Curriculum for

Certified Professional for Software Architecture (CPSA)®
Advanced Level

Module
BLOCKCHAIN

Low-Trust Consensus in Decentralized Applications

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List of Learning Goals

Introduction: General information about the iSAQB Advanced Level

What does an Advanced Level Module convey?

- The iSAQB Advanced Level offers modular training in three competence areas with flexible pathways through the programme. It acknowledges and supports individual strengths and focus points.
- The certification is based on a homework paper. Grading and oral examination will be carried out through an expert designated by iSAQB.

What qualifications do Advanced Level (CPSA-A) graduates gain?

CPSA-A graduates are able to:

- design medium to large IT systems idependently and based on solid methodical foundations
- take technical and operational responsibility in IT systems with medium to high criticality
- design and document measures to achieve quality requirements and support development teams implementing those measures
- manage communication relevant to architecture in medium to large development teams

Requirements for the CPSA-A certification

- successful training and graduation of Certified Professional for Software Architecture, Foundation Level® (CPSA-F)
- at least three years industrial, full-time experience in the IT sector; including collaboration on design and development of at least two different IT systems
  - exceptions may be granted (for example: contributions to open source projects)
- participation at iSAQB Advanced Level trainings worth at least 70 credit points from two different areas of competence
  - existing certifications (for example: Sun/Oracle Java architect, Microsoft CSA) may be credited
- passing the CPSA-A certification exam

Basics

What does the module “BLOCKCHAIN” convey?

The umbrella term "blockchain" describes a set of emerging, heterogeneous technologies for designing distributed systems that – while generally assuming little to no trust between parties – are able to establish consensus about stored data and procedures. Pioneered as a system to allow transfer of cryptographically secure monetary tokens, blockchains have since evolved to application platforms for executing smart contracts written in domain-specific languages. While cryptocurrencies are usually designed to lack a central authority, many industrial use cases admit partial cooperation between parties. The central idea common to all blockchain implementations is that transactions can be stored in an append-only ledger that is being kept on multiple nodes, increasing resiliency and decreasing the potential for fraudulent post-hoc modifications.

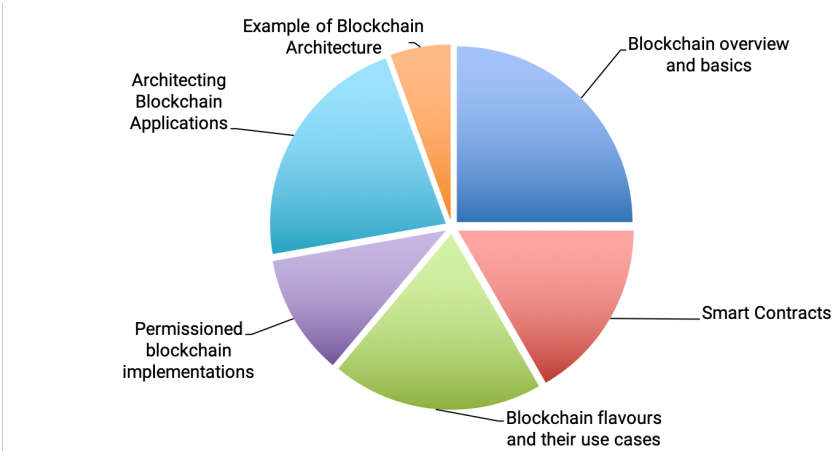
Participants of this module will learn to recognize and classify use cases of blockchain technology. They will gain a deep understanding the differences and trade-offs between their various flavours (public vs. permissioned, Proof-of-Authority/Stake/Work, smart contracts). Platform requirements and abilities, including languages for smart contracts and their testing and deployment, will be discussed.

The BLOCKCHAIN module focuses on the transfer of software engineering aspects from traditional methodologies to blockchain technologies. Participants will be able to make informed decisions about the tooling choices and be able to design decentralized applications.

