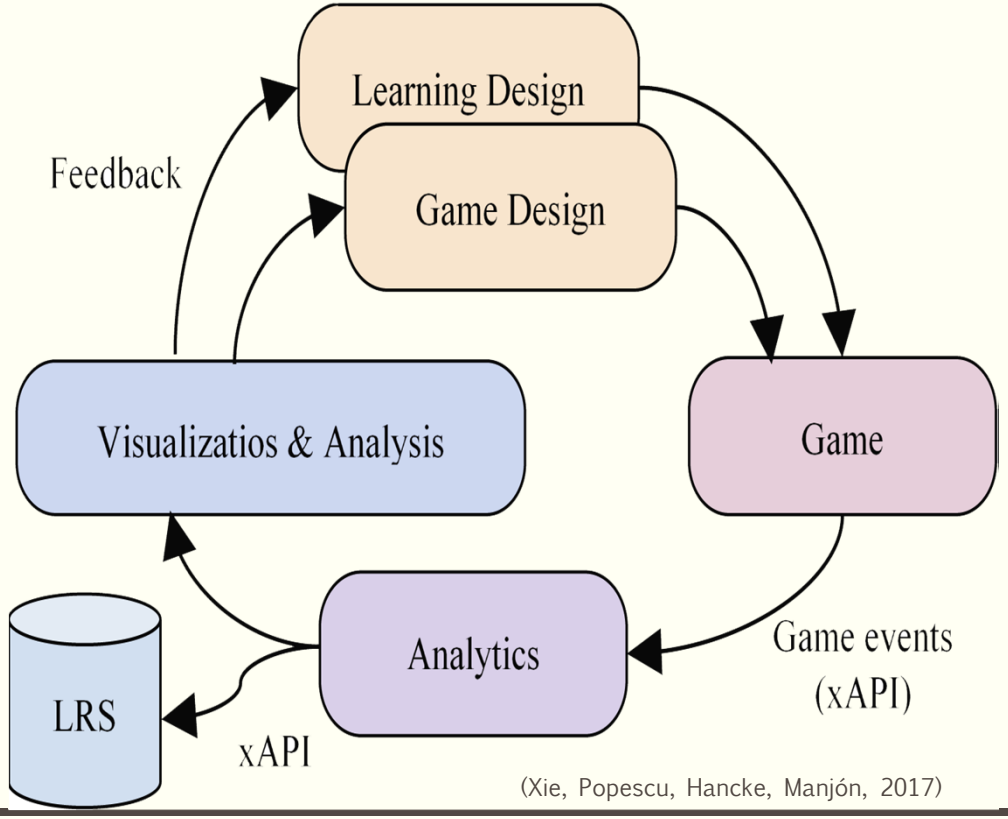
A SYSTEMATIC LITERATURE REVIEW ON LEARNING ANALYTICS FOR SERIOUS GAMES



(Xie, Popescu, Hancke, Manjón, 2017)

Thesis Goals & Objectives

- Serious Games and their use as a tool
- The uses of learning analytics in serious games
- Learning analytics steps and methodologies
- Game analytics and their uses in game learning analytics
- Methodologies and existing tools for incorporating learning analytics in SGs
- Barriers and limitations

Thesis Goals & Objectives

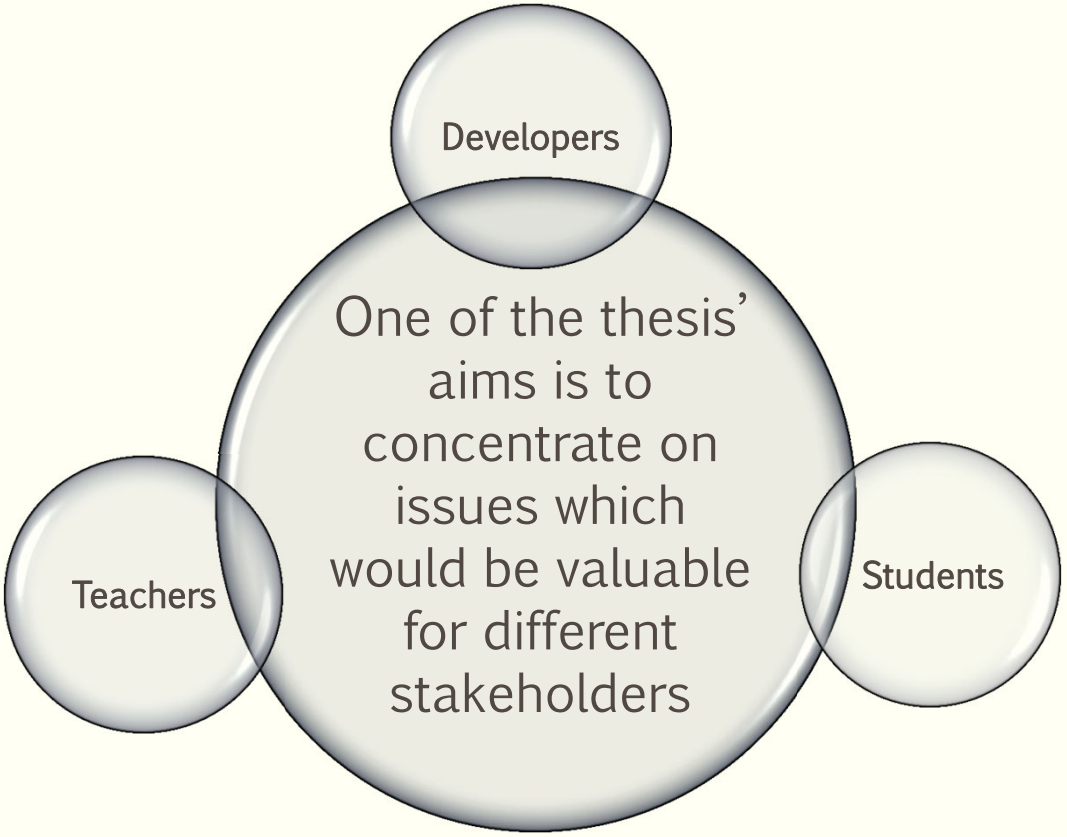
Could we identify patterns by applying LA in SGs so as to pre-establish an expert performance baseline and thus predict learning outcomes?

Could commercial games analytics be useful for serious game learning analytics?

Are there defined methodologies for implementing LA in SGs?

Are there any empirical studies for integrating LA in SGs?

