper Quartile	4.0

Appendix 2: Survey 2 (#2)

Closed questions

How do you prefer to learn?

A. I prefer to learn using pictures, graphics and/or images.
(Possible answers: Not at all - To little degree - To some degree - To moderate degree - To high degree)

B. I prefer listening to sound and music, for instance listening to a teacher or an audio book.
(Possible answers: Not at all - To little degree - To some degree - To moderate degree - To high degree)

C. I prefer to learn with written elaborations, documents or text.
(Possible answers: Not at all - To little degree - To some degree - To moderate degree - To high degree)

D. I prefer to learn using my hands or sense of touch or body feeling, for example in an experiment or physical simulation.
(Possible answers: Not at all - To little degree - To some degree - To moderate degree - To high degree)

E. I prefer to learn using logic, reasoning and/or systems, as I have a great power of imagination. It's all in my mind.
(Possible answers: Not at all - To little degree - To some degree - To moderate degree - To high degree)

F. I prefer to learn alone and use self-study, as I need the silence and appropriate solitude for best effects.
(Possible answers: Not at all - To little degree - To some degree - To moderate degree - To high degree)

G. I prefer to learn in groups or with other people, as I want to share my thoughts and ideas with other people. With a talk I am able to develop my conceptions.
(Possible answers: Not at all - To little degree - To some degree - To moderate degree - To high degree)

Open questions

H. In which environment do you learn best? (e.g.: In a comfort chair at home. Or: In my university library. Etcetera…)
(Possible answer: free text)

I. Give reasons, why…
(Possible answer: free text)

J. What kind of media/sources/material helps you the most? (for instance: e-learning, handwritten transcript or paper book)
(Possible answer: free text)

K. Give reasons, why…
(Possible answer: free text)

L. What platforms do you usually use to access learning content? (e.g.: LinkedIn Learning, YouTube, etc.)
(Possible answer: free text)

M. Give reasons, why…
(Possible answer: free text)

N. What platforms (incl. social media platform) do you use get in touch with your peer group? (for example: Facebook, WhatsApp or LinkedIn)
(Possible answer: free text)

O. Give reasons and explain, why you think they are useful.
(Possible answer: free text)

General information

P. How old are you?
(Possible answers: 20-29, 30-39, 40-49, 50 and above. Prefer not to say.)

Q. What is your gender?
(Possible answers: Female, male, diverse. Prefer not to say)

R. What part of the industry do you work in? (for example: Testing, Design, Sales, Installation, Management, Manufacturing, …)
(Possible answer: free text)

S. What is your profession? (e.g.: Mechanical Engineer, Electrician, Common Laborer, IT Specialist, …)
(Possible answer: free text)

T. In which hierarchy level do work? (for instance: Beginner, Apprentice, Middle Management, Top Management, …)
(Possible answer: free text)

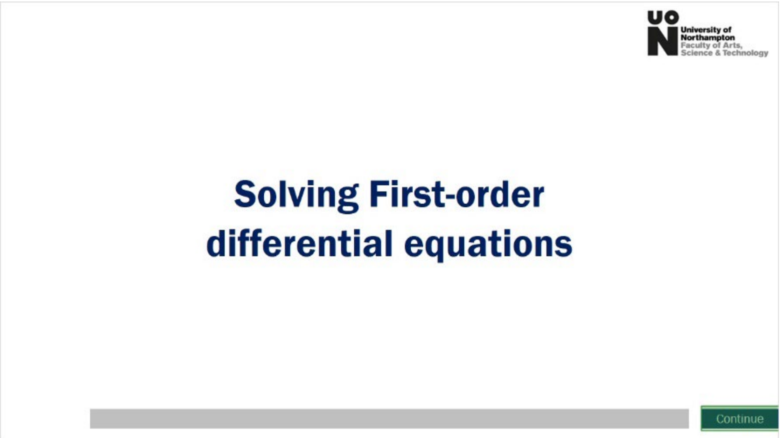
U. In which geographical region do you work? (e.g.: UK, Europe, Belgium, North America, China, Australia, Africa, …)
(Possible answer: free text)

V. In which geographical region were you born? (e.g.: UK, Europe, Belgium, North America, China, Australia, Africa, …)
(Possible answer: free text)

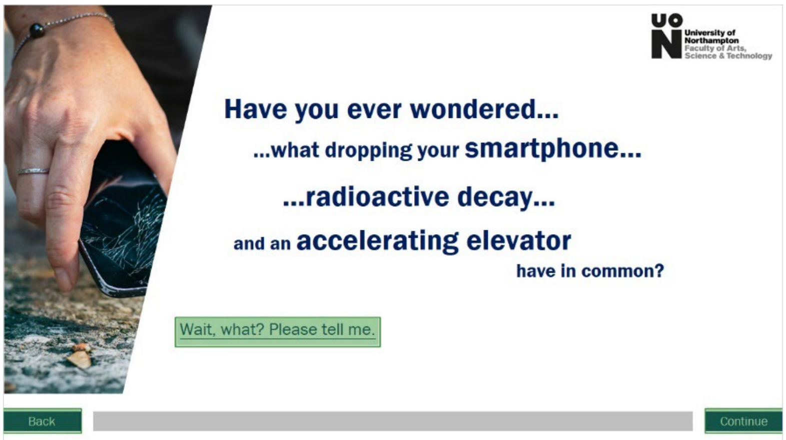
Appendix 3: Comparison of two different Learning Approaches (#3)

A. e-learning approach

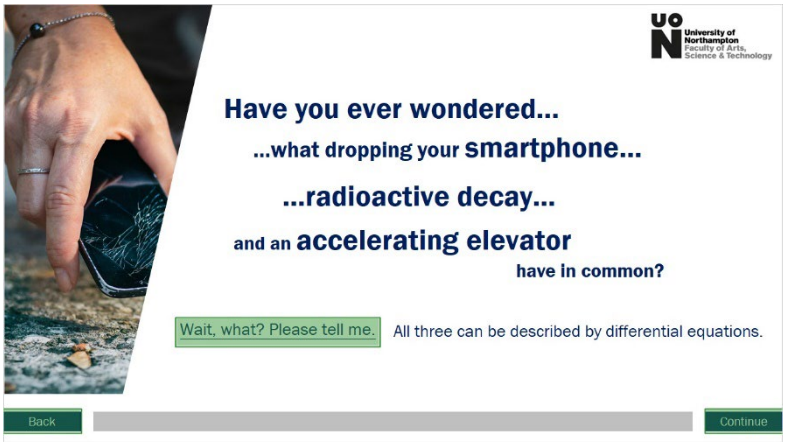
1.1 Homepage



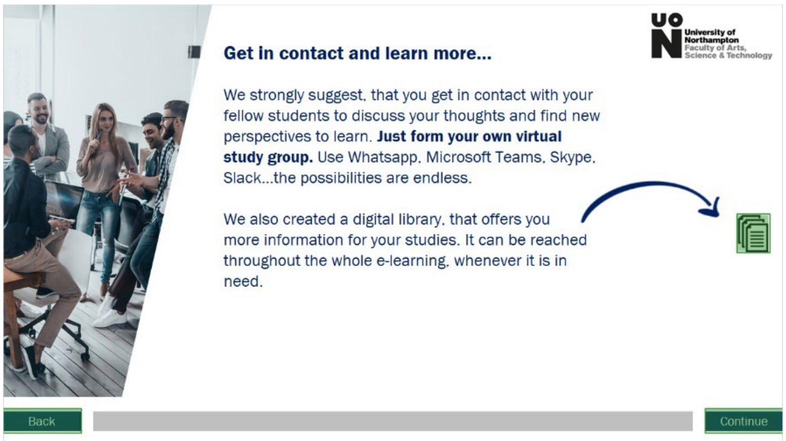
1.2 Introduction



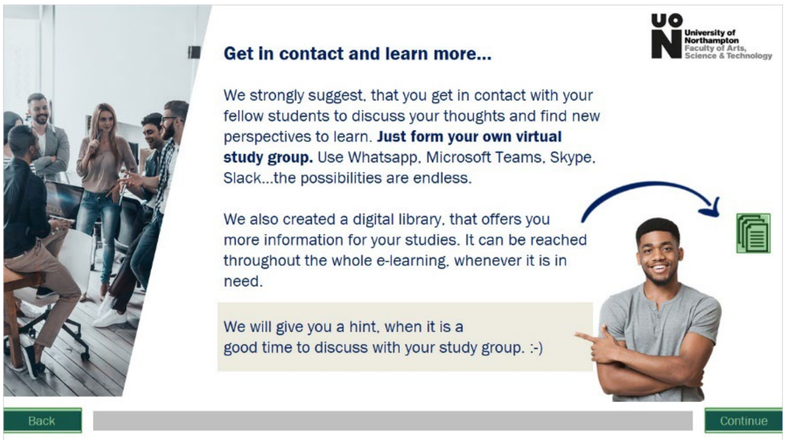
Feedback (slide level)



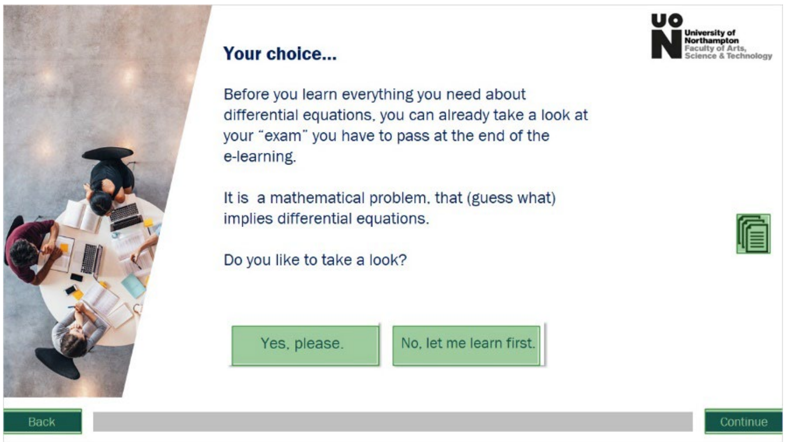
1.3 Interaction



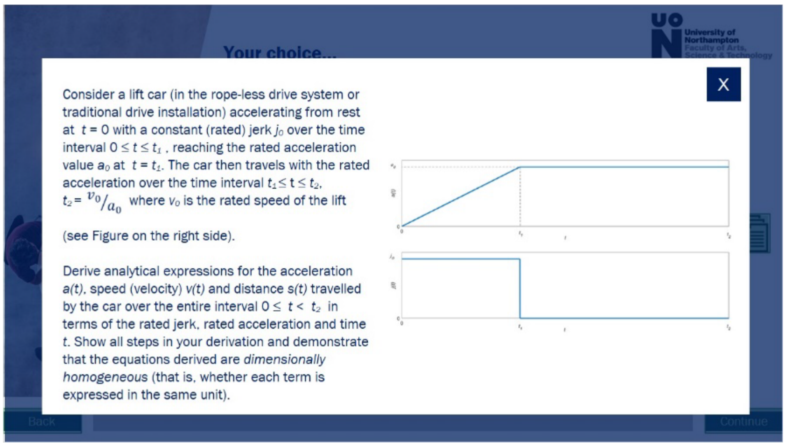
Please note: Study group (slide level)



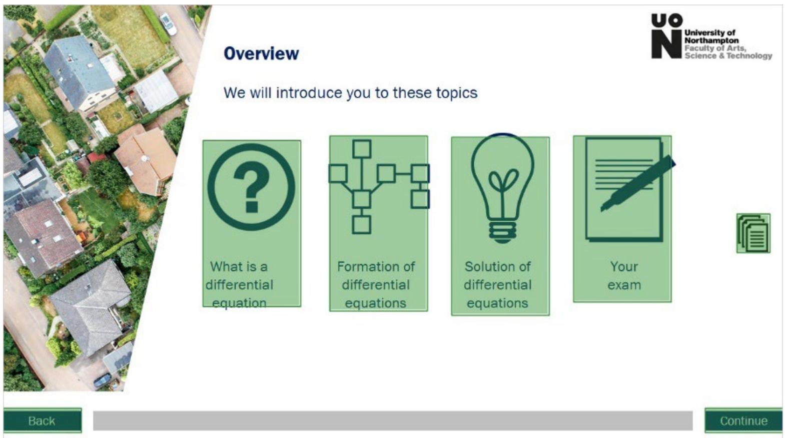
1.4 Assignment Yes or No



Assignment (slide level)