Curriculum structure and recommended durations

Content	Recommended minimum duration (minutes)
1. Blockchain overview and basics	270
2. Smart Contracts	180
3. Blockchain flavours and their use cases	210
4. Permissioned blockchain implementations	120
5. Architecting blockchain applications	240
6. Example of Blockchain Architecture	60
Sum	1080 (18h)

Durations



Duration, didactics, and further details

The durations mentioned below are recommendations. A course for the BLOCKCHAIN should last at least 3 days. Provides may vary length, didactics, type and structure of exercises, and structure of the course. In particular, examples and exercises are left unspecified in this curriculum.

Licensed courses for BLOCKCHAIN contribute the following credit points to the Advanced Level graduation:

Methodical Competence:	10 Points
Technical Competence:	20 Points
Communicative Competence:	0 Points

Prerequisites

Participants should have the following prerequisite knowledge:

- basic theoretical and practical database skills
- knowledge of any modern programming language

Additional knowledge that may be helpful, but is not required, for understanding advanced concepts:

- distributed systems and consensus algorithms
- basic JavaScript experience

We explicitly do not require knowledge in the following fields:

- cryptography, cryptocurrencies

Structure of the curriculum

The sections of the curriculum are laid out as follows:

- **Terms/concepts**: core terminology of the topic
- **Instruction/exercise time**: specifies the minimum durations for instruction and exercise blocks for licensed trainings
- **Learning goals**: describes in detail the lessons, including core terminology and concepts

This section outlines the knowledge to be gained in the training sessions. The learning goals are classified according to the following categories:

- What should the participants **be able to do**? Participants should be able to apply these concepts by themselves without guidance. In courses, these topics should be covered by exercises and are part of the examination BLOCKCHAIN and/or the final examination of the iSAQB Advanced Level.
- What should the participants **understand**? These topics may be part of the examination {curriulum-short}.
- What should the participants **know**? These topics (terminology, concepts, methods, practices) may aid understanding or motivate broader concepts. They are not part of the examination and may be

discussed in trainings on a basic, abstract level.

Further information, terminology, translations

To the extent necessary for understanding the curriculum, we have added definitions of technical terms to the iSAQB glossary and complemented them by references to (translated) literature.

1. Blockchain overview and basics

Duration: 180 min.	Exercise time: 90 min.

This topic area introduces participants to the basic components of a blockchain. Training providers may choose to any blockchain to illustrate the concepts. Given that Bitcoin pioneered many of these components and combined them in a way that defines blockchains to this date, it is recommended to use it as a running example. While Bitcoin's focus and main application is squarely a cryptocurrency, it exhibits a structure on whose basis subsequent topics can be explained.

1.1. Essential terms

(cryptographic) hashing, public/private cryptography, addresses, wallets, transactions, blocks, mining, nodes, peer-to-peer networking, blockchain, cryptocurrency, (distributed) ledger, Proof-of-Work, Byzantine fault tolerance, Nakamoto consensus

1.2. Learning goals

LG 1-1: Definition of Blockchain Terminology

- know the definition of Blockchain and DLT
- know the main concepts and terminology of Blockchain and Distributed Ledger Technologies (DLT)
- know the definition of Smart Contracts and Decentralised Applications (DApps)
- understand how Blockchain Technology enabled Cryptocurrencies and Tokens

LG 1-2: Basic operation of a blockchain

- understand the interaction of all components to form a coherent system
  - a peer-to-peer network composed of nodes that propagate transactions and blocks
  - a miner as a special type of node that forges blocks that include transactions
  - a wallet as a piece of software that manages addresses
- able to navigate the complex terminology of blockchains
  - the role of Bitcoin (or any other blockchain) as a stereotypical cryptocurrency
  - the generalized role of the blockchain as a distributed, append-only ledger

LG 1-3: Cryptographic primitives

- know the cryptographic properties of hashing and digital signatures
  - a hash function can be computed easily, but finding the inverse is computationally infeasible
  - a signature algorithm requires a private key to produce a signature, but only a public key to verify

LG 1-4: Nakamoto consensus

- understand the design constraints leading to Byzantine fault tolerance
- know the notion of "longest chain wins"

- understand the evolution of the protocol itself by majority
- understand the mechanisms of soft and hard forks

LG 1-5: Trade-offs

- able to appraise the trade-offs of a blockchain compared to a traditional architecture
- understand the hardware resources required for Proof-of-Work
- know the advantages and disadvantages of a distributed, no-trust approach

1.3. References

- Andreas Antonopoulos: "Mastering Bitcoin: Unlocking Digital Cryptocurrencies"

2. Smart Contracts

Duration: 90 min.	Exercise time: 90 min.

This topic area incrementally extends – based on the basic terminology – the notion of blockchains to include the ability for executing arbitrary, client-defined code. With Ethereum being the first and to date most mature example of this technology, it is recommended to use it as a running example.

2.1. Essential terms

Virtual Machine, instructions, gas, gas price, bytecode, online wallets, DAO, Truffle, security

2.2. Learning goals

LG 2-1: Smart contracts basics

- able to create transactions
  - a wallet such as Metamask to interact with the network
- know main applications for smart contracts
  - Ethereum ERC-20 for arbitrary, transferable tokens
  - online wallets, multi-signature wallets

LG 2-2: Developing smart contracts

- implement and deploy smart contracts
- call smart contracts
  - estimating transaction fees based on gas required and the gas price
- develop, test and deploy smart contracts, for example using Truffle

LG 2-3: Virtual machines

- know the compilation pipeline from a high-level language to bytecode
- know basic instructions

LG 2-4: Security risks and implications

- know historic security flaws
  - unintended draining of the DAO contract
  - unintended destruction of Parity online wallet contracts
- able to estimate security risks for smart contracts
  - avoiding method reentrancy
  - avoiding double spending
- apply traditional methodologies to smart contracts
  - extensive unit testing with Truffle

2.3. References

- Andreas Antonopoulos, Gavin Wood: "Mastering Ethereum: Building Smart Contracts and Dapps"
- Consensys: "Ethereum Smart Contract Best Practices, https://consensys.github.io/smart-contract-best-practices/known_attacks/

3. Blockchain flavours and their use cases

Duration: 120 min.	Exercise time: 90 min.

This topic area aims to collect and classify the abundant variations of blockchain technologies that have proliferated since Bitcoin. It is crucial for the understanding of the participants that the training provider carves out relevant features and compares them across technologies. Given the volatile nature of the field, this should be based on regularly updated market research; as such, the flavours listed below are open-ended and should be updated to reflect new developments.

3.1. Essential terms

Proof-of-Work, Proof-of-Stake, Proof-of-Authority, public blockchains, private blockchains, permissioned blockchains, consensus algorithms, sidechains, state channels, trust, decentralization, immutable history, business processes, onboarding, privacy, security, arbitrators

3.2. Learning goals

LG 3-1: Feature axes

- understand block mining strategies
  - Proof-of-Work
  - Proof-of-Stake
  - Proof-of-Authority
- understand access control mechanisms
  - public, private and permissioned blockchains
  - sidechains
  - state channels
- know consensus algorithms
- know smart contract languages
- oracles
- naming services
- understand design trade-offs of blockchain flavours

LG 3-2: Choosing the best technology

- identify criteria for uses cases that benefit from blockchain technology
  - decentralization, trust model, malicious actors, competency, longevity
  - integrity and immutability of history
  - criteria for parties to join the network, access control, onboarding, arbitration
  - privacy and security of personal data
  - anonymity, pseudonymity, identity

- identify use cases based on functional and non-functional requirements
- apply traditional requirement engineering techniques to blockchain use cases
- transform business processes to a smart contract

3.3. References

- Bogensperger et al.: "Die Blockchain-Technologie: Chance zur Transformation der Energiewirtschaft?", https://www.ffe.de/attachments/article/846/Blockchain_Teilbericht_UseCases.pdf

4. Permissioned blockchain implementations

Duration: 90 min.	Exercise time: 30 min.

For a lot of business use cases, permissioned blockchains are likely the only reasonable choice. Corporations generally have no incentive to publish internal processes to a public blockchain. But as opposed to the public blockchain space that is domineered by a few implementations with few degrees of freedom, the permissioned space usually offers a lot more flexibility to tailor a solution. This topic area should provide an overview of major concepts in this space.

4.1. Essential terms

Corda, Hyperledger Fabric, Ethereum, X.509, TLS

4.2. Learning goals

LG 4-1: Permissioned blockchain implementations

- understand the benefits of permissioned blockchain regarding traditional businesses use cases
- understand the advantages of explicit governance
  - know the differences between in-chain and offchain governance
  - understand how to adjust access, verification, user rights and network structure to fit governance requirements
- know the trade-offs of reintroducing a certain level of centralisation while maintaining some of the inherent benefits of blockchain technology
- analyse quality attributes of permissioned blockchains (E.g. Corda, Hyperledger, Enterprise Ethereum)
  - know how to increase the performance by choosing different consensus algorithms
- know the technological differences in implementing major permissioned blockchains

LG 4-2: Infrastructure

- understand the infrastructure necessary for permissioned blockchains
  - X.509 and TLS are standards used for authentification and encryption
- understand the deployment patterns and their major implications on the functioning of the network
- be able to systematically comprehend and analyse the deployment patterns of major permissioned blockchains

5. Architecting blockchain applications

Duration: 150 min.	Exercise time: 90min.

Smart contracts by themselves are not sufficient to build Blockchain-powered applications. They need an external infastructure powering interaction between users and contracts. Decentralization is the key pattern for designing robust applications.

5.1. Essential terms

Decentralized applications, sidechains, state channels, light clients, ipfs, off-chain storage

5.2. Learning goals

LG 5-1: Architecting blockchain applications

- understand how Blockchain works as a software component of storage, computation and communication.
- know processes to design Blockchain applications
- know patterns for interaction, data management, security and contract structure.
- understand how to integrate Blockchain into a larger system.
- understand the principles of a Decentralised Application (DApp)
  - a smart contract that runs on the blockchain
  - an open source web application that interacts with the chain on behalf of the user
- undestand how to incentivize rational actors to behave a certain way using game theory

LG 5-2: Scalability

- understand the scalability challenges of public and permissioned blockchain implementations
  - understand the correlation between trust and bandwidth
  - know the performance trade-offs of PoW, PoS and PoA strategies
  - know hardware implementations of mining
- estimate the required computing power on server and client sides
  - able to design applications with light clients

LG 5-3: Storage

- understand the storage format and capacity of data on blockchains
- know the difference between on- and off-chain storage
- know the difference between replicated databases and decentralized storage
- know alternative storage methods
  - able to use distributed hash tables
  - able to understand peer-to-peer storages

LG 5-4: Privacy & Governance

- understand the durability of transactions on the blockchain
- design applications with regulatory compliance in mind
  - use hashes and salts for pseudonyms
  - know of zero-knowledge proofs

6. Example of Blockchain Architecture

Duration: 60 min.	Exercise time: 0min.

Within each licensed training there must be at least one example of blockchain architecture presented, discussed and evaluated. The type and severity of the examples may differ for each training provider or depend on the interests of the participants and are not specified by iSAQB.

References

This section contains references that are cited in the curriculum.

- Xiwei Xu, Ingo Weber, Mark Staples - Architecture for Blockchain Applications (2019, Springer)
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- Mike Hearn - Corda: A distributed ledger
- Patrick Rosenberger - Bitcoin und Blockchain (2018, Springer Berlin Heidelberg)
- Bellaj Badr - Blockchain By Example (2018, Packt)
- Imran Bashir - Mastering Blockchain (2017, Packt)
- Eric Traub - Learn Blockchain Programming with JavaScript (2018)
- Florian Bartholomae, Marcus Wiens - Spieltheorie: Ein anwendungsorientiertes Lehrbuch (2016, Gabler Verlag)
- Christian Kanzow, Alexandra Schwartz - Spieltheorie: Theorie und Verfahren zur Lösung von Nash- und verallgemeinerten Nash-Gleichgewichtsproblemen (2018, Springer International)
- Karl Wüst, Do you Need a Blockchain?: https://allquantor.at/blockchainbib/pdf/wust2017do.pdf
- Satoshi Nakamoto, Bitcoin: A Peer-to-Peer Electronic Cash System: https://bitcoin.org/bitcoin.pdf
- Vitalik Buterin, A Next-Generation Smart Contract and Decentralized Application Platform: https://github.com/ethereum/wiki/wiki/White-Paper
- E. Androulaki et al., Hyperledger Fabric: A Distributed Operating System for Permissioned Blockchains http://arxiv.org/abs/1801.10228