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Design, Development, Implementation and Assessment of Skill Formation Process in the Frame of VET for R&D Staff

Intellectual Output 2: Curriculum on R&D and Innovation

Abstract

At the beginning of this project, based on the research in this field, no specific interactive curriculum based on R&D and innovation in order to apply R&D staff was found. Within this project, we aimed to fill this gap. The developed curriculum will satisfy a great opportunity for a wide group of R&D staff from different disciplines who are interested in R&D and innovation to improve their job-related skills.

In this curriculum, a new curriculum which is developed to improve knowledge and research skills of R&D staff is introduced after completing IO2. The brief description of all courses are given herein. After a comprehensive need analysis carried out in IO1, ten courses are decided to be included in this curriculum by the project partners.

This curriculum can be applicable or adoptable for countries except our partnering countries. Since the project provides open-access, the curriculum will be translated into our project partners's languages, Turkish, Italian and Spanish from English in their video shootings.

1. Introduction

In today's world, where science and technology fields are experiencing new developments day by day, R&D has the undeniable importance both in the private sector and in the countries. The importance and value of knowledge are increasing rapidly, while innovation is becoming the key to competitiveness.



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Due to the activities carried out by our organization, it is observed that the engineers working in the industry are deficient on R&D and innovation subjects and that the vocational education required under these headings is not given to the engineers at the undergraduate level and the education given at the graduate and even doctorate levels is insufficient. By taking this international problem into account, the main aim of our project is to implement transnational activities and collaborations which are focusing on supporting and developing R&D and innovation based vocational training of the engineers in both EU and Turkey. These initiatives and collaborations include the creation of an expanded international joint vocational training curriculum, the development of ICT-based innovative, effective and sustainable tools (the development and implementation of the e-learning tool), as well as a skill-formation certification which is planned to be given at international level and added into higher education curricula. Our project is based on the contemporary matters such as R&D, supporting the personnel working within R&D studies and international collaborations focusing on work-oriented learning. The target group in this project is those who are working within the scope of R&D.

At this stage of the project, in IO2, we have determined ten courses included into the developed curriculum as a result of the outputs of IO1. In the following sections, the descriptions of the courses are introduced.

2. The Utilized Methodology

For the design stage of the curriculum, Dick and Carey's curriculum design model is applied, which includes a set of events and phenomena in which the designer identifies learning objectives and instructional strategies to achieve those goals. The courses have been decided as a result of the need analysis received from the questionnaire form applied to R&D staff. The curriculum has been prepared by Target TTO, IBOX, VITECO, MAN and İstanbul University Cerrahpaşa. The topics firstly determined by Target TTO have been evaluated by all project partners and necessary changes have been made. Within the scope of stated activities, it is foreseen that the training will include ten (10) topics. These topics have been shared evenly among Target TTO, IBOX, VITECO and İstanbul University Cerrahpaşa, then appropriate instructors have been determined and needed video materials have been prepared. The post-processing of the video shootings is still carrying out at this moment.



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The topics of ten courses and the corresponding organization leader selected among project partners for video shooting are listed below:

- | | |
|----------------------------------------------|----------------------------------|
| 1- Introduction to R&D | (IBOX) |
| 2- Experimental Product Design – DFX | (IBOX) |
| 3- Business Model | (VITECO) |
| 4- TRIZ | (Target TTO) |
| 5- Intellectual Property Rights | (Target TTO) |
| 6- Industry 4.0 | (Target TTO) |
| 7- Data Analysis and Statistics | (Target TTO) |
| 8- Problem Solving Approach | (İstanbul University Cerrahpaşa) |
| 9- Project Development Stages and Techniques | (İstanbul University Cerrahpaşa) |
| 10- Project Management | (İstanbul University Cerrahpaşa) |

The curriculum profile has been elaborated and structured according to ECVET guidelines. The profile describes the key activities (learning units) and for each activity skills and knowledge needed. A set of ECVET points are allocated to each unit in order to allow its recognition and transfer in other existing official qualifications and comparison with similar profiles in different countries, which is given in Table 1.