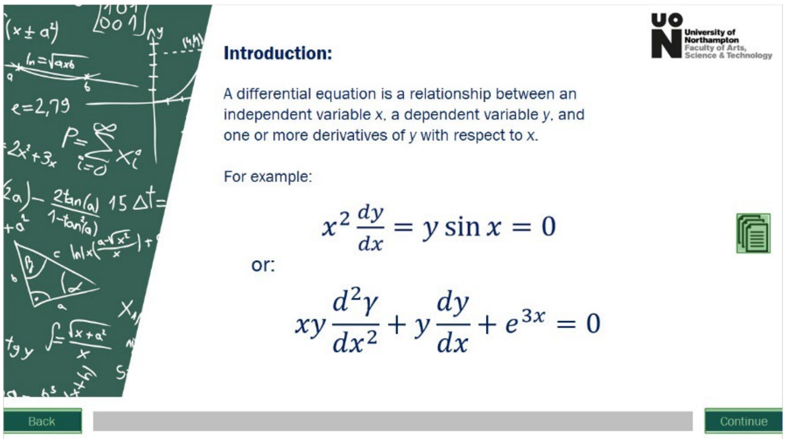


1.5 No title

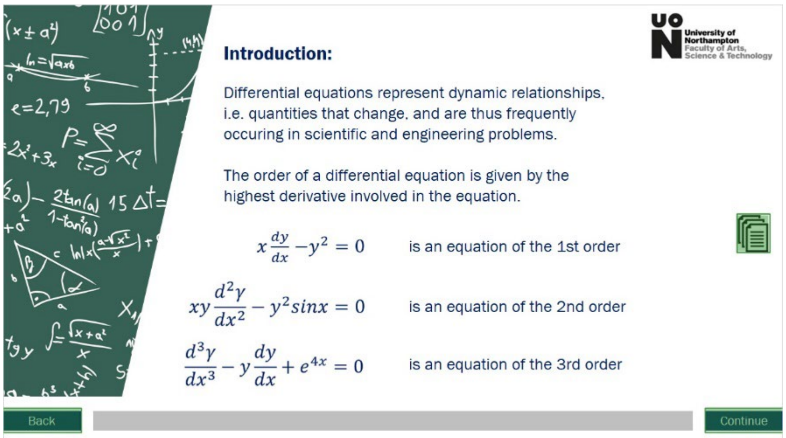


Please note (slide level)

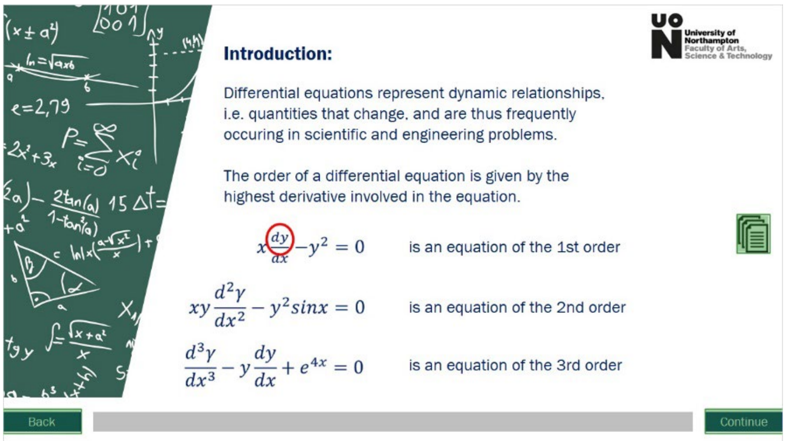
1.6 No title



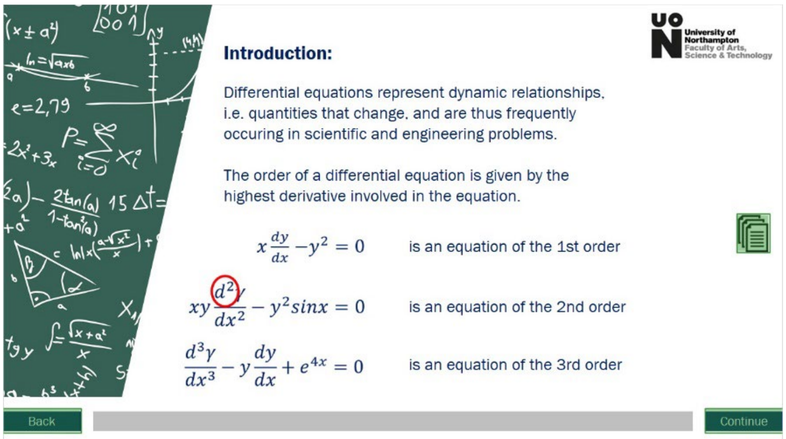
1.7 No title



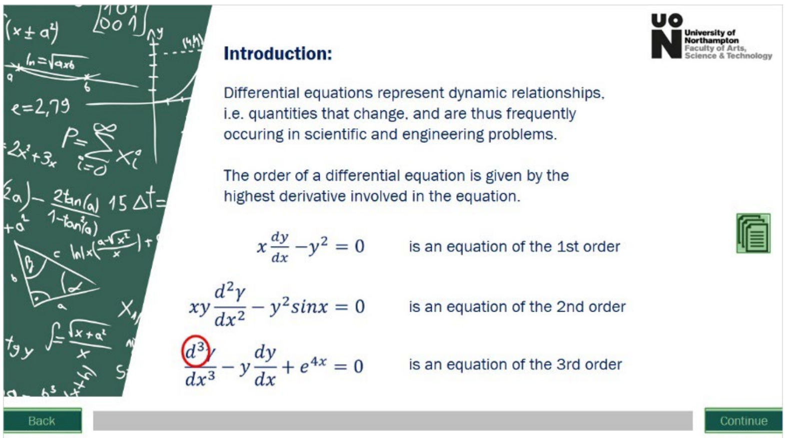
Highlight_1 (slide level)



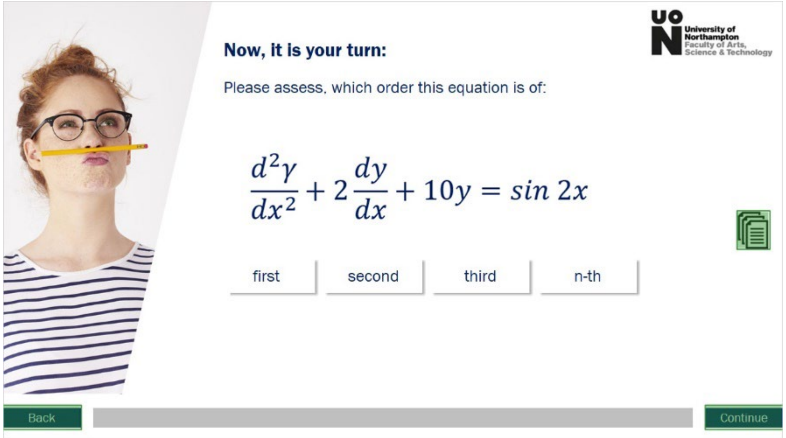
Highlight_2 (slide level)



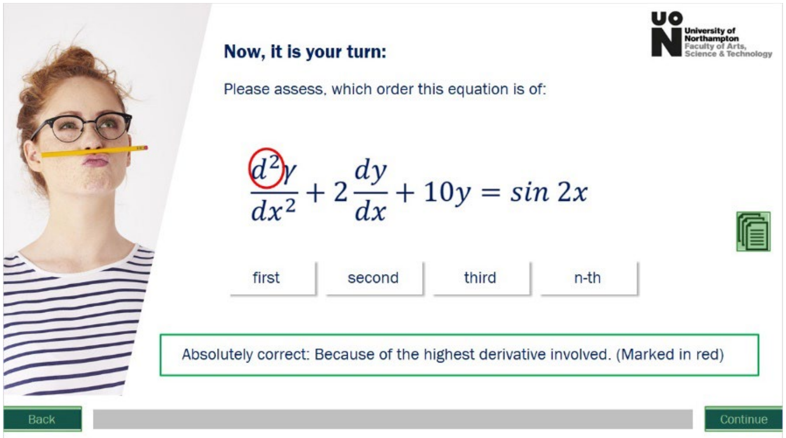
Highlight_2 - Copy (slide level)



1.8 No title



Correct (slide level)



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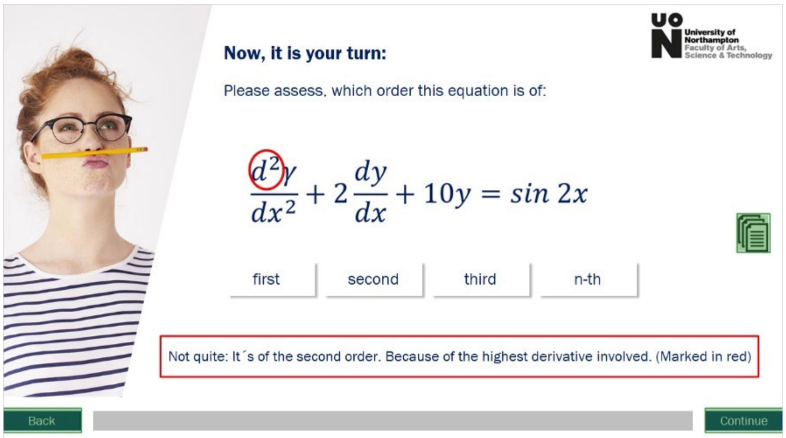
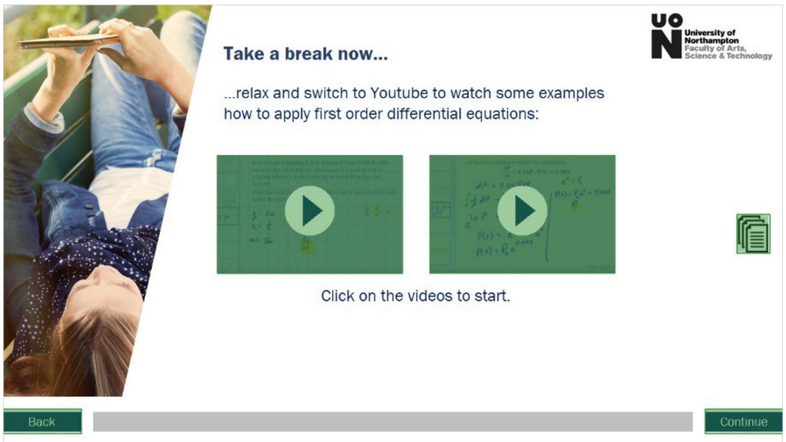
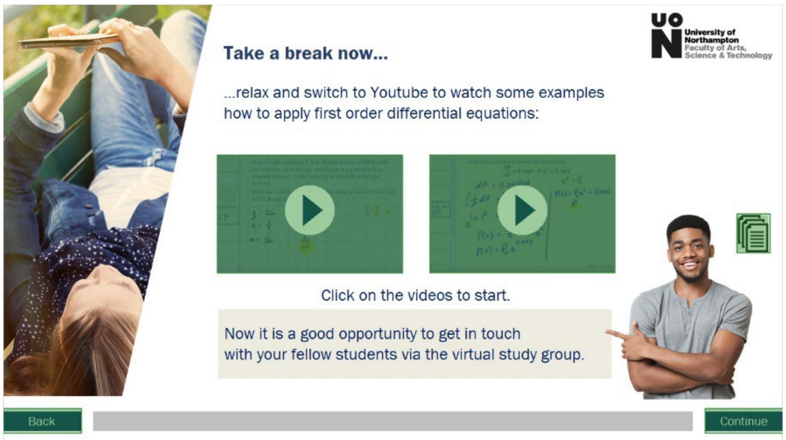


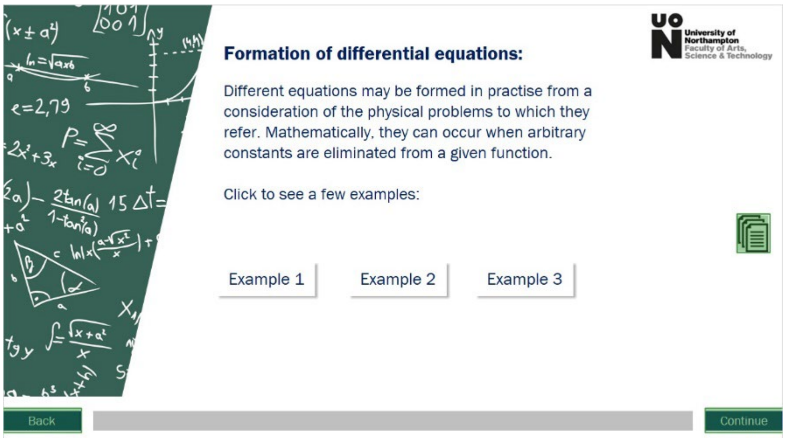
1.9 No title



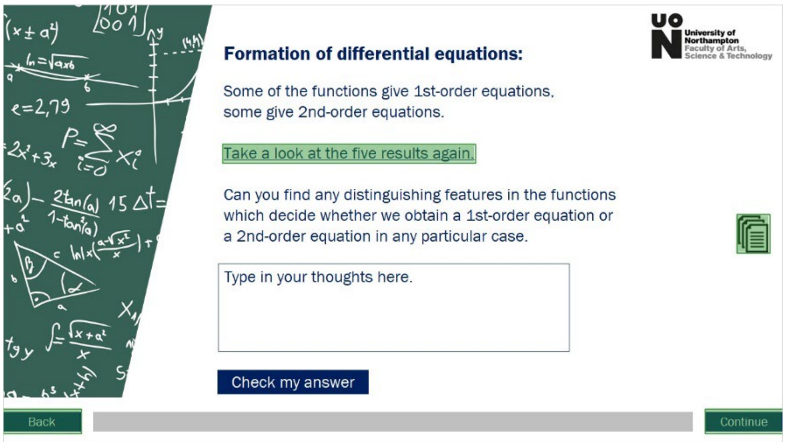
Please note: Study group (slide level)



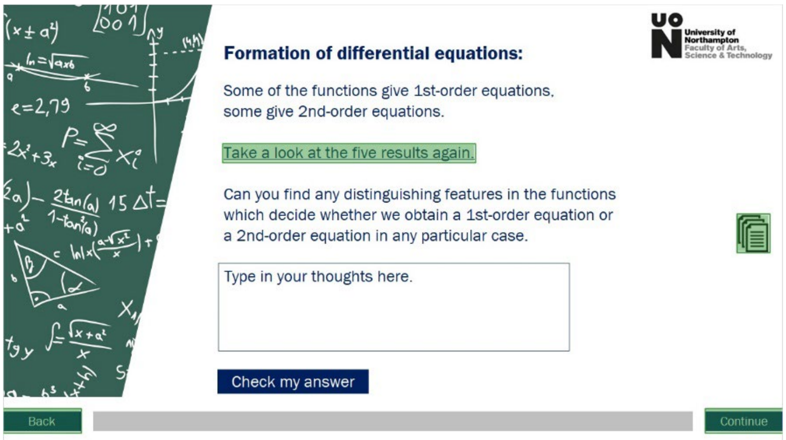
1.10 Jump platform



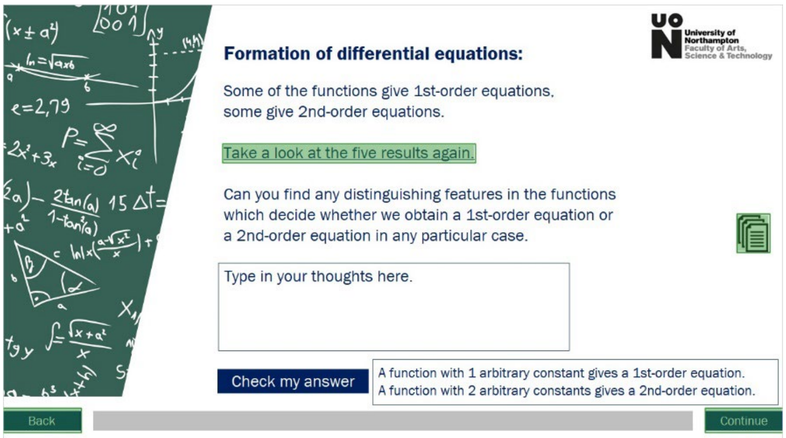
1.11 Entry field



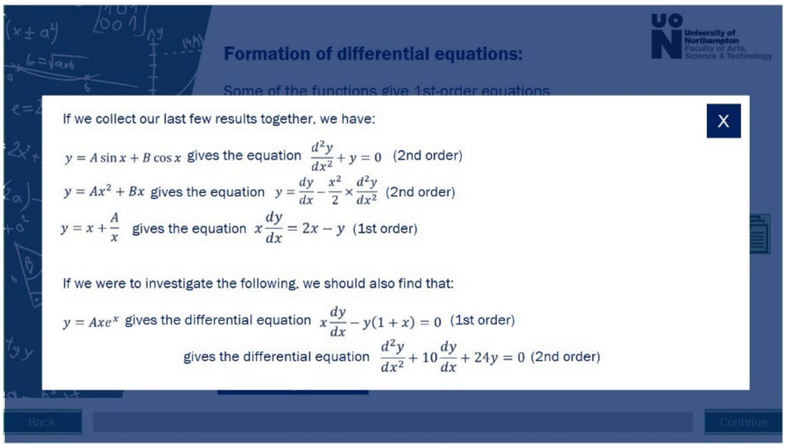
Incorrect (slide level)



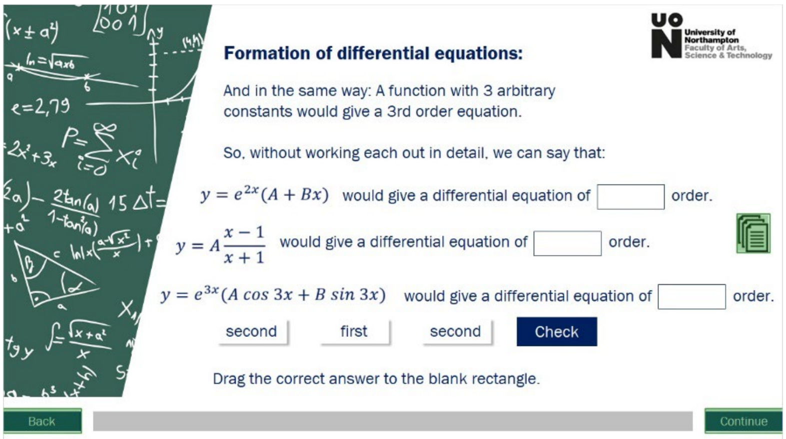
Feedback (slide level)



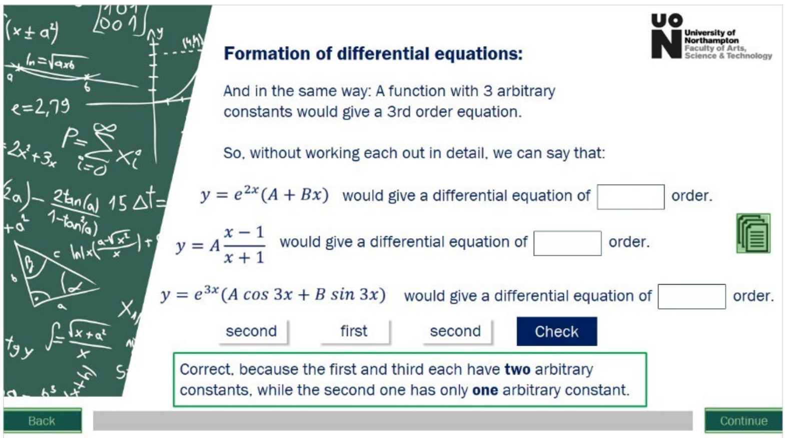
Pop-up (slide level)



1.12 Drag-and-Drop



Correct (slide level)



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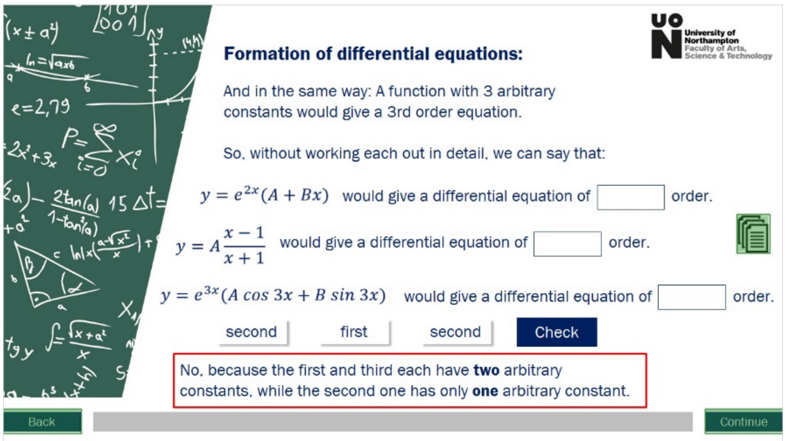
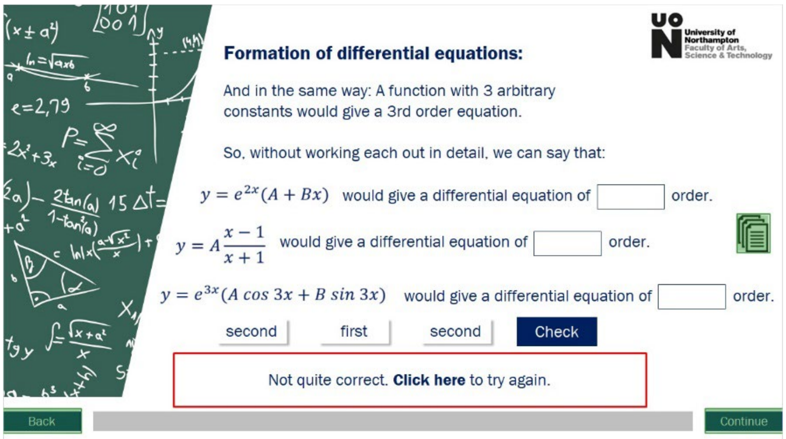
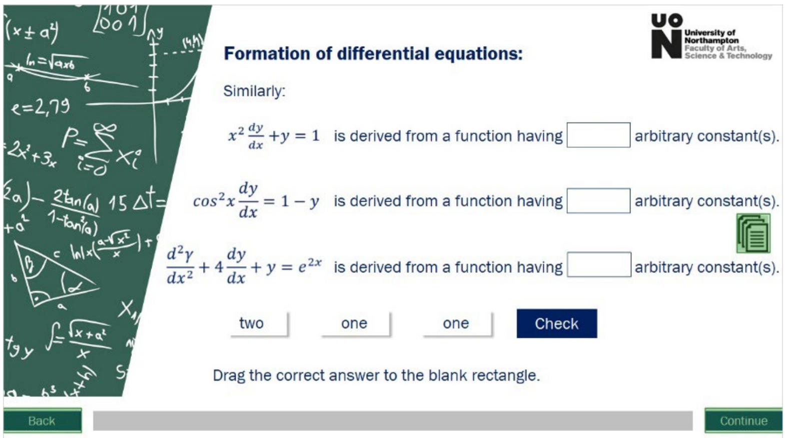


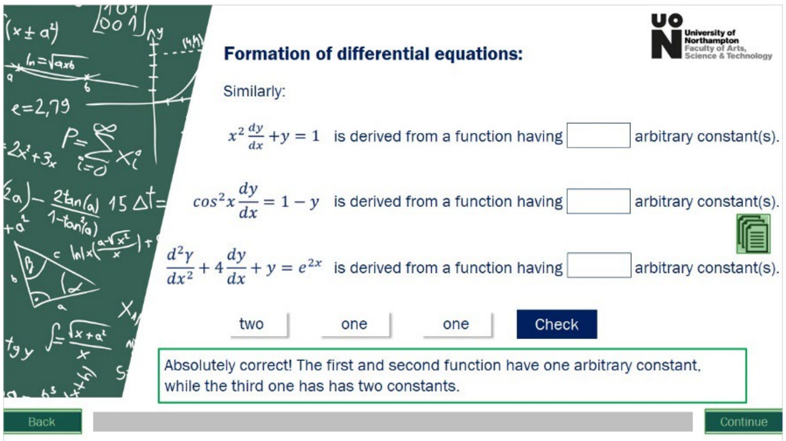
Try Again (slide level)



1.13 Drag-and-Drop



Correct (slide layer)



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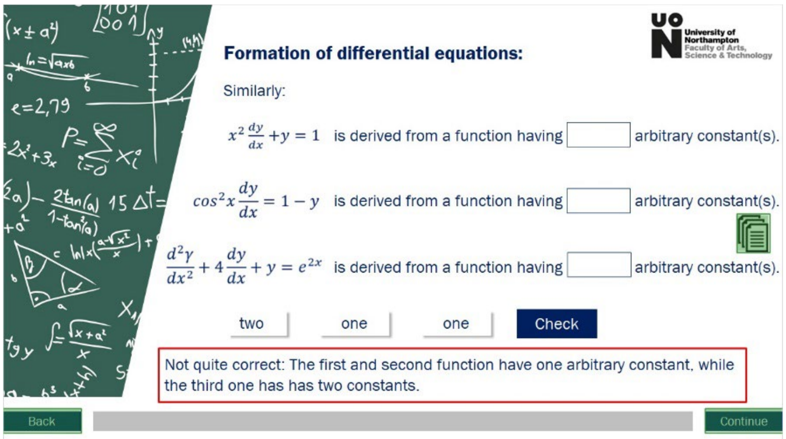
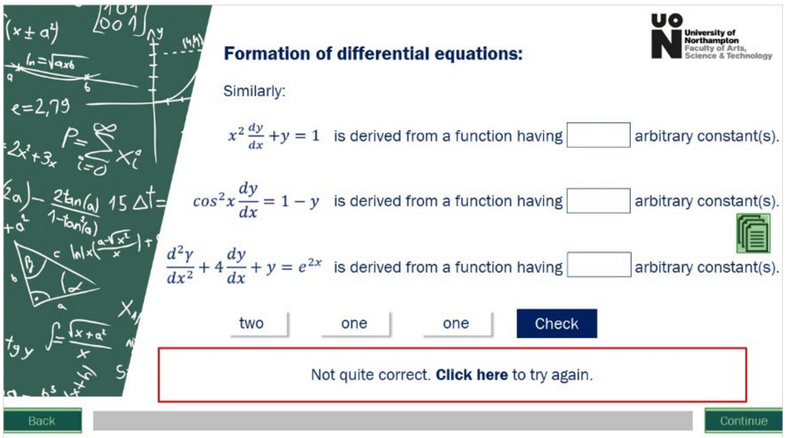
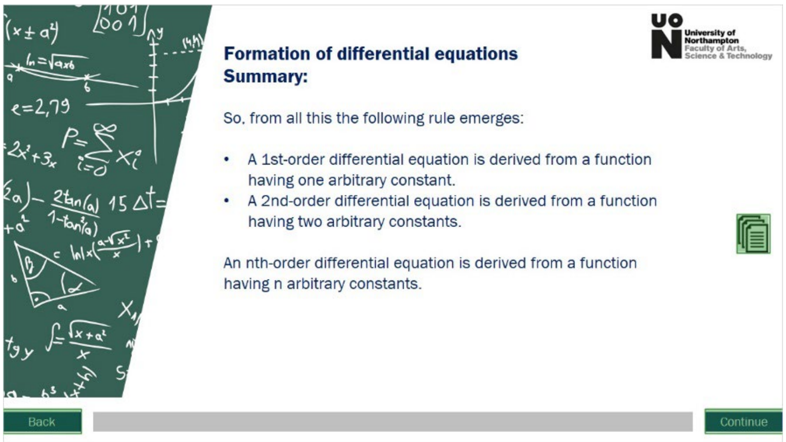


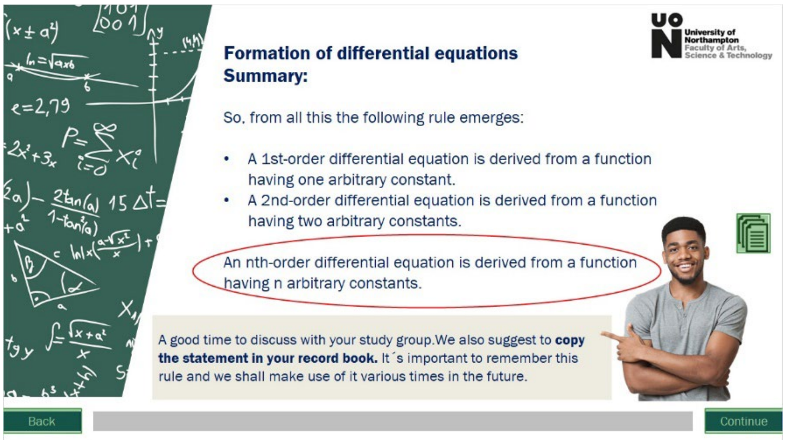
Try Again (slide layer)



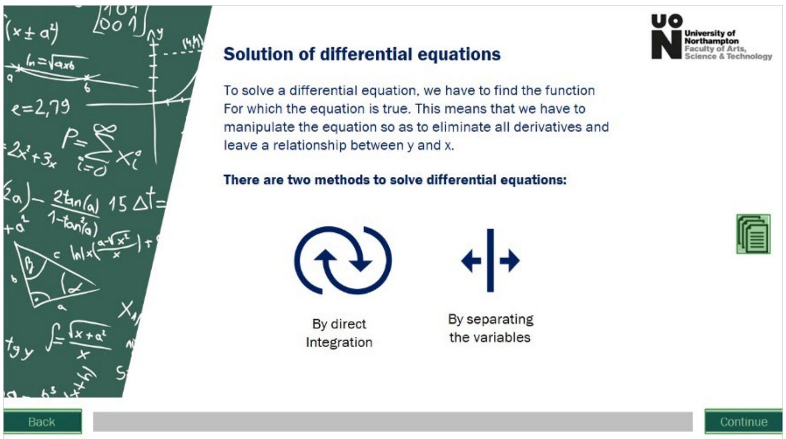
1.14 No title



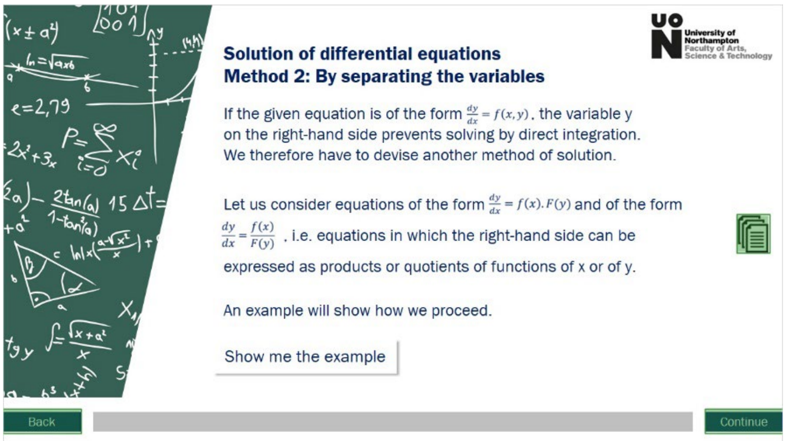
Please note: Study group (slide layer)



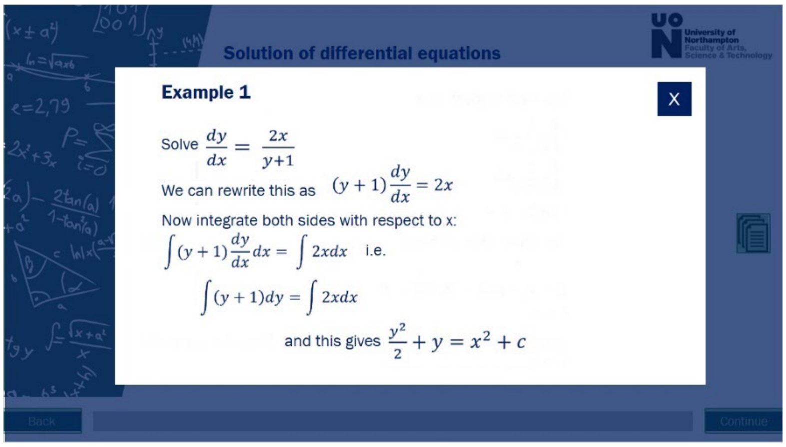
1.15 Solution of differential equations



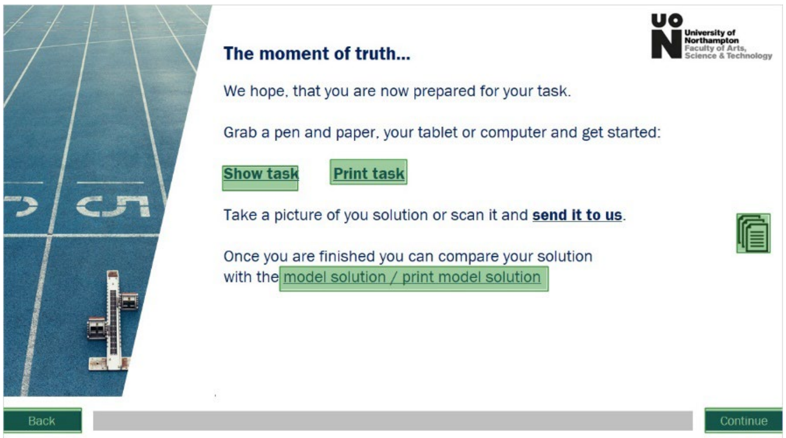
1.16 Solution_2



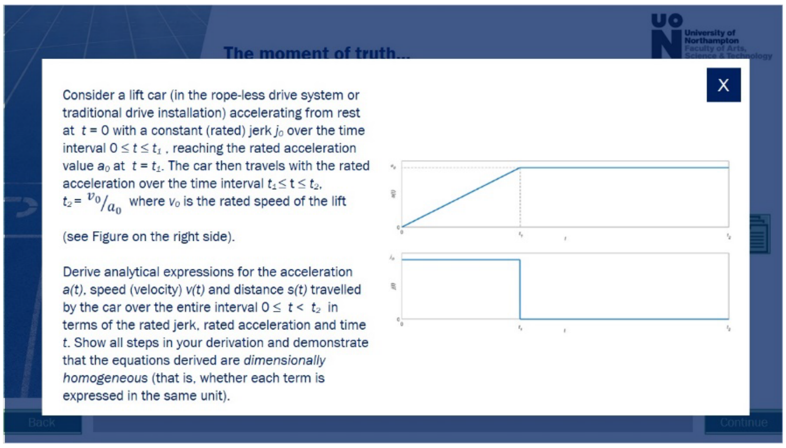
Example 1 (slide layer)



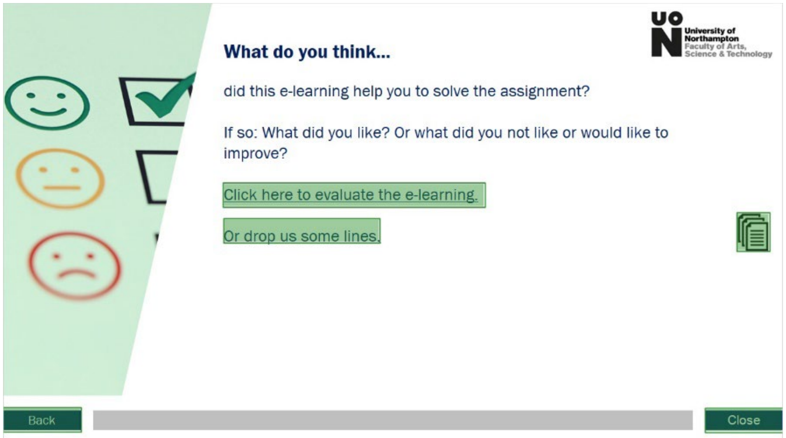
1.17 Assignment



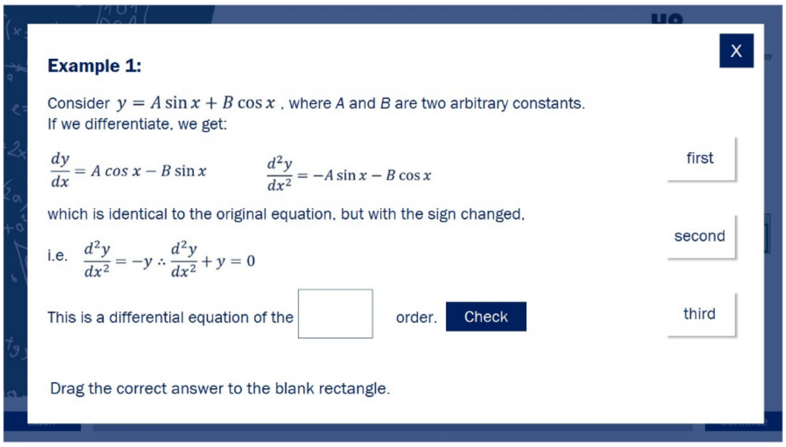
Assignment_1 (slide layer)



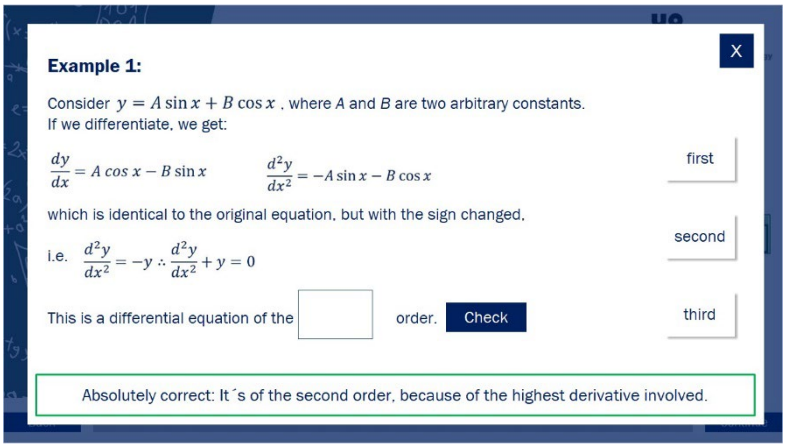
1.18 No title



1.19 Example_1



Correct (slide layer)



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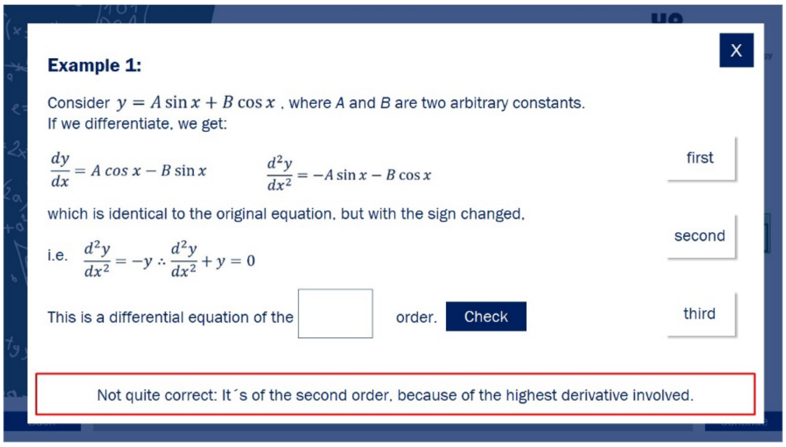

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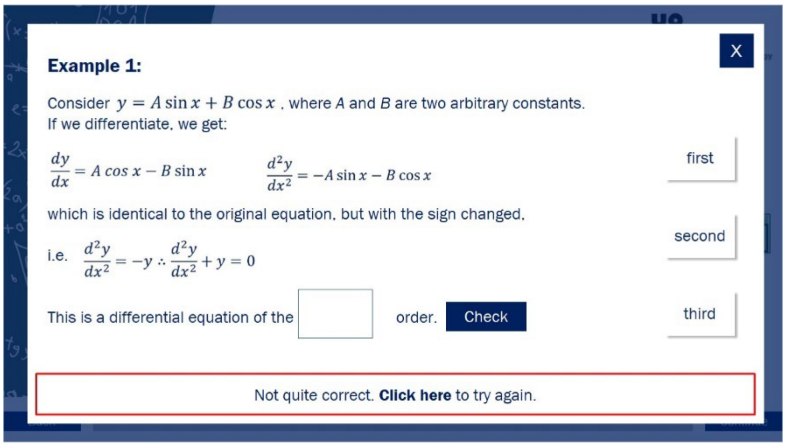
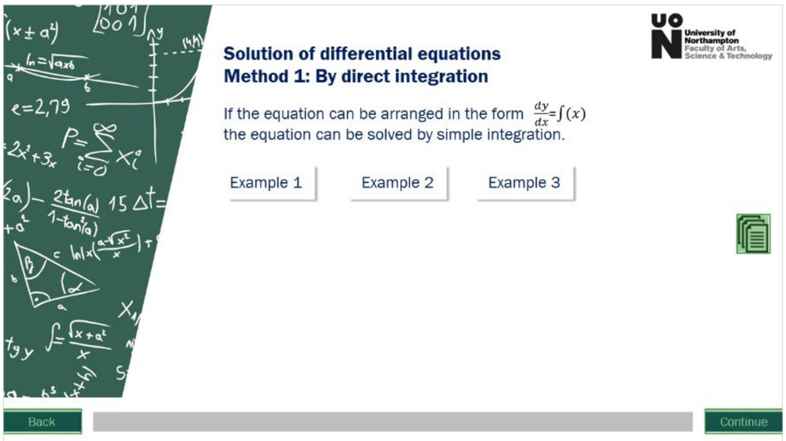