Introduction - Theoretical background



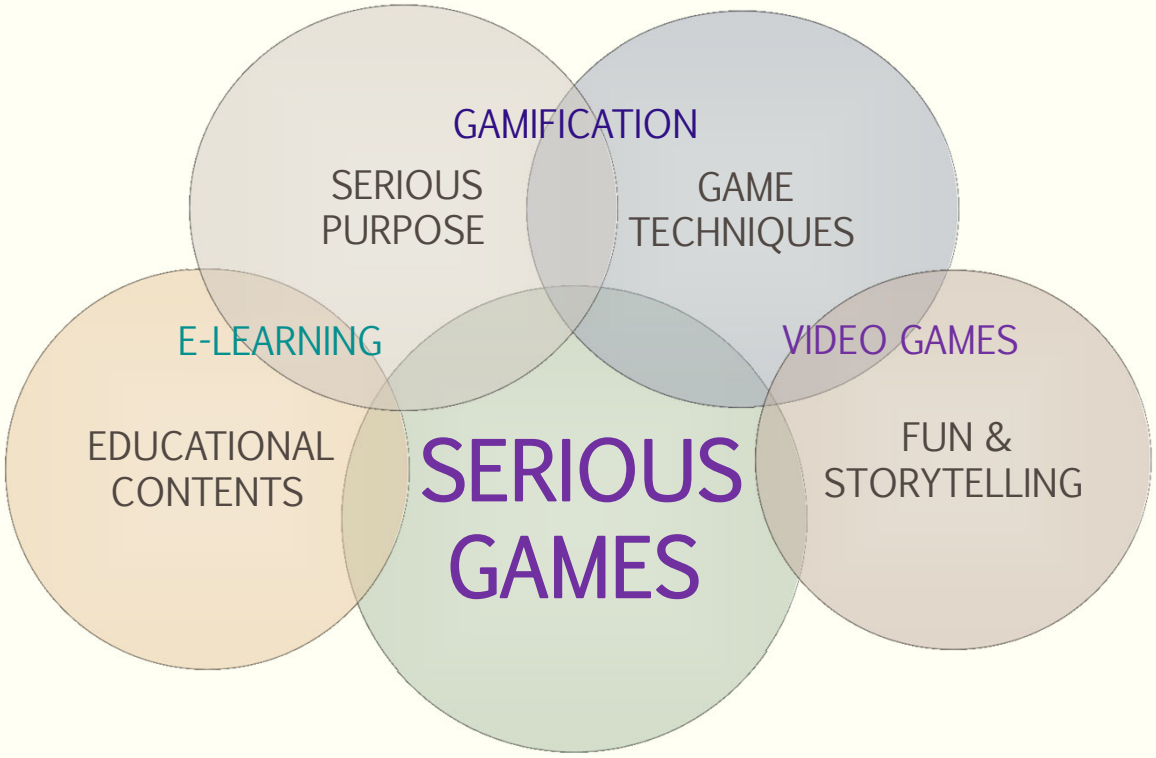
Achievements

- **Developers:**
  - SGs' design improvement
- **Educators:**
  - Insight of learning process
  - Classroom management & evaluation
- **Students:**
  - Self-assessment & motivation