Table 1. The curriculum Profile according to ECVET Guidelines

LEARNING UNIT	LEARNING OUTCOME	COMPETENCE/SKILL	N. HOURS TEACHING	N. HOURS SELF STUDY	TOTAL N. HOURS	ECTS
Introduction to R&D	Understanding on what is Innovation and what is not	How to detect Innovation	1	3	4	0.4
	To know the different types of Innovation					
	Understand the importance of R&D to corporations					
	Understand the structure of Innovation Ecosystems and the Public Funding	To know on the different bodies working on R&D				
Experimental Product Design	Understand the importance of DFX Product Design to corporations	Determine the competitive advantages of companies	1	3	4	0.4
	To know the Eco-	Methodology of product				



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	design and environmental product design	lifecycle analysis				
	To know the different types of product design prototype	How to differentiate prototypes				
Business Model	Understand what is a Business Model		1,5	2,5	4	0,4
	Learning about the Business Model Canvas	How to use the Business Model Canvas				
	Learning about the 3 Questions Model	How to use the 3 Question Model				
	Learning about the Bridge Model	How to use the Bridge Model				
TRIZ	Understand TRIZ and systematic innovation	Overall Problem Solving Approach by TRIZ	1	3	4	0,4
	Understand Levels of Innovation for TRIZ	Gains the steps from levels of innovation to TRIZ strategies				
	Learning about the TRIZ steps	Gains TRIZ Contradiction Matrix				
	Adapts TRIZ Solution to Specified Problem	How to adapt any problem to TRIZ solution				
Intellectual Property Rights	Understand Fundamentals of IP rights	How to use different IP rights for innovation management	1	0,5	1,5	0.4
	Understand basics of patent application strategies	How to create patent application strategy				
	Understand basics of reading patent bibliographic information	How to use patent bibliographic patent information				
	Understand patent searching strategies	How to use patent databases				
	Understand patent data analysis	How to use patent data				
Industry 4.0	Understand the need for Industry 4.0	To determine a need for digital transforming	1	3	4	0.4
	Understand the industrial revolutions and their key innovations	How to differentiate industries, determine the revolution degree of a company				
	Learning about Cyber Physical systems and related concepts	Knowledge about cyber physical systems, big data, cloud systems, and their applications				
	Learning about Intelligent Objects and Intelligent Production systems	Knowledge about intelligence of objects and production systems				
Data Analysis and Statistics	Classifying the list of input variables.	Develop a plan to investigate a large number of independent variables (inputs) that can	1	3	4	0.4



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		control the response variable (s).				
	Updating the list of input variables.	To investigate the effect of independent factors on a variable response factor.				
	ANOVA study; Updating the list of input variables	To understand the use of the ANOVA table to determine the effect of multiple input variables on a response.				
	Correlation/Regression analysis; Updating the input list	To use correlation & regression tools to narrow the list of continuous input variables.				
Problem Solving Approach	To know the challenge and understand the issues and benefits of a problem solving approaches	To be able to identify the primary cause of the problem Determine what happened. Determine why it happened. Figure out what to do to reduce the likelihood that it will happen again.	1	3	4	0,4
	To know how to change one's state of mind	To come up with many supporting details as possible to be able to Identify how the change in the process or system affects customers				
	To know the problem-solving tools and know how to use them	To be able to Clarify and identify the problem				
	To have an effective problem-solving process	To change perspectives to redefine the problem.				
	Being able to contribute in a working group	to come up with innovative solutions, make a decision, and take action quickly				
	To know how to lead a problem solving like a project					
	Project Development stages and Techniques	Aligning the corporate strategy and the R&D strategy	To be able to align corporate strategy and the R&D strategy	1	3	4
Developing R&D management strategies to maximize the outputs		To be able to develop R&D management strategies to maximize the economic value produced by the R&D project outputs				
Selecting and balancing R&D portfolios		To be able to select R&D portfolios				