1.20 Solution_1



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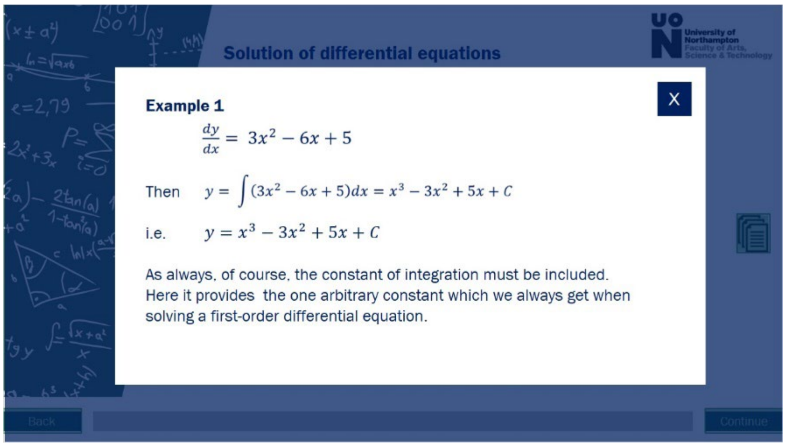

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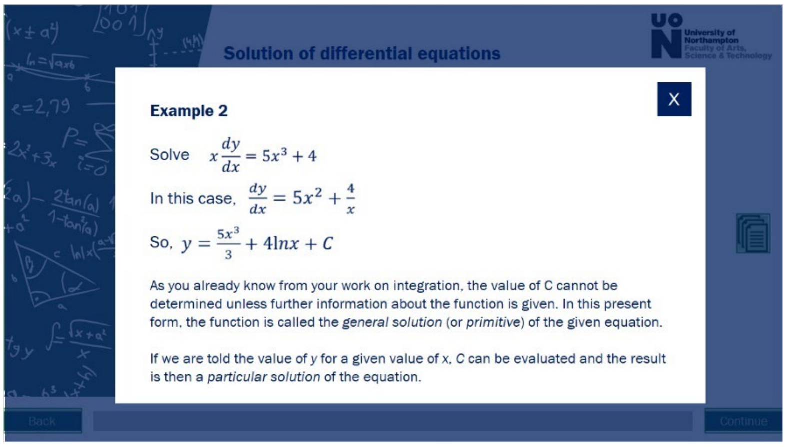

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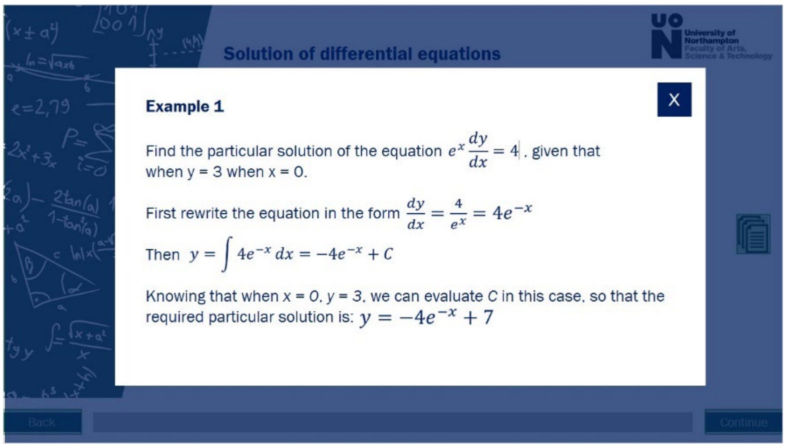

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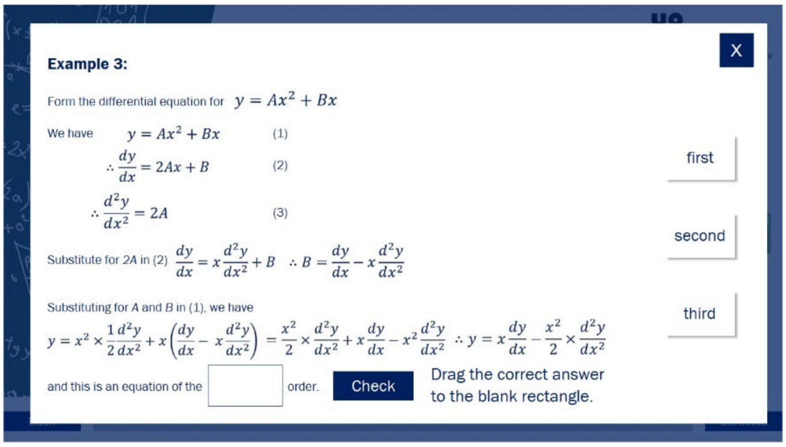

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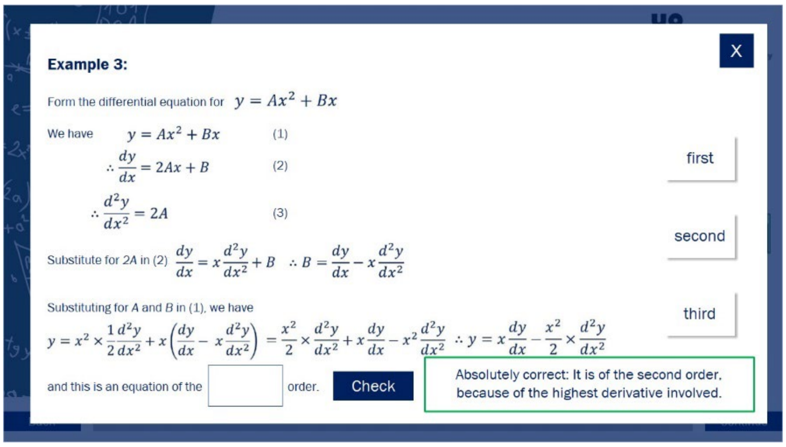

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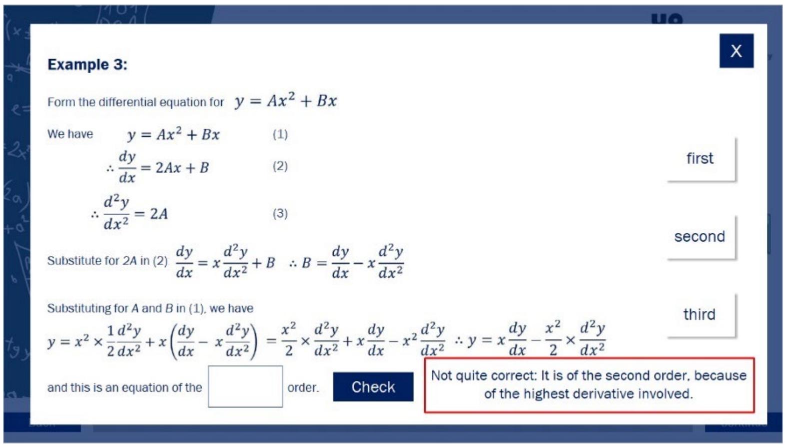

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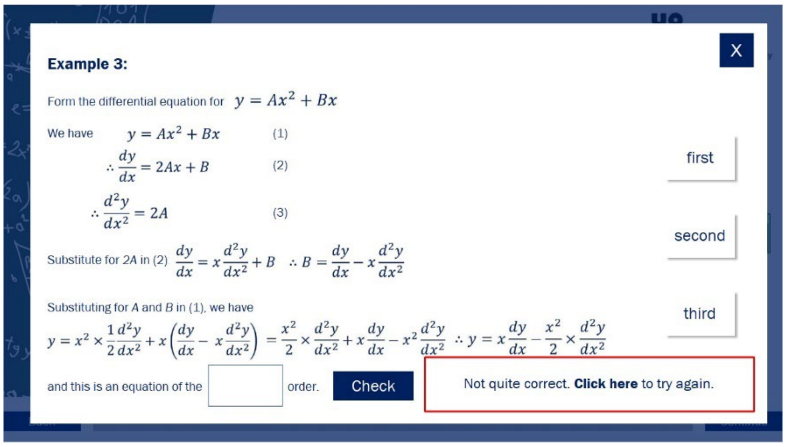
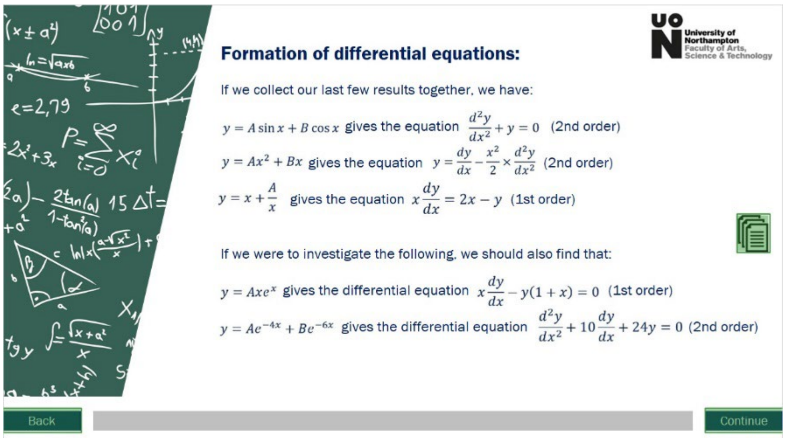


1.22 Formation_2



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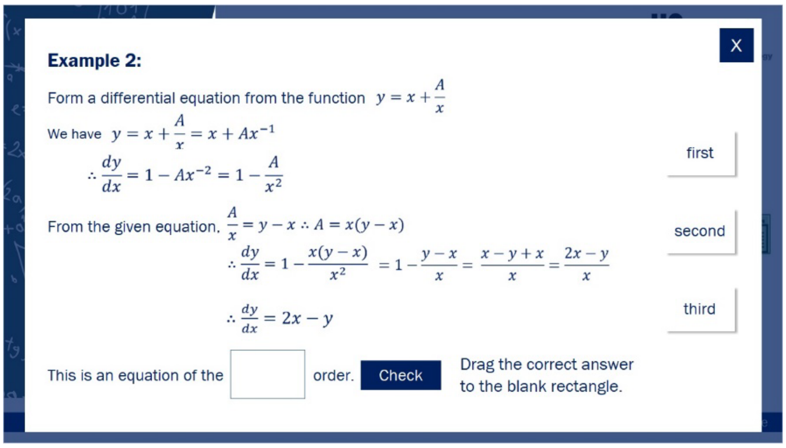
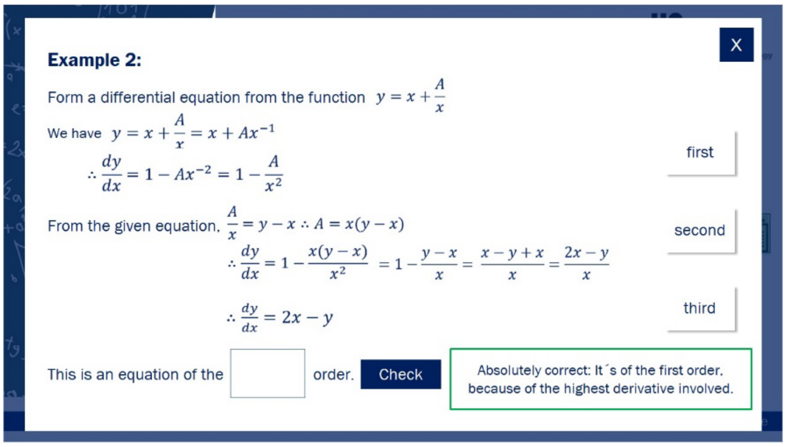


Correct (slide layer)



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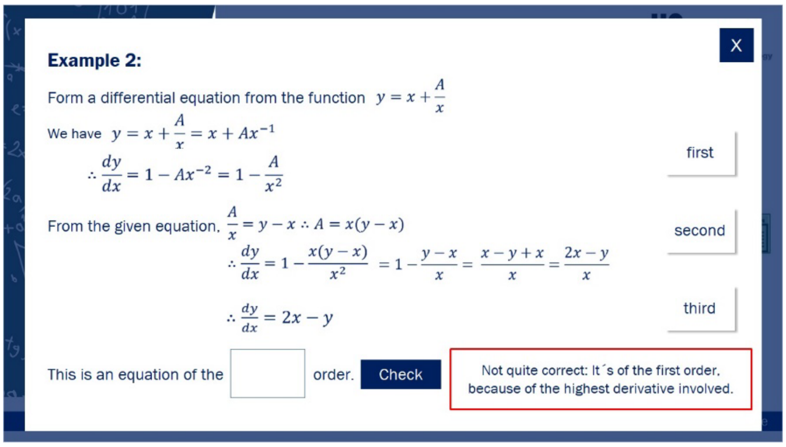

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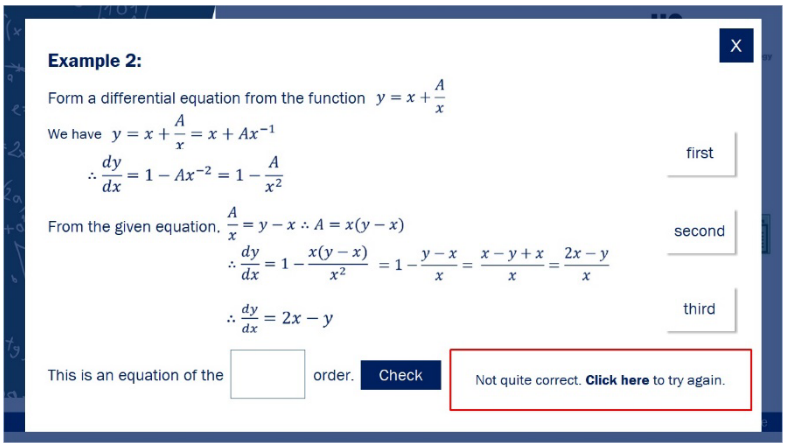


B. Standard Distance Learning Approach

Programme 24

First-order differential equations

Frames 1 to 83

Learning outcomes

When you have completed this Programme you will be able to:

- Recognize the order of a differential equation
- Appreciate that a differential equation of order n can be derived from a function containing n arbitrary constants
- Solve certain first-order differential equations by direct integration
- Solve certain first-order differential equations by separating the variables
- Solve certain first-order homogeneous differential equations by an appropriate substitution
- Solve certain first-order differential equations by using an integrating factor
- Solve Bernoulli's equation

1031

1032 *Engineering Mathematics*

Introduction

1

A *differential equation* is a relationship between an independent variable, x, a dependent variable y, and one or more derivatives of y with respect to x.

e.g. $x^2\frac{dy}{dx} = y\sin x = 0$

$xy\frac{d^2y}{dx^2} + y\frac{dy}{dx} + e^{3x} = 0$

Differential equations represent dynamic relationships, i.e. quantities that change, and are thus frequently occurring in scientific and engineering problems.

The *order* of a differential equation is given by the highest derivative involved in the equation.

$x\frac{dy}{dx} - y^2 = 0$ is an equation of the 1st order

$xy\frac{d^2y}{dx^2} - y^2\sin x = 0$ is an equation of the 2nd order

$\frac{d^3y}{dx^3} - y\frac{dy}{dx} + e^{4x} = 0$ is an equation of the 3rd order

So that $\frac{d^2y}{dx^2} + 2\frac{dy}{dx} + 10y = \sin 2x$ is an equation of the ....order.

2

second

Because

In the equation $\frac{d^2y}{dx^2} + 2\frac{dy}{dx} + 10y = \sin 2x$, the highest derivative involved is $\frac{d^2y}{dx^2}$.

Similarly:

(a) $x\frac{dy}{dx} = y^2 + 1$ is a ....order equation

(b) $\cos^2 x\frac{dy}{dx} + y = 1$ is a ....order equation

(c) $\frac{d^2y}{dx^2} - 3\frac{dy}{dx} + 2y = x^2$ is a ....order equation

(d) $(y^3 + 1)\frac{dy}{dx} - xy^2 = x$ is a ....order equation

On to Frame 3

First-order differential equations 1033

3

(a) first (b) first (c) second (d) first

Next frame

Formation of differential equations

4

Differential equations may be formed in practice from a consideration of the physical problems to which they refer. Mathematically, they can occur when arbitrary constants are eliminated from a given function. Here are a few examples.

Example 1

Consider $y = A\sin x + B\cos x$, where A and B are two arbitrary constants.

If we differentiate, we get:

$\frac{dy}{dx} = A\cos x - B\sin x$

and $\frac{d^2y}{dx^2} = -A\sin x - B\cos x$

which is identical to the original equation, but with the sign changed.

i.e. $\frac{d^2y}{dx^2} = -y \quad \therefore \frac{d^2y}{dx^2} + y = 0$

This is a differential equation of the .... order.

5

second

Example 2

Form a differential equation from the function $y = x + \frac{A}{x}$.

We have $y = x + \frac{A}{x} = x + Ax^{-1}$

$\therefore \frac{dy}{dx} = 1 - Ax^{-2} = 1 - \frac{A}{x^2}$

From the given equation, $\frac{A}{x} = y - x \quad \therefore A = x(y - x)$

$\therefore \frac{dy}{dx} = 1 - \frac{x(y-x)}{x^2}$

$= 1 - \frac{y-x}{x} = \frac{x-y+x}{x} = \frac{2x-y}{x}$

$\therefore x\frac{dy}{dx} = 2x - y$

This is an equation of the .... order.

1034 *Engineering Mathematics*

6

first

Now one more.

Example 3

Form the differential equation for $y = Ax^2 + Bx$.

We have $y = Ax^2 + Bx$ (1)

$\therefore \frac{dy}{dx} = 2Ax + B$ (2)

$\therefore \frac{d^2y}{dx^2} = 2A$ (3) $A = \frac{1}{2}\frac{d^2y}{dx^2}$

Substitute for $2A$ in (2): $\frac{dy}{dx} = x\frac{d^2y}{dx^2} + B$

$\therefore B = \frac{dy}{dx} - x\frac{d^2y}{dx^2}$

Substituting for A and B in (1), we have:

$y = x^2.\frac{1}{2}\frac{d^2y}{dx^2} + x\left(\frac{dy}{dx} - x\frac{d^2y}{dx^2}\right)$

$= \frac{x^2}{2}.\frac{d^2y}{dx^2} + x.\frac{dy}{dx} - x^2.\frac{d^2y}{dx^2}$

$\therefore y = x\frac{dy}{dx} - \frac{x^2}{2}.\frac{d^2y}{dx^2}$

and this is an equation of the .... order.

7

second

If we collect our last few results together, we have:

$y = A\sin x + B\cos x$ gives the equation $\frac{d^2y}{dx^2} + y = 0$ (2nd order)

$y = Ax^2 + Bx$ gives the equation $y = x\frac{dy}{dx} - \frac{x^2}{2}.\frac{d^2y}{dx^2}$ (2nd order)

$y = x + \frac{A}{x}$ gives the equation $x\frac{dy}{dx} = 2x - y$ (1st order)

If we were to investigate the following, we should also find that:

$y = Axe^x$ gives the differential equation $x\frac{dy}{dx} - y(1 + x) = 0$ (1st order)

$y = Ae^{-4x} + Be^{-6x}$ gives the differential equation $\frac{d^2y}{dx^2} + 10\frac{dy}{dx} + 24y = 0$ (2nd order)

Some of the functions give 1st-order equations: some give 2nd-order equations. Now look at the five results above and see if you can find any distinguishing features in the functions which decide whether we obtain a 1st-order equation or a 2nd-order equation in any particular case.

When you have come to a conclusion, move on to Frame 8

8

A function with 1 arbitrary constant gives a 1st-order equation.
A function with 2 arbitrary constants gives a 2nd-order equation.

Correct, and in the same way:

A function with 3 arbitrary constants would give a 3rd order equation.
So, without working each out in detail, we can say that:

(a) $y = e^{-2x}(A + Bx)$ would give a differential equation of .... order.

(b) $y = A\dfrac{x-1}{x+1}$ would give a differential equation of .... order.

(c) $y = e^{3x}(A\cos 3x + B\sin 3x)$ would give a differential equation of .... order.

9

(a) 2nd (b) 1st (c) 2nd

Because

(a) and (c) each have 2 arbitrary constants,
while (b) has only 1 arbitrary constant.

Similarly:

(a) $x^2\dfrac{dy}{dx} + y = 1$ is derived from a function having .... arbitrary constants.

(b) $\cos^2 x\dfrac{dy}{dx} = 1 - y$ is derived from a function having .... arbitrary constants.

(c) $\dfrac{d^2y}{dx^2} + 4\dfrac{dy}{dx} + y = e^{2x}$ is derived from a function having .... arbitrary constants.

10

(a) 1 (b) 1 (c) 2

So, from all this, the following rule emerges:

A 1st-order differential equation is derived from a function having 1 arbitrary constant.

A 2nd-order differential equation is derived from a function having 2 arbitrary constants.

An *n*th-order differential equation is derived from a function having *n* arbitrary constants.

Copy this last statement into your record book. It is important to remember this rule and we shall make use of it at various times in the future.

Then on to Frame 11

Solution of differential equations

11

To solve a differential equation, we have to find the function for which the equation is true. This means that we have to manipulate the equation so as to eliminate all the derivatives and leave a relationship between y and x. The rest of this particular Programme is devoted to the various methods of solving *first-order differential equations*. Second-order equations will be dealt with in the next Programme.

So, for the first method, move on to Frame 12

12

Method 1: *By direct integration*

If the equation can be arranged in the form $\dfrac{dy}{dx} = f(x)$, then the equation can be solved by simple integration.

Example 1

$$\frac{dy}{dx} = 3x^2 - 6x + 5$$

Then $y = \int (3x^2 - 6x + 5)dx = x^3 - 3x^2 + 5x + C$

i.e. $y = x^3 - 3x^2 + 5x + C$

As always, of course, the constant of integration must be included. Here it provides the one arbitrary constant which we always get when solving a first-order differential equation.

Example 2

Solve $x\dfrac{dy}{dx} = 5x^3 + 4$

In this case, $\dfrac{dy}{dx} = 5x^2 + \dfrac{4}{x}$ So, $y = $ ....

13

$$y = \frac{5x^3}{3} + 4\ln x + C$$

As you already know from your work on integration, the value of C cannot be determined unless further information about the function is given. In this present form, the function is called the *general solution* (or *primitive*) of the given equation.

If we are told the value of y for a given value of x, C can be evaluated and the result is then a *particular solution* of the equation.

▶

Example 3

Find the particular solution of the equation $e^x\dfrac{dy}{dx} = 4$, given that $y = 3$ when $x = 0$.

First rewrite the equation in the form $\dfrac{dy}{dx} = \dfrac{4}{e^x} = 4e^{-x}$.

Then $y = \int 4e^{-x}\,dx = -4e^{-x} + C$

Knowing that when $x = 0$, $y = 3$, we can evaluate C in this case, so that the required particular solution is $y = $ ....

14

$$y = -4e^{-x} + 7$$

Method 2: *By separating the variables*

If the given equation is of the form $\dfrac{dy}{dx} = f(x, y)$, the variable y on the right-hand side prevents solving by direct integration. We therefore have to devise some other method of solution.

Let us consider equations of the form $\dfrac{dy}{dx} = f(x).F(y)$ and of the form $\dfrac{dy}{dx} = \dfrac{f(x)}{F(y)}$, i.e. equations in which the right-hand side can be expressed as products or quotients of functions of x or of y.

A few examples will show how we proceed.

Example 1

Solve $\dfrac{dy}{dx} = \dfrac{2x}{y+1}$

We can rewrite this as $(y+1)\dfrac{dy}{dx} = 2x$

Now integrate both sides with respect to x:

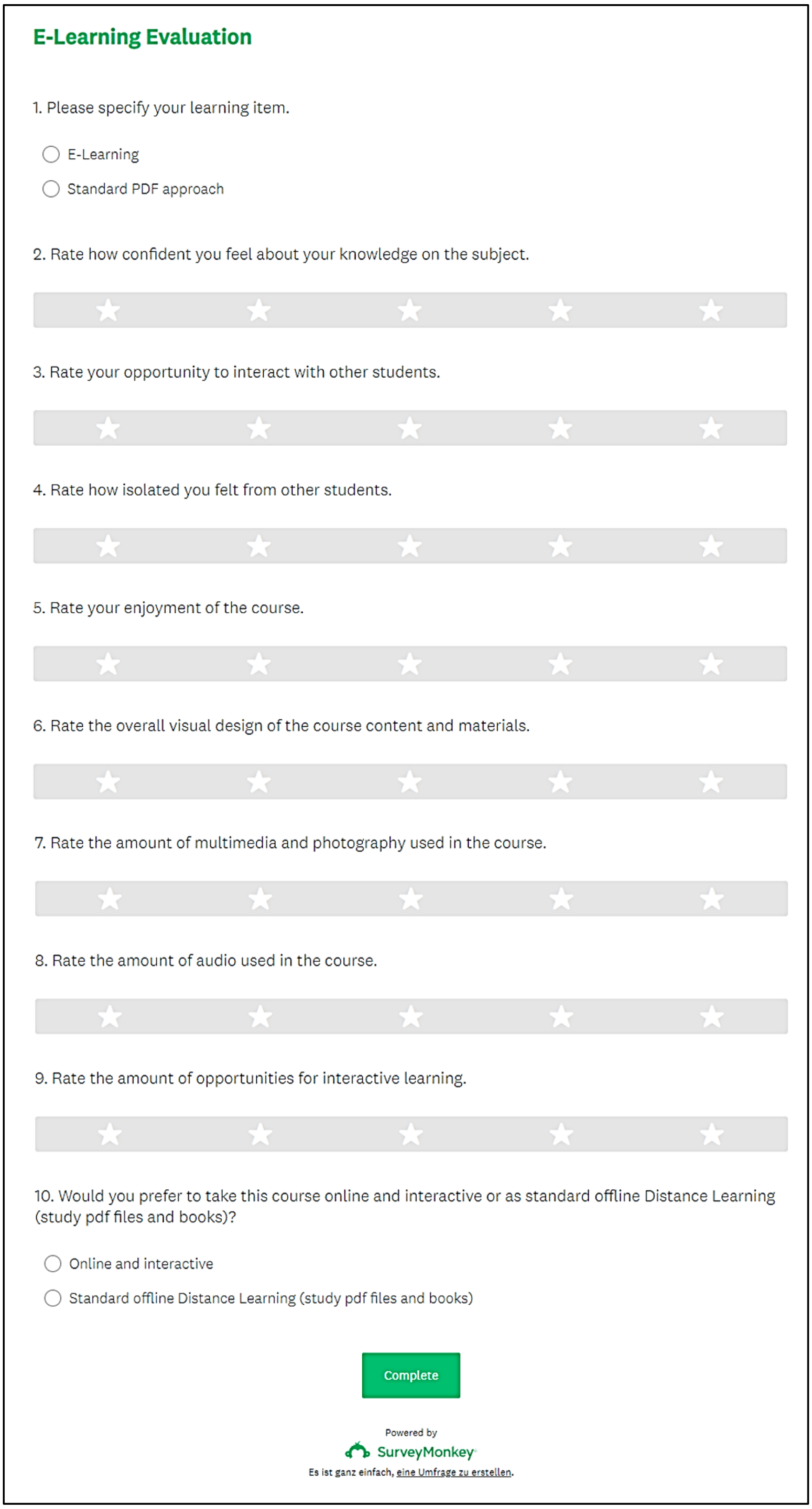
$$\int (y+1)\frac{dy}{dx}dx = \int 2x\,dx \quad \text{i.e.}$$

$$\int (y+1)\,dy = \int 2x\,dx$$

and this gives $\dfrac{y^2}{2} + y = x^2 + C$

C. Evaluation of Learning Experience

Online survey (available from www.surveymonkey.de/r/M82KS5G)



E-Learning Evaluation

1. Please specify your learning item.

- ◯ E-Learning
- ◯ Standard PDF approach

2. Rate how confident you feel about your knowledge on the subject.

☆ ☆ ☆ ☆ ☆

3. Rate your opportunity to interact with other students.

☆ ☆ ☆ ☆ ☆

4. Rate how isolated you felt from other students.

☆ ☆ ☆ ☆ ☆

5. Rate your enjoyment of the course.

☆ ☆ ☆ ☆ ☆

6. Rate the overall visual design of the course content and materials.

☆ ☆ ☆ ☆ ☆

7. Rate the amount of multimedia and photography used in the course.

☆ ☆ ☆ ☆ ☆

8. Rate the amount of audio used in the course.

☆ ☆ ☆ ☆ ☆

9. Rate the amount of opportunities for interactive learning.

☆ ☆ ☆ ☆ ☆

10. Would you prefer to take this course online and interactive or as standard offline Distance Learning (study pdf files and books)?

- ◯ Online and interactive
- ◯ Standard offline Distance Learning (study pdf files and books)

Complete

Powered by
SurveyMonkey
Es ist ganz einfach, eine Umfrage zu erstellen.

Results[20]

E-LEARNING	PDF
1.)Rate how confident you feel about your knowledge on the subject.	
4, 4, 5, 5, 4, 4, 5, 5	4, 3, 2, 3, 2, 3, 3, 2
2.)Rate your opportunity to interact with other students.	
5, 4, 4, 4, 4, 4, 5, 4	2, 1, 1, 1, 1, 1, 1, 1
3.)Rate how isolated you felt from other students.	
1, 2 , 2, 2, 2, 1, 1, 1	2, 5, 5, 5, 5, 5, 5, 1
4.)Rate your enjoyment of the course.	
5, 4, 5, 5, 4, 5, 5, 5	2, 2, 1, 3, 1, 2, 2, 1
5.)Rate the overall visual design of the course content and materials.	
5, 4, 5, 5, 4, 5, 5, 5	1, 1, 1, 1, 2, 1, 1, 1
6.)Rate the amount of multimedia and photography used in the course.	
5, 4, 5, 4, 5, 4, 5, 5	1, 1, 1, 1, 1, 1, 1, 1
7.)Rate the amount of audio used in the course.	
5, 4, 3, 4, 4, 4, 4, 5	1, 1, 1, 1, 1,1, 1, 1
8.)Rate the amount of opportunities for interactive learning.	
5, 4, 5, 4, 4, 4, 5, 5	1, 1, 1, 1, 1,1 ,1, 1
9.)Would you prefer to take this course online and interactive or as standard offline Distance Learning (study pdf files and books)?	
online, online, online, online, online, online, online, online	online, online, online, standard, online, online, online, online

[20] Star rating let's people rate a product/service with a number of stars (here 1 to 5 stars)

Appendix 4: Interview Questions (#4)

1. You have a background in engineering and/or you work in an R&D or technical environment in the Lift Industry. New & innovative products and technologies are coming into market every now and then. To stay up-to-date, you want to learn more about those new technologies and products.

   Q1: In which format or mode would like to receive the information about new technologies and products (e.g.: application of linear motor technology, vibration control measures or lightweight composite materials)?

2. You know that Ride Quality is an essential criterion for the assessment of a lift installation. You are reasonably familiar with Machine Dynamics, System/Car Vibration, Mathematical Models, Software and Calculation Methodologies.

   Q2: How do you prefer to learn respectively expand your subject matter knowledge about the topics mentioned above? Please consider your individual Learning Preferences.

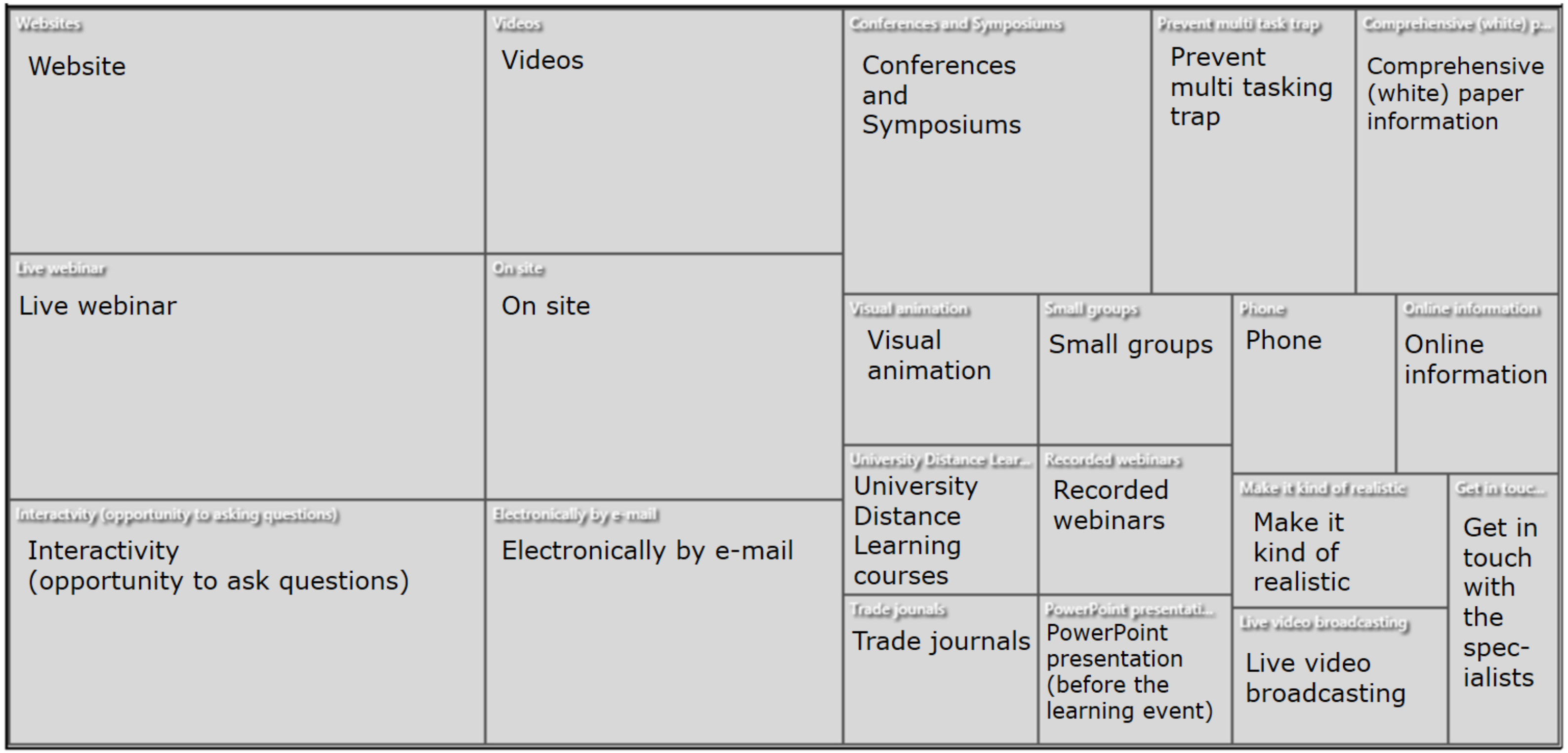
3. Most people are somehow familiar with Social Media platforms (e.g. Facebook, WhatsApp, LinkedIn). These platforms became an ordinary communication tool to chat and to stay in touch with family, friends and colleagues all over the world.

   Q3: How do you expect to learn with your Social Network, if Social Media should support your learning journey?

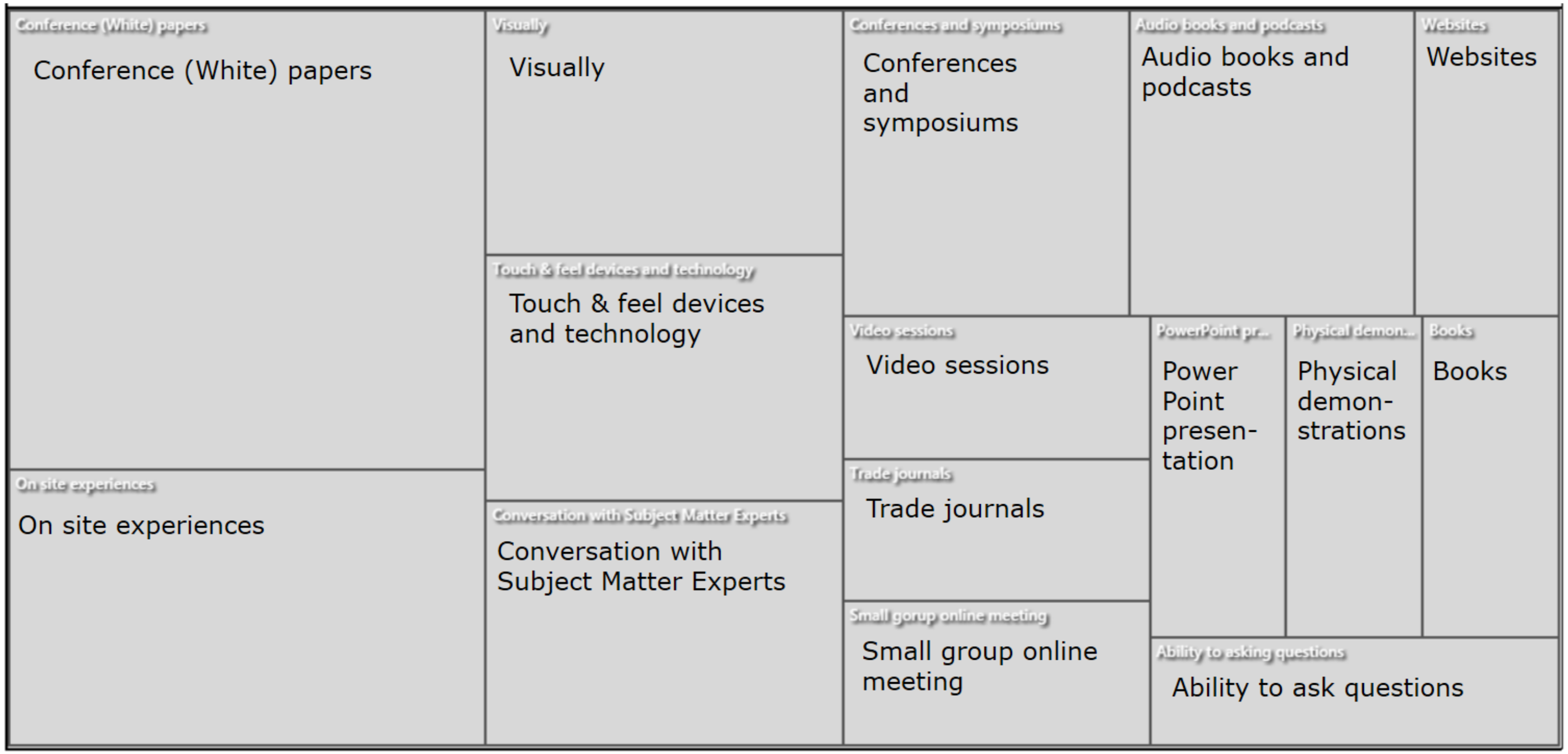
   Q4: What kind of information do you typically exchange?

Appendix 5a: Word Cloud (Interviews)

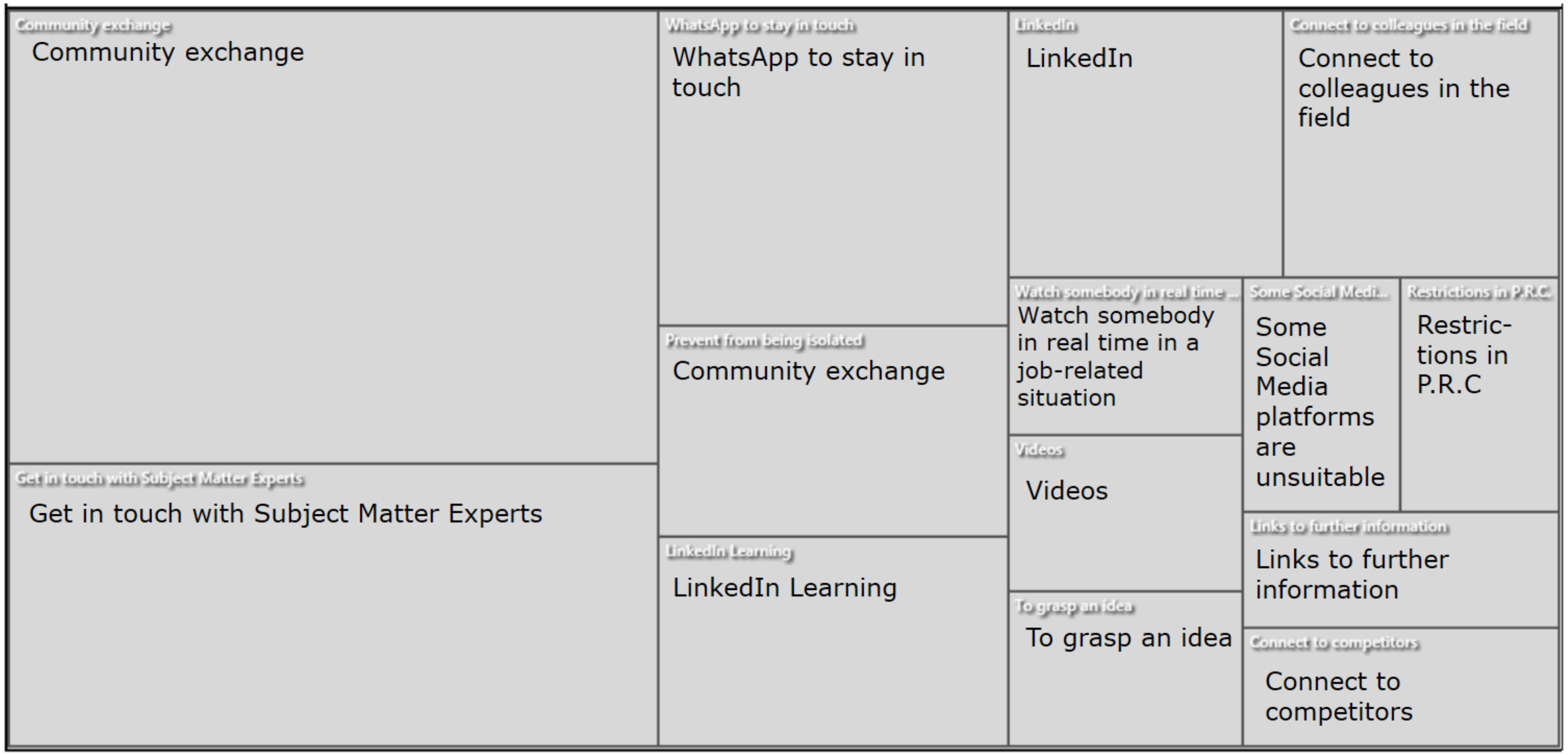
Appendix 5b: Visualization of answers to Question 1



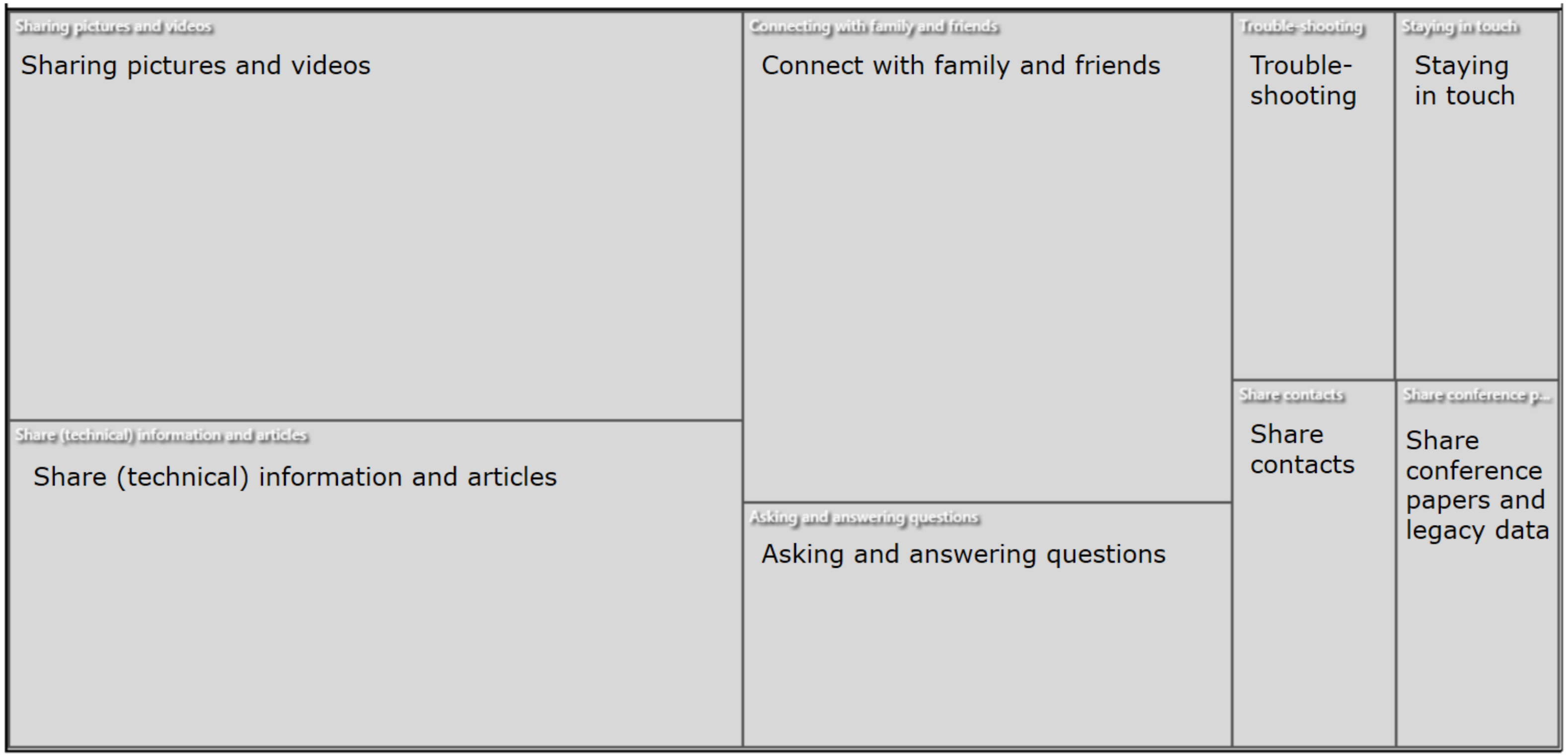
Appendix 5b: Visualization of answers to Question 2



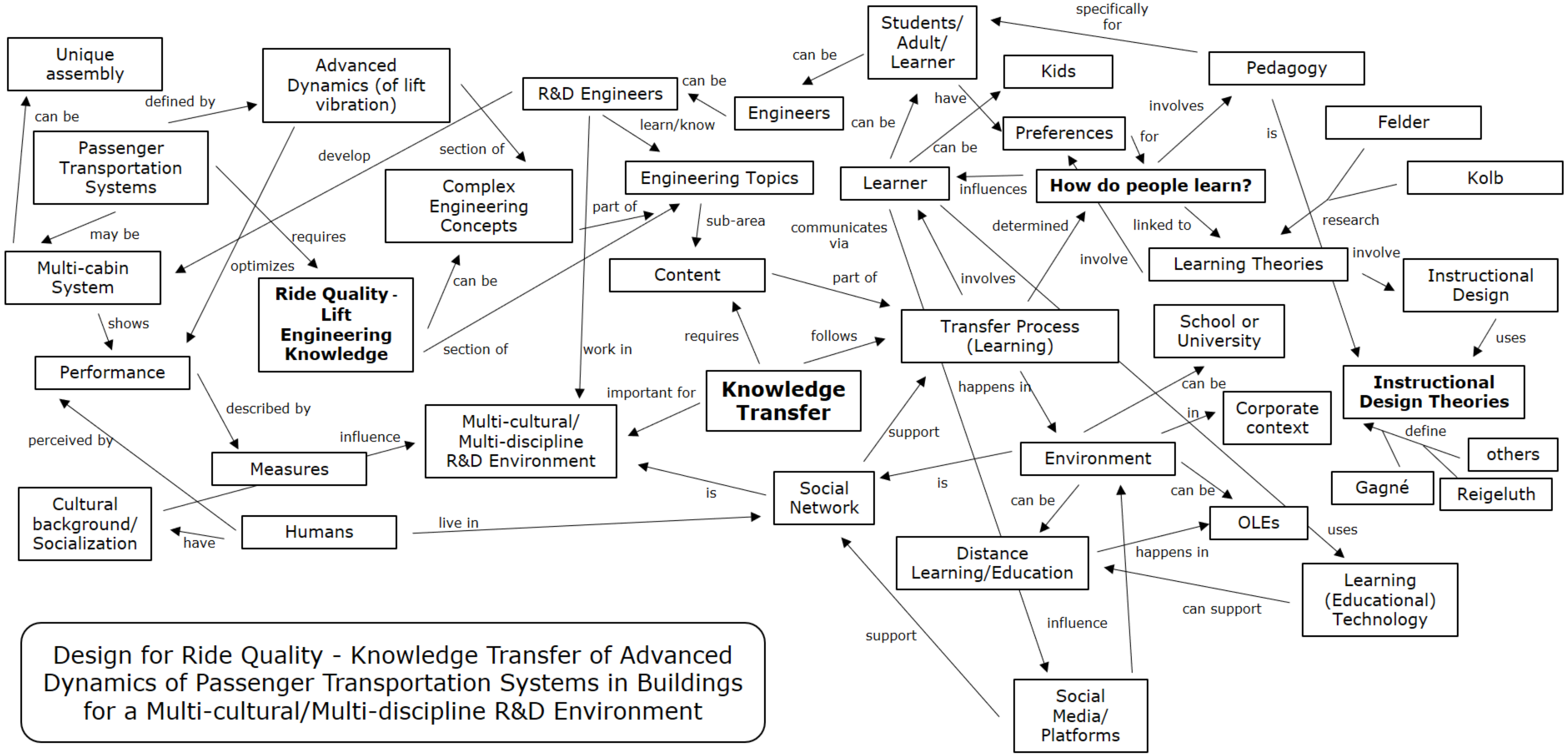
Appendix 5b: Visualization of answers to Question 3



Appendix 5b: Visualization of answers to Question 4



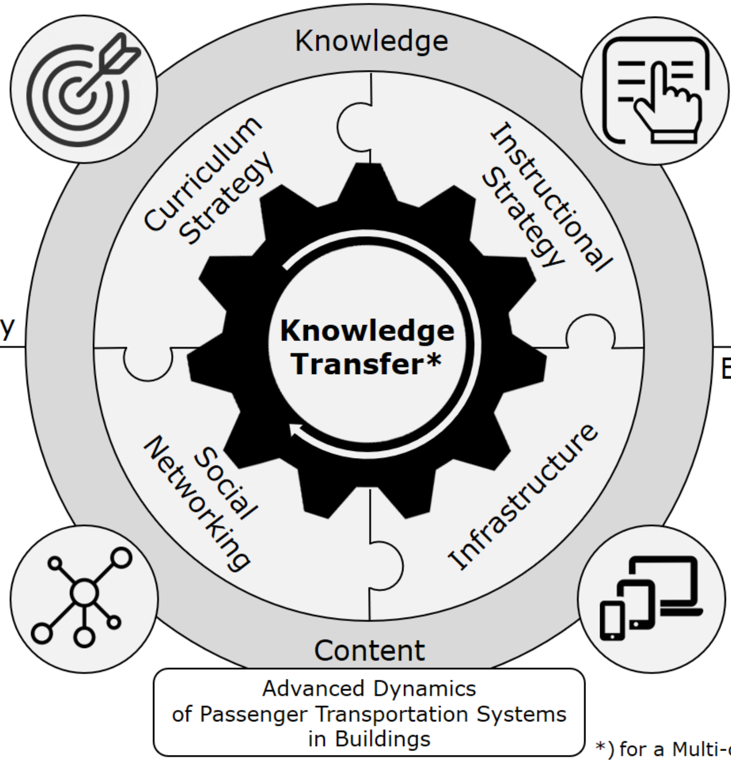
Appendix 6: Concept Map



Appendix 7: Components of successful Knowledge Transfer

Curriculum Strategy
- Effective Program Management
- Trainings Needs Analysis
- Relevancy
- Alignment to Business Strategy with Leadership buy-in
- Goals, metrics and success measures (evaluation)
- Marketing & Communication

Instructional Strategy
- Suitable Pedagogy and Instructional Design (e.g.: active participation, audience relevance, collaboration)
- Awareness for Learning Preferences
- Provide effective digital design for Distance Learning (include: activity, scenarios, interactivities, visuals, animation, audio)



Social Networking
- Provide the *University* feeling
- Engage with student groups, other professionals or Subject Matter Experts
- Enhance student involvement and engagemenet
- Supplement teaching in traditional classroom environments
- Enriching existing curriculum through creative, learning experiences
- Opportunity to share curriculum-related resources

Infrastructure
- Apply entire range of Education Technology
- Responsive mobile design
- Assessment tools
- Various forms of digital learning (webinars, e-learning, videocasts, etc.)
- Allow face-to-face (symposiums, site visits, etc.)

*) for a Multi-cultural/Multi-discipline R&D Environment