INTRODUCTION - THEORETICAL BACKGROUND

Serious Games
Learning Analytics
Game Learning Analytics

SERIOUS GAMES

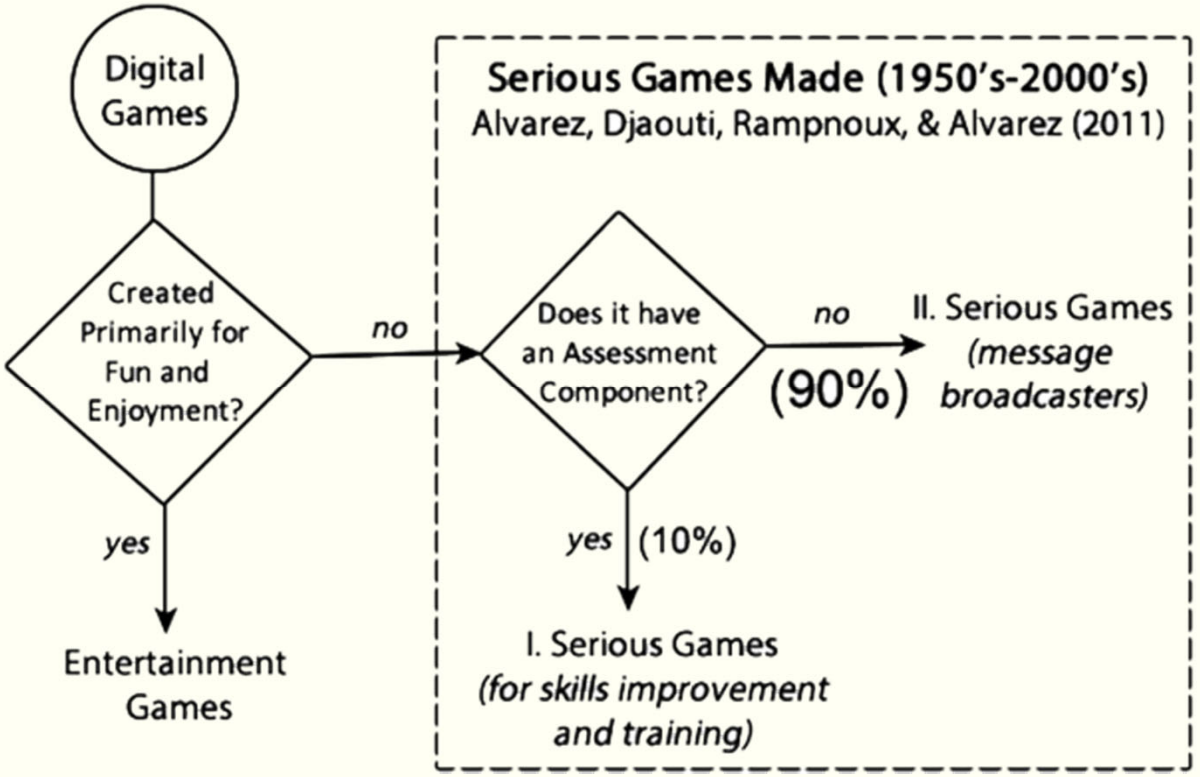


http://sde.uom.gr/index.php/2018/03/05/seriousgames/

SERIOUS GAME DESIGN contains

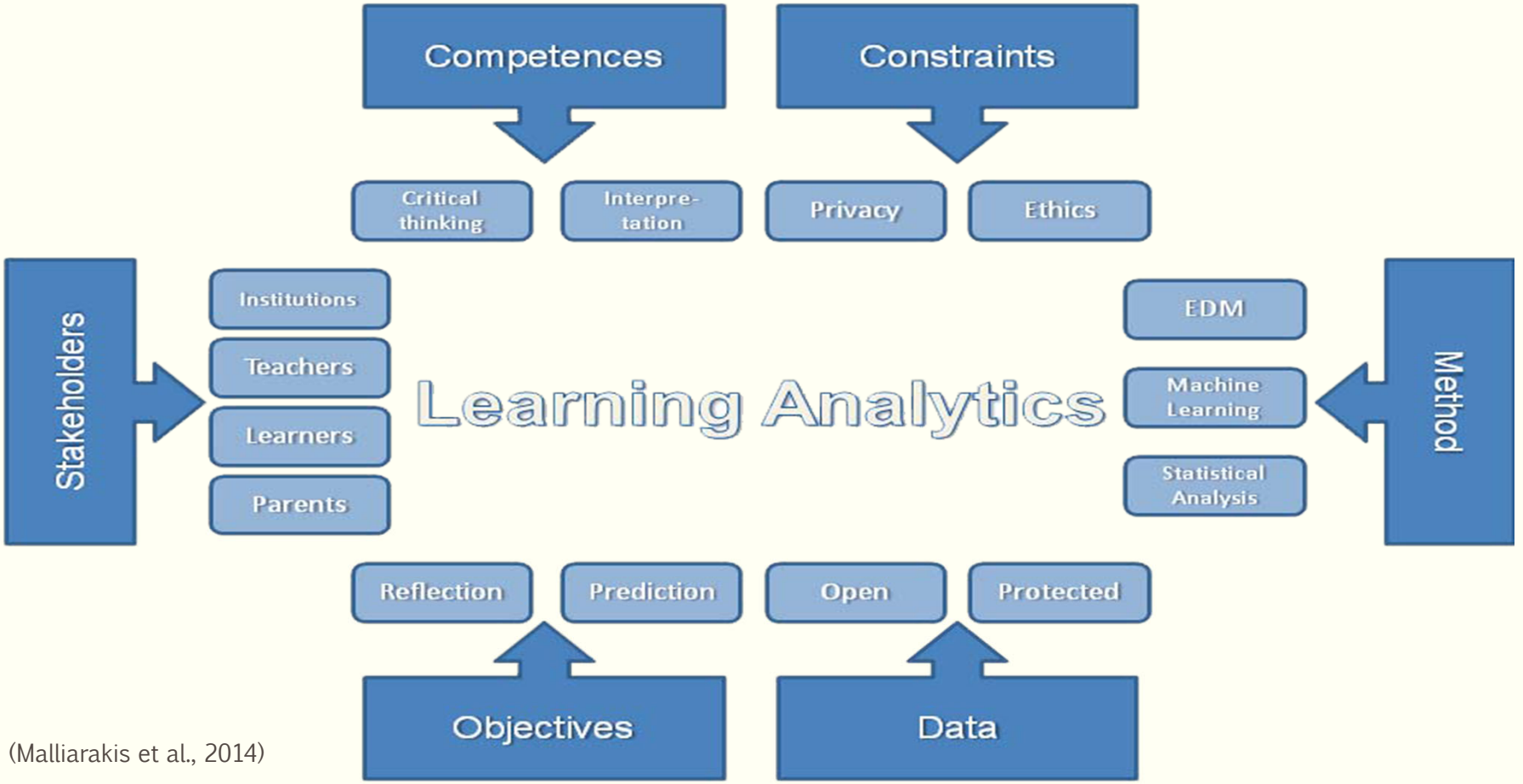
- ✓ Clear goals
- ✓ Repeatable tasks for knowledge consolidation
- ✓ Monitoring of students' progress
- ✓ Encouraging increased time on task
- ✓ Adjusting the learning difficulty level

Difference between Entertainment Games and SGs



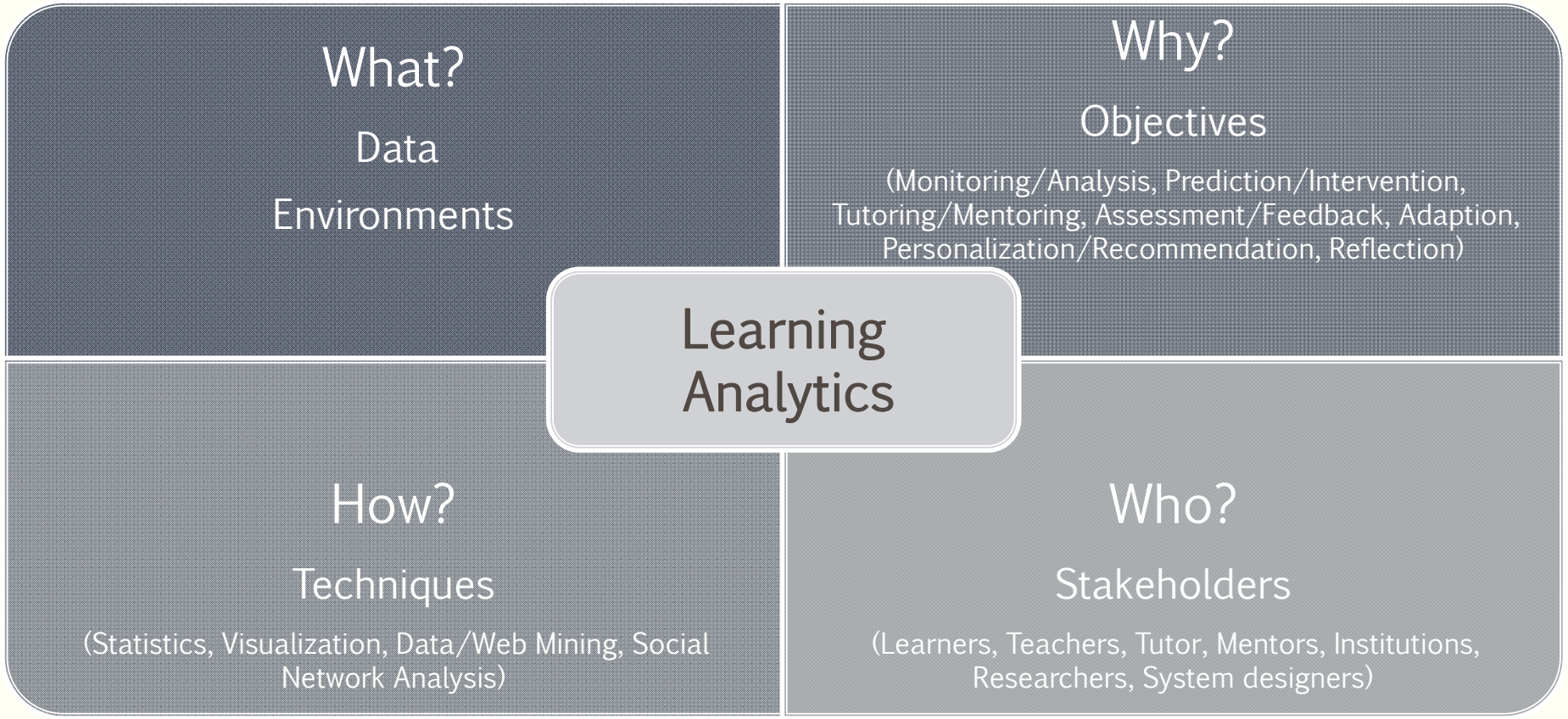
(Loh et al., 2015)

Learning Analytics



(Malliarakis et al., 2014)

Learning Analytics



(Chatti et al., 2012)

Learning Analytics Steps

"Learning Analytics is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs".

Related with: EDM, BI, VA

- Collect large amount of data
- Translate data into information or actionable insights
- Use the information for different purposes (personalization & adaptation, assessment, predict the best course in the future)

VLEs
MOOC
} Big data sets ➡ standardizing LA

Game Analytics & Game Learning Analytics

- Game analytics techniques have developed from learning analytics but include different goals and vocabulary. The main purpose of game analytics is to improve gameplay and turn the game to an enjoyable activity, improve game design and create attractive content so as to increase sales revenue.

- Serious games analytics is the “actionable metrics developed through problem definition in training/learning scenarios and the application of statistical models, metrics, and analysis for skills and human performance improvement and assessment, using serious games as the primary tools for training”.