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	Developing a sales strategy	To be able to develop a sales strategy to ensure all facets of the business prioritize customer satisfaction as the primary concern				
	Evaluating R&D projects	To be able to evaluate R& projects				
	Test tools for Minimum Viable products	To be able to test tools for minimum viable products to gather important feedback and estimate market interest from the earliest stages business				
Project Management	Apply a set of best practice project management skills to a project	To know how to use core tools and techniques for managing projects through life cycles	1	3	4	0,4
	Manage the scope, cost, timing, and quality of the project	To be able to apply project management best practices in initiating, planning, executing and closing a project.				
	Successfully plan and implement projects	To be able to apply project management best practices in initiating, planning, executing and closing a project.				
	Complete a project within budget and on schedule	To be able to managing the budget of the project and ensure to close on time.				
	Delegate responsibilities to project team members	To be able to manage a project team.				
	Manages project risk, including identifying, analyzing and responding to risk	To be able to analyze risk in the project				

3. Results and Discussion

At the end of IO2, ten courses have been determined as a result of a comprehensive need analysis, and then the course details including course contents, related chapters and sub-sections, scope, etc. have been revealed. In this section, the details of each course will be introduced.



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3.1. Introduction to R&D

The aims of the course on R&D and innovation are:

1. To promote critical capacity and improve business competitiveness, through the definition, implementation and management of R&D environments and processes.
2. To know the integration of R&D management into new business models using the most appropriate tools and methodologies.
3. Lay the groundwork for starting to implement R&D along the guidelines of European R&D support policies.
4. To know processes that serve to support decision making in the Ideation step from R&D

The course content is given as:

Chapter 1: Introduction to Innovation

- 1.1 The need of Innovation
- 1.2 R&D Types
- 1.3 Innovation Ecosystems

Chapter 2: The Innovative Company

- 2.1 Methodology for Innovation: Ideation - Piloting - Implementation
- 2.2 Leadership and Motivation
- 2.3 Project Management

Chapter 3: European R&D support policies

- 3.1 The European R&D framework
- 3.2 EU R&D public funding programs: Horizon Europe
- 3.3 EU Project Management

Chapter 4: Decision making processes: Technology Surveillance, Benchmarking and Competitive Intelligence

- 4.1 Basis for Technology Surveillance
- 4.2 Benchmarking analysis
- 4.3 Process of Competitive Intelligence



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3.2. Experimental Product Design – DFX

The aims of the course on Product Experimental Design are:

1. Stimulating inventiveness to foster innovation.
2. Develop, systematize and structure the creative process.
3. Promote creativity and ingenuity for the development of innovative products.
4. Develop the ability to imagine, create and represent new product ideas.
5. Provide knowledge and develop skills to carry out experimental product design.

The course content is given as:

Chapter 1: Analysis of design and functionality

- 1.1 Product definition; product features and requirements
- 1.2 Conceptual design; innovative, adaptive, conception
- 1.3 Selection of alternatives; feasible solutions

Chapter 2: Product Design

- 2.1 Restriction Analysis.
- 2.2 Strategies and ability to explore different design possibilities
- 2.3 Detail specification

Chapter 3: Redesign for product innovation

- 3.1 Stages of the methodology

Chapter 4: Eco-design and environmental design of products

- 4.1 Introduction to eco-design and environmental design
- 4.2 Life-cycle analysis methodologies.

Chapter 5: Product Prototype

- 5.1 Types of prototypes and their classification
- 5.2 Design Validation

3.3. Business Model

This course aims to broaden the knowledge of business models as well as showing possible business models and practical ways to use them. The course introduces the concepts, tools, and principles of business model design as well as its role in the innovation process. The main emphasis will be on understanding how firm's resources and capabilities should serve as a basis on which business model can be designed in order to achieve a sustainable competitive



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advantage. In addition, the difference between the vision to get toward a long-term goal and the tool to execute a business strategy will be analyzed.

The course content is given as:

Chapter 1: Introduction to Business Model

- 1.1 Business Model Definition
- 1.2 Business Plan vs. Business Model
- 1.3 Business Model vs. Business Strategy

Chapter 2: The Business Model Canvas

- 2.1 The nine Building Blocks
 - 2.1.1 Value Proposition
 - 2.1.2 Customer Interface
 - 2.1.3 Infrastructure Management
 - 2.1.4 Profit Equation
- 2.2 Practical tips and suggestions

Chapter 3: The Three Questions Model

- 3.1 How does it work and why does it help entrepreneurs?
- 3.2. What are you selling?
- 3.3. To whom are you selling?
- 3.4. For how much are you selling?

Chapter 4: The Bridge Model

- 4.1. Bridge 1 - Start My Business: from “I Have An Idea” to “I Have A New Business”
- 4.2. Bridge 2 - Growing my Business. From “I have a new business” to “ I have a successfully operating business”
- 4.3 Bridge 3 - Strengthen my Business. Make my business more secure. From “I have a successfully operating business” to “I have a growing business”
- 4.4 Bridge 4 – Strengthen my Business. From “I have a growing business” to “I have a sustainably strong business”



3.4. TRIZ

The aims of the course on Theory of Inventive Problem Solving (TRIZ) are:

1. To develop an understanding on overall problem solving approach by TRIZ, implementation of TRIZ to systematic innovation and to promote practical techniques to all professionals working for R&D centers.
2. To gain the steps from levels of innovation to TRIZ strategies and to know the inventive principles to eliminate technical contradictions
3. To gain TRIZ Contradiction Matrix and to solve the problems by using Altshuller's 40 principles of TRIZ (40 inventive principles)
4. To adapt any problem to TRIZ solution by identifying the problem, formulating the problem, referring to previously well solved problem and finalize the ideal solution
5. This course offers a package of practical techniques to all professionals working for R&D centers, which help to analyze existing products and situations, extract root problems, reveal potential opportunities for evolution, and generate new solution concepts in a systematic way.

Followings are the main contents of the course.

Chapter 1: Introduction to TRIZ

- 1.1 What is TRIZ and Systematic Innovation
- 1.2 History and Background
- 1.3 Theory of Inventive Problem Solving
- 1.4. How TRIZ Works

Chapter 2: Levels of Innovation for TRIZ

- 2.1 Altshuller's 5 Levels of Innovation
- 2.2 TRIZ Strategies
- 2.3 TRIZ Contradictions
- 2.4 Overall Problem Solving Approach by TRIZ
- 2.5. Ideal Final Result

Chapter 3: TRIZ Principles

- 3.1 Example of TRIZ Principles
- 3.2 Inventive Principles to Eliminate Technical Contradictions

Chapter 4: TRIZ Steps

- 4.1 Technical Contradictions (39 TRIZ Features)



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4.2 Engineering Parameters

4.3 Altshuller's 40 Principles of TRIZ (40 Inventive Principles)

4.4 TRIZ Contradiction Matrix

Chapter 5: TRIZ Steps on Specified Problem

5.1 Identifying the Problem

5.2 Formulate the Problem

5.3 Previously Well Solved Problem

5.4 Adapt TRIZ Solution to Specified Problem

5.5 Example (Beverage Can)

3.5. Intellectual Property Rights

This course aims to provide information about basics of IP and strategic use of patent information for innovation management.

The course content is given as:

Chapter 1: Fundamentals of IP Rights

1.1. Patent

1.2. Utility Model

1.3. Industrial Design

1.4. Trademark

Chapter 2: Basics of patent application strategies

2.1. Patentability requirements

2.2. Advantages of patent application

2.3. Patent application routes

Chapter 3: Basics of reading patent bibliographic information

3.1. Understanding bibliographic information of a patent document

3.2. Parts of a patent document

Chapter 4: Basics of patent searching strategies

4.1. Technology scouting platforms

4.2. Patent search databases

4.3. Patent Terminology

4.4. Search tips



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Chapter 5: Basics of patent data analysis to use for competitive intelligence

- 5.1. The magic of patent information
- 5.2. How to use patent information as a competitive intelligence tool
- 5.3. Examples of patent data analysis
- 5.4. Commercialization routes for IP

3.6. Industry 4.0

The main purpose of the course to give brief information about Industry 4.0 and its technologies, to give the requirements of Industry 4.0, and to explain the reasons to be ready of transforming our companies to the fourth industrial revolution.

The course content is given as:

Chapter 1: Motivation

- 1.1 Changes in Manufacturing Industry
- 1.2 German Manufacturing Industry
- 1.3 Birth of Industry 4.0
- 1.4 Technology and Innovation Management
- 1.5 Reasons for Requirement of Industry 4.0

Chapter 2: Industrial Revolutions

- 2.1 Industry 1.0
- 2.2 Industry 2.0
- 2.3 Industry 3.0
- 2.4 Summary of Industrial Revolutions

Chapter 3: Industry 4.0 – Main Concepts

- 3.1 The Fourth Industrial Revolutions
- 3.2 Definition for Industry 4.0
- 3.3 Economic Potential of Industry 4.0
- 3.4 Automation Pyramid and Industry 4.0
- 3.5 Other Industry 4.0 Approaches of the World

Chapter 4: Cyber-Physical Systems (CPS)

- 4.1 Definitions for Cyber-Physical Systems
- 4.2 Components of CBS



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4.3 Essential Dimensions of CBS

4.4 Digital Twin

Chapter 5: Intelligent Object

5.1 Definition of Intelligent Objects

5.2 Behaviour of Intelligent Objects

5.3 Intelligent Object and Intelligent System

Chapter 6: Internet of Things and Services (IOTS)

6.1 Definition of Internet of Things and Services

6.2 Internet of Things (IoT)

6.3 Internet of Services (IoS)

6.4 Internet of Everything (IoE)

Chapter 7: Identification Technologies

7.1 Introduction to Identification Technologies

7.2 Barcode

7.3 RFID

7.4 Indoor Global Positioning System (GPS)

7.5 Machine to Machine (M2M) Communication

Chapter 8: Sensors and Actuators

8.1 Sensors

8.2 Actuators

8.3 The Benefits of Sensors and Actuators

Chapter 9: Big Data

9.1 Definition of Big Data

9.2 5Vs of Big Data

9.3 Usage of Big Data

Chapter 10: Cloud Systems

10.1 Definition of Cloud Systems

10.2 Cloud Manufacturing

10.3 The Requirements of Cloud Based Processing

10.4 Cloud Computing

10.5 Edge Computing



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Chapter 11: Artificial Intelligence (AI)

11.1 Definition of Intelligence and Artificial Intelligence (AI)

11.2 Capabilities of AI

11.3 Machine Learning (ML)

Chapter 12: Additive Manufacturing

12.1 Definition of Additive Manufacturing

12.2 Stereolithography (SL)

12.3 Fused Deposition Modelling (FDM)

12.4 Selective Laser Sintering (SLS)

12.5 Laminated Object Manufacturing (LOM)

12.6 Laser Engineered Net Shaping (LENS)

12.7 Advantages and Disadvantages of Additive Manufacturing

Chapter 13: Augmented Reality / Virtual Reality

13.1 Virtualization Technologies

13.2 Virtual Reality (VR)

13.3 Augmented Reality (AR)

13.4 AR / VR and CPS

3.7. Data Analysis and Statistics

The aims of the course on R&D and innovation are:

1. To introduce the use of the statistics science in a research and development environment.
2. To create awareness about statistical tools and their use via a statistical software package to draw visual graphs and causal conclusions from experimental data.
3. To improve the data analysis and interpretation skills of the personnel working in the research and development departments of enterprises.

The course content is given as:

Chapter 1: Introduction to Analysis

1.1 What is a process?

1.2 Why do we need a plan?

1.3 Critical Questions



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- 1.4 Hypothesis Testing
- 1.5 Variable Definitions
- 1.6 Define Your Data Correctly!
- 1.7 Hypothesis Testing Guide
- 1.8 Characteristic Questions: Univariate
- 1.9 Characteristic Questions: $Y = f(X's)$
- 1.10 DMAIC: Summary on Analyse Phase

Chapter 2: One Sample Analysis (Continuous)

- 2.1 Characteristic Questions: Univariate
- 2.2 Framework
- 2.3 Graphing Your Data
- 2.4 Checking the Normality Assumptions
- 2.5 Confidence Intervals
- 2.6 Interpretation Confidence Intervals
- 2.7 Confidence Interval Calculation
- 2.8 Confidence Interval for the Population Mean
- 2.9 What is the t-Distribution?
- 2.10 t-Distribution vs. Normal Distribution
- 2.11 Confidence Interval for Population Standard Deviation
- 2.12 Compare Actual Estimated Mean to a Hypothesized (Test) Mean
- 2.13 Compare Actual Estimated Std Dev to a Hypothesized (Test) Std Dev

Chapter 3: Two Sample Analysis

- 3.1 Hypothesis Testing States
- 3.2 Why We Test Population Parameters Against Each Other?
- 3.3 Comparing Two Variances
- 3.4 Test for Equal Variance
- 3.5 What is $F_{critical}$?
- 3.6 Test for Unequal Variances (JMP)
- 3.6 Pen Cap Machines Example
- 3.7 Normality Test for Machine #1
- 3.8 Normality Test for Machine #2
- 3.9 Hypothesis Testing Using JMP
- 3.10 Comparing Two Means



3.11 Population 1 Mean vs. Population 2 Mean

3.12 Hypothesis Testing - Variables

3.13 Paired Comparisons (T-tests)

3.14 Paired Comparison: Shoes Example

Chapter 4: Analysis of Variance (ANOVA)

4.1 Multiple Means Comparison (ANOVA)

4.2 Analysis of Variance Highlights

4.3 Anova Method: Step 1: State the practical question

4.4 Step 2: State the Hypothesis

4.5 Step 3: Construct the Anova Table

4.6 Example: Experimental Setup

Chapter 5: Correlation & Regression

5.1 Definitions

5.2 Why Do We Use These Tools?

5.3 Correlation Description

5.4 Data Requirements

5.5 Correlations

5.6 Estimating the Correlation Coefficient

5.7 Abuse and Misuse of Correlation

5.8 Stork Example

5.9 Correlation Example 1

5.10 Correlation Example 2

5.11 Regression Analysis Description

5.12 Coefficient of Determination, R-Squared

5.13 Regression Example (Fitted Line Plot)

5.14 Class Examples

5.15 Summary Comments

3.8. Problem Solving Approach

The main purpose of the course is to give brief information about problem solving tools to be able to recognize different problems which are a kind of day-to-day management in the life of a business.



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The course content is given as:

Chapter 1: Strategies for Problem Cause Identification

1.1 Root Cause Analysis

1.2 Fishbone Diagram

1.3 5 Whys

Chapter 2: Divergent Creative Problem Solving Techniques

2.1 Brainstorming

2.2 Mind Mapping

2.3 A3 Thinking

2.4 Creative Thinking

2.5 Critical Thinking

2.6 Design Thinking

Chapter 3 - Problem Solving Techniques to Change Perspective

3.1 Constructive Controversy (the art of arguing)

3.2 CATWOE

3.9. Project Development Stages and Techniques

The main purpose of the course to give the keys to succeed in R&D project development stages, building marketing and sales strategies.

The course content is given as:

Chapter 1: The Interdependence between Corporate Strategy, Technology Strategy and R&D Strategy- Defining a R&D Mission Aligned with Corporate Strategy

Chapter 2: Developing Business Models to Maximize the Economic Value Produced by the R&D Project Outputs

Chapter 3 - Selecting Your R&D Portfolio

Chapter 4 - Tools to Use for Focusing on the Real Problems and Needs of Customers

Chapter 5 - How to Carry Out Analysis of the Customers, Market Opportunity and Competition

Chapter 6 - How to Test the First Versions of the Product Being Developed (Minimum Viable Product) at the Early Stages of the Development

Chapter 7 - Developing a Sales Strategy

Chapter 8 - Evaluating R&D Projects



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3.10. Project Management

The main purpose of the course to give the keys to succeed in project management, to give the common project management mistakes that most managers experience and the 8 steps of the project closure.

The course content is given as:

Chapter 1 - Getting Started with Project Management

Chapter 2 - Initiating a Project

Chapter 3 - Planning a Project

Chapter 4 - Project Time Management

Chapter 5 - Planning Project Budget, Quality, and Communications

Chapter 6 - Planning for Risk

Chapter 7 - Managing Project Work, Scope, Schedules, and Cost

Chapter 8- Controlling the Project

Chapter 9 - Closing a Project

Chapter 10 - Project Management Basic Mistakes and Tips to Avoid Them

4. Conclusion

During this stage of the project, ten courses for the developed curriculum for R&D staff have been determined with their details. In this curriculum, the courses, their profile according to ECVET guidelines, scopes and contents are introduced.



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