Game Learning Analytics

Data Collection

- What should be tracked?
- Extensive data
- Intensive data
- Basic sets of interaction traces: generic & game specific
- In situ data collection: log files, game telemetry, and information trails
- Traces are stores in LRS

Data Analysis

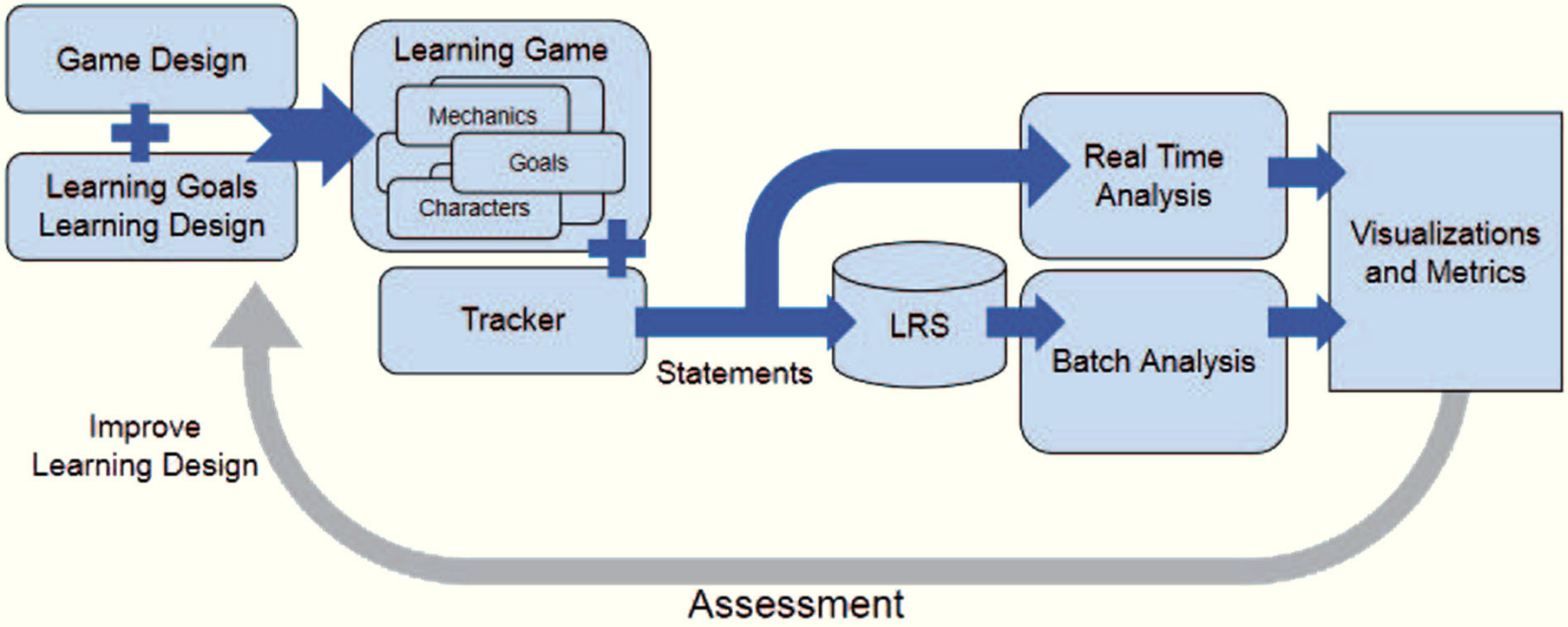
- Merge data for data mining & statistical processing
- Aggregation of intensive data
- Academic or predictive analysis.
- General or Game specific analysis
- Real-time analysis
- Cluster analysis: identify solution strategies and error patterns of students, and general profiles

Data visualization

- Real-time visualization
- Graphical representations
- Students: performance feedback
- Teachers: monitor, intervene, assess learning & game effectiveness
- Developers: game design
- Personalization, adaptation, evaluation, prediction
- Legal issues, data privacy
- Alerts & Warnings

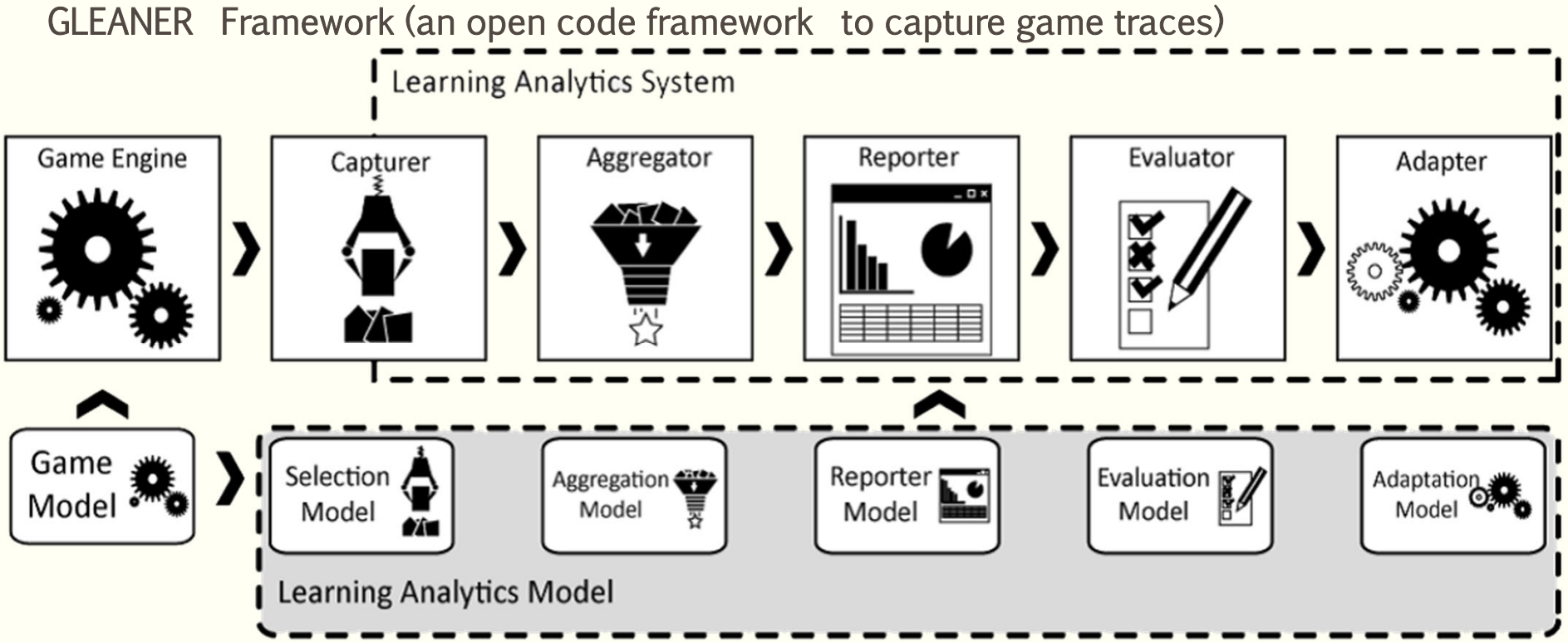
Architecture

An overview of Game Learning Analytics



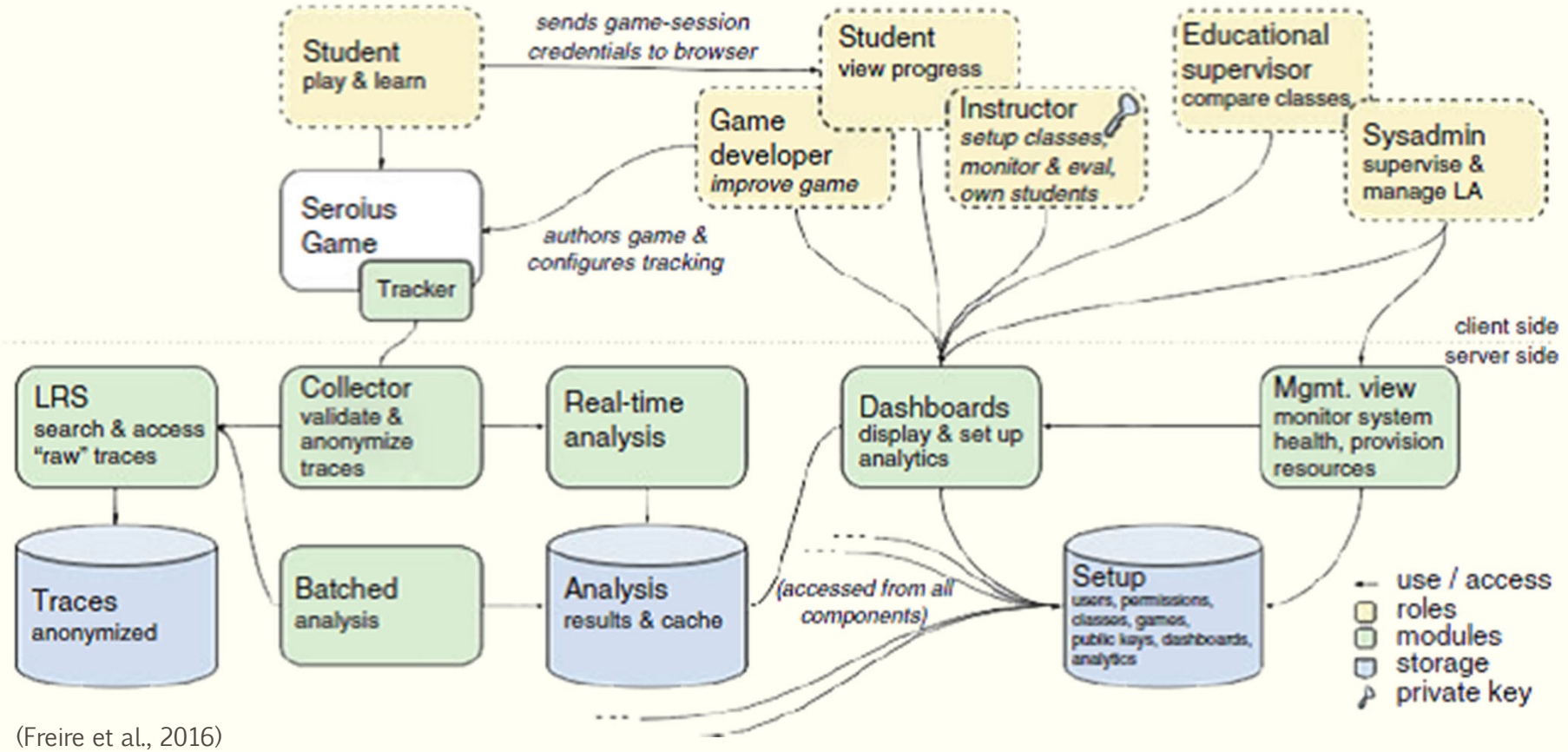
(Alonso-Fernandez, Calvo, et al., 2017)

The Games and LEarning ANalytics for Educational Research



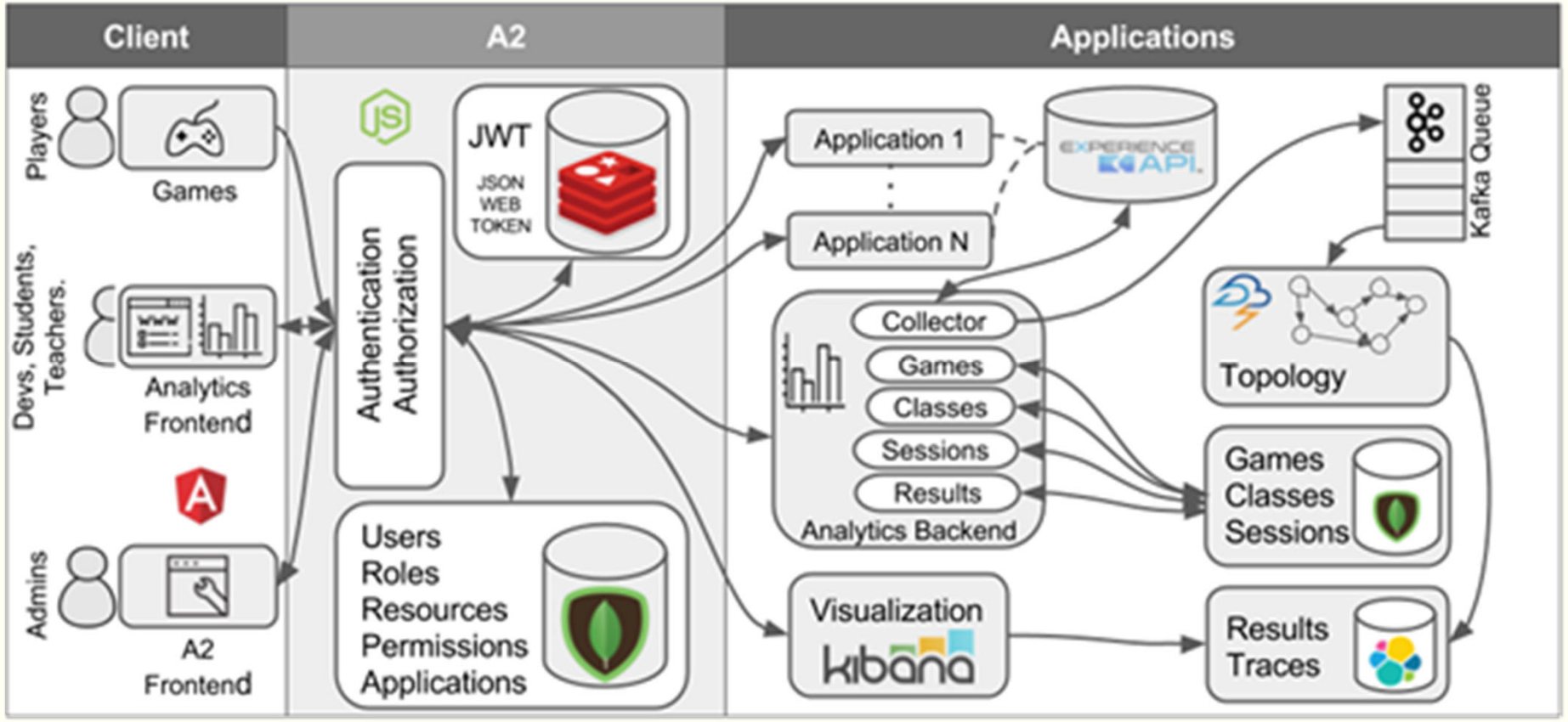
(Hauge et al., 2014)

Learning Analytics architecture at RAGE project



(Freire et al., 2016)

Overview of RAGE architecture and technologies

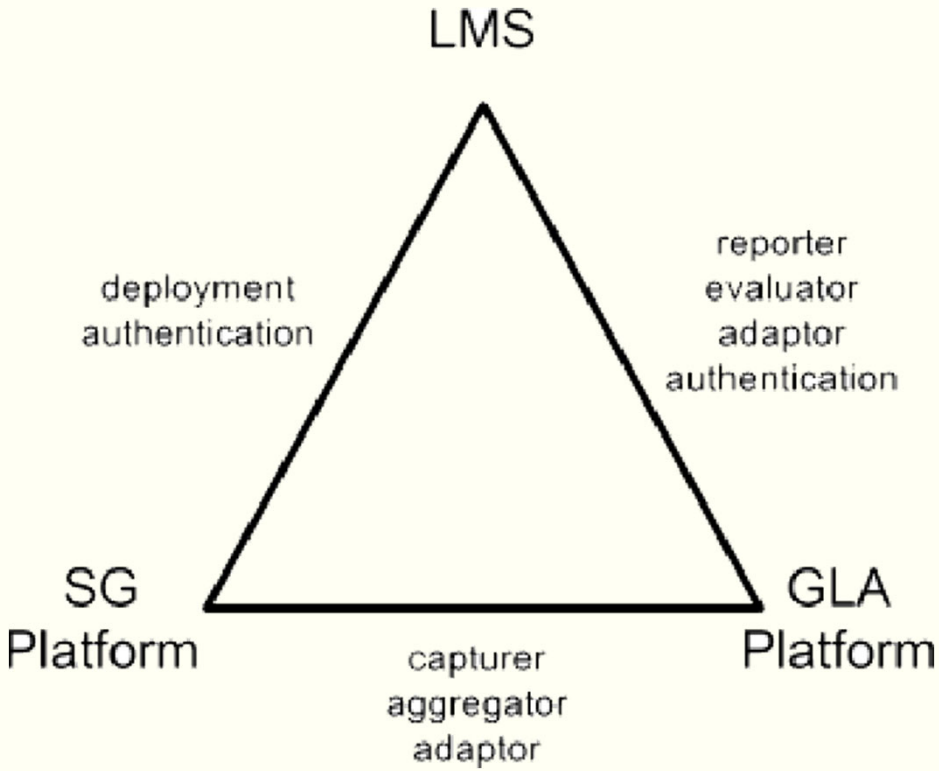


(Rage Analytics Overview · E-Ucm/Rage-Analytics Wiki · GitHub,)

Game learning analytics platform

This approach aims to simplify the integration among serious games LA platforms and LA platforms

- LMS: basic information collection in educational platforms
- IMS & SCORM: standardized interaction model
- SGs + LMSs with e-learning standards
- Collector component in analytics platform: simplifies integration with xAPI and IMS Caliper standards



(Freire et al., 2016)

Methodology

The SLR followed the guidelines proposed by the Kitchenham, B. (2004), Procedures for performing systematic reviews.

Steps:

- Identification of the research
- Selection of studies
- Quality assessment of the studies
- Data extraction
- Data synthesis
- Research questions, discussion, and conclusions

Methodology: Literature search & Selection of the studies

1. Literature search: ("educational game"* or "serious game"*) and learning analytics*
2. Digital libraries: Research Gate, Science Direct, ACM Digital Library, Scopus, Springer, IEEE Xplore, and Academia.
3. Selection process:

Inclusion	Exclusion
Learning Analytics and Serious Games	Non-English studies
The use of LA in SGs	Studies that were irrelevant
Methodologies and tools to apply LA in SGs	
Real-time LA in SGs	
GLA for educators	
Systematizing LA in SGs	

- Step1: Studies were reviewed by the title, abstract and key words
- Step2: Relevant study was fully studied

Methodology: Quality Assessment of studies

Study analysis properties

General properties
- ✓ Author names
- ✓ Project name (case study used in paper)

Purpose properties
- ✓ Uses of LA in SGs
- ✓ LA steps
- ✓ Methodologies
- ✓ Existing tools for incorporating LA in SGs
- ✓ Barriers
- ✓ Purpose of study

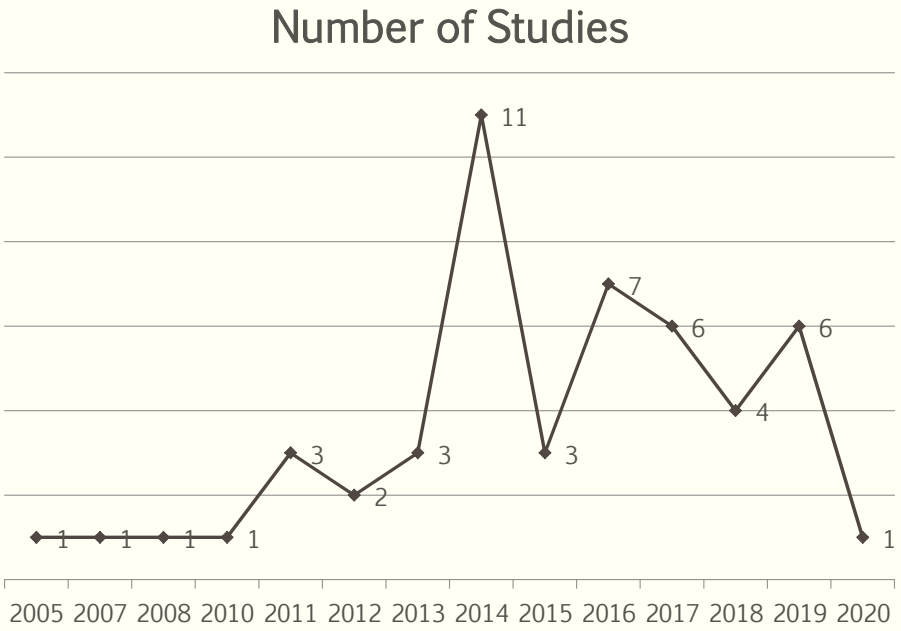
Microsoft Office Excel was used for data extraction

Inclusion criteria	Exclusion criteria
Studies include methodologies, steps, uses of LA with SG	Studies include commercial game and game analytics
Studies include standards to systematize LA in SGs and simplify educator's effort	Studies include specific games evaluation (e.g. puzzle game)
	Studies presenting LA outside of a game environment

RESULTS

Qualitative analysis & Qualitative analysis

Results: Quantitative analysis



Results: Qualitative analysis

RQ1: Could we identify patterns by applying LA in SGs so as to pre-establish an expert performance baseline and thus predict learning outcomes?

The learning analytics reference model shall be considered in the early design stages of SGs, and questions included in this model shall be answered.

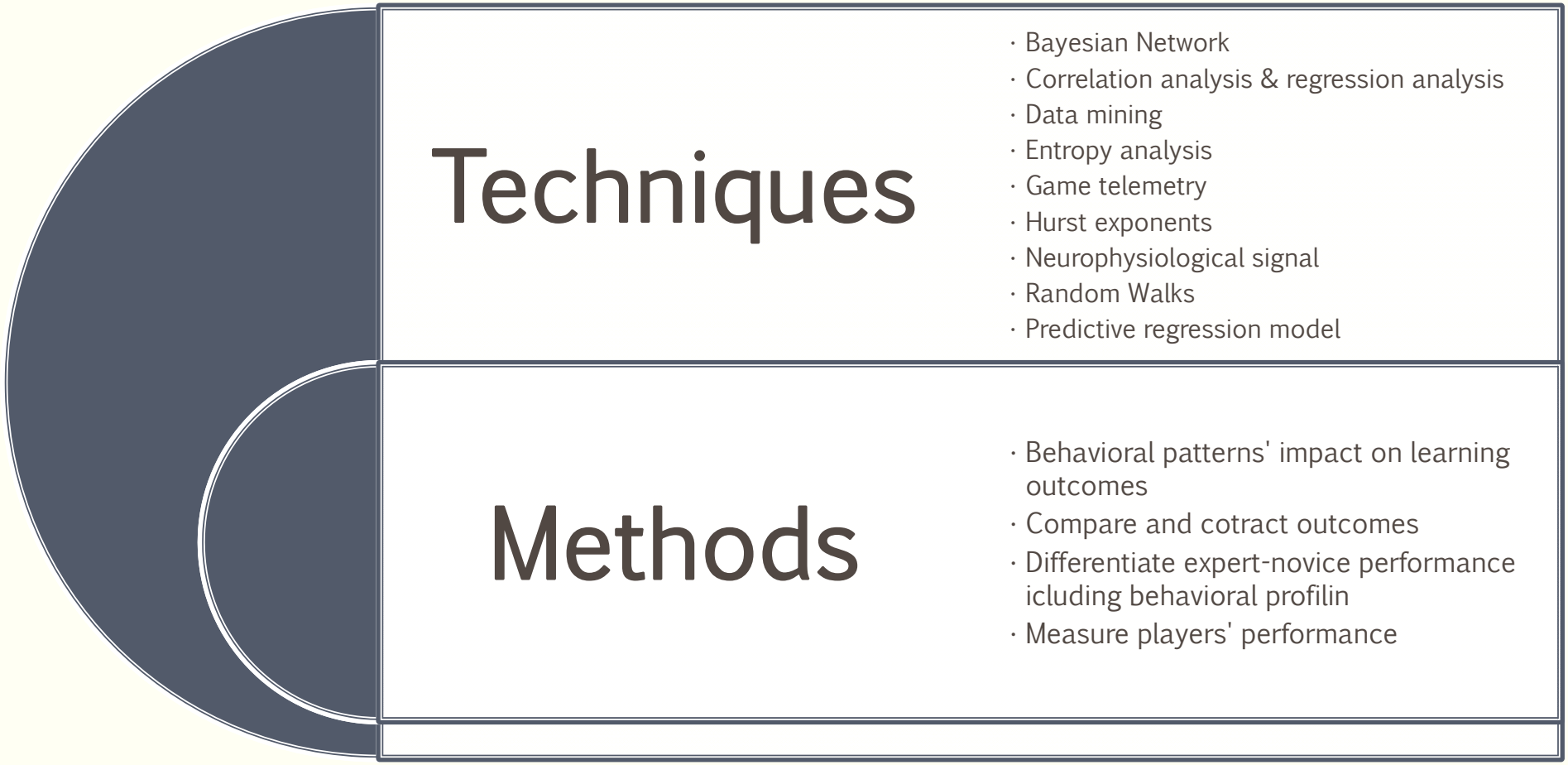
- What type of data shall be gathered for analysis?
- Who are the stakeholders of the analysis,?
- Why the data shall be analyzed,?
- How the data shall be analyzed?

The prediction model shall reveal future learners' performance and knowledge based on learners' present actions and achievements. Therefore to predict learning outcomes it is essential to build the learner's profile.

Studies categorization shows that the behavioral patterns reflect students learning outcomes, as well as distinguishing expert-novice performance including behavioral profiles. Player's performance assessment can be measured by defining performance variables. Behavioral patterns can be identified by studying players' course of actions and applying data mining and analysis to the in-game interaction data.

Results: Qualitative analysis

RQ1: Prediction of learning outcomes



Results: Qualitative analysis

RQ1: Behavioral patterns identification

Techniques

- Cluster analysis
- Correlation analysis
- Cosine similarity
- Data mining
- Entropy analysis
- Expert/Novice course of action (COA)/profiles
- Expertise Performance Index
- Game telemetry
- Hurst analysis
- Maximum Similarity Indices (MSI) score
- Random Walks
- Statistical Processes
- Visualization

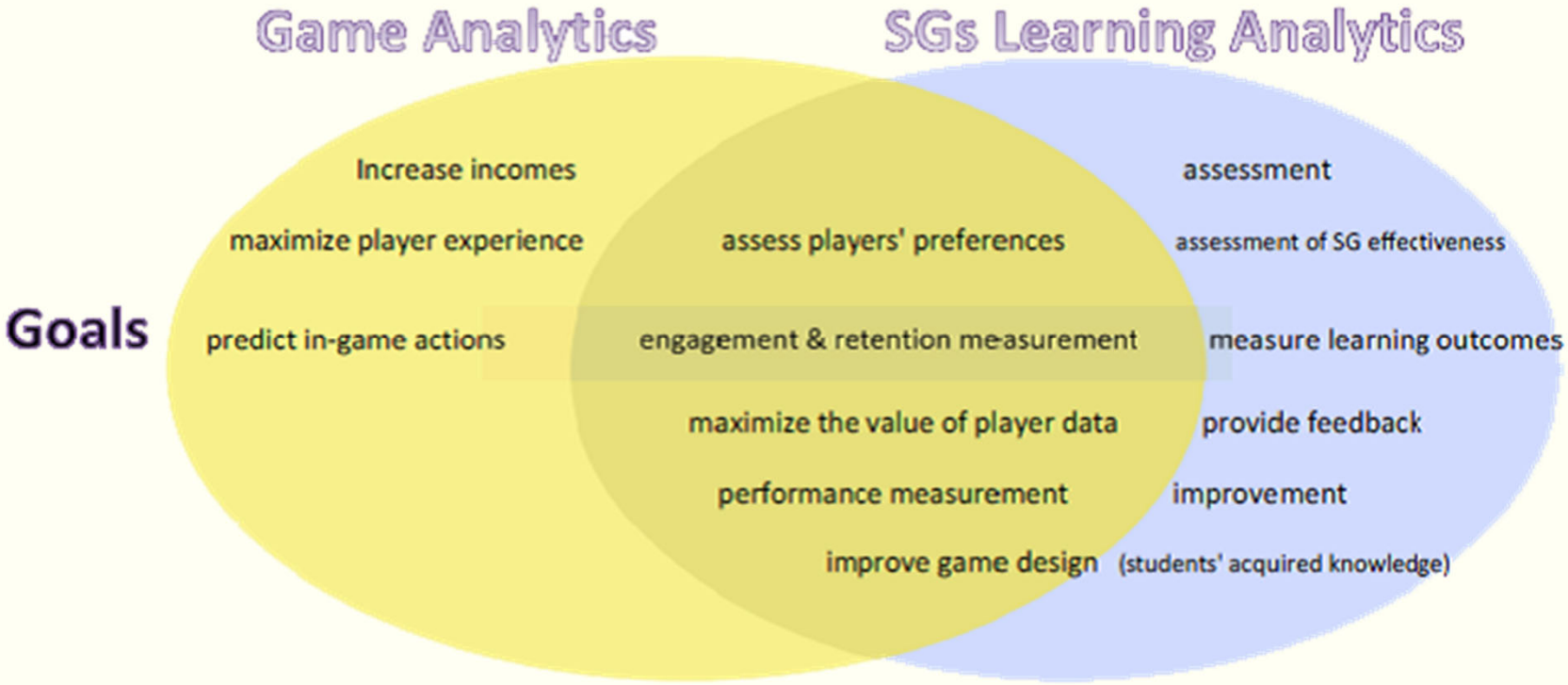
Method

- Compare patterns
- Retrace COA
- Identify concealed patterns
- Identify expert and novice performance
- Identify neurophysiological patterns
- Measure performance
- Patterns classification

Results: Qualitative analysis

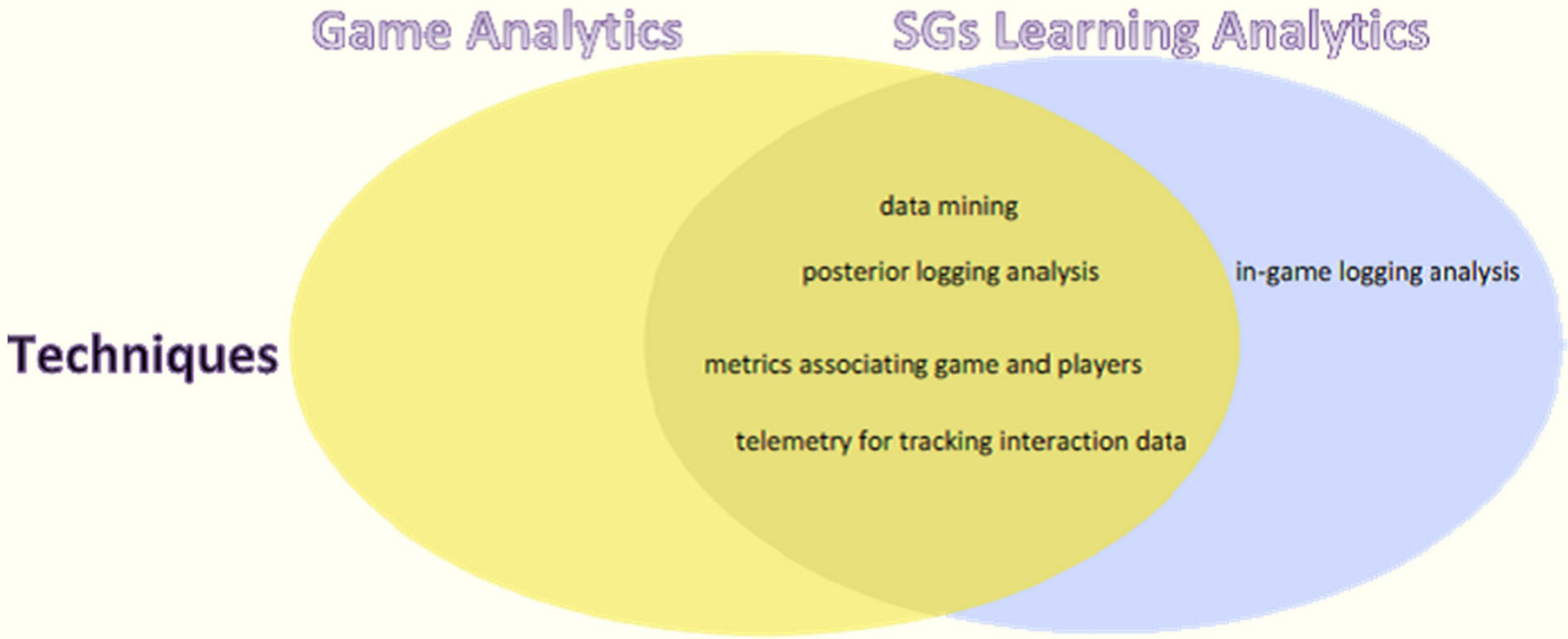
RQ2: Could commercial games analytics be useful for serious games learning analytics?

GA methods and practices may contribute to the SGs learning analytics.



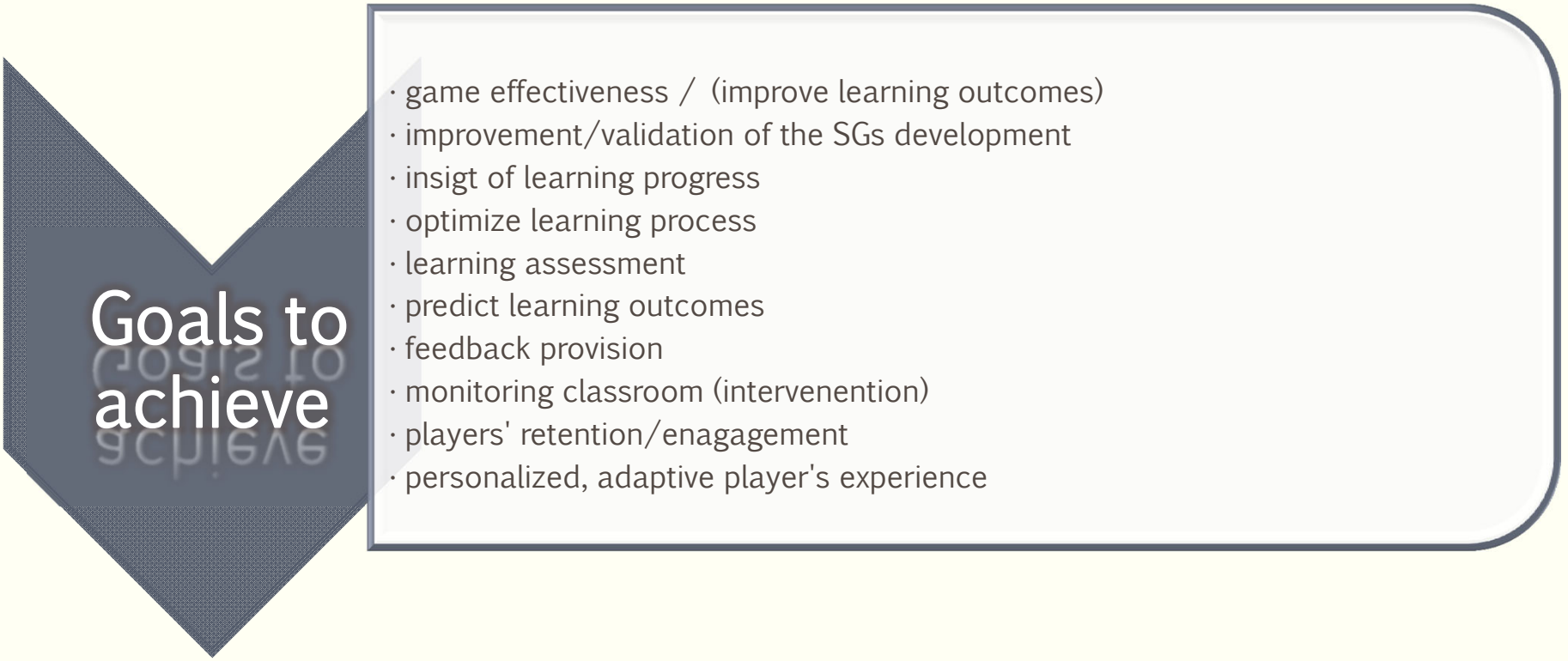
Results: Qualitative analysis

GA Analytics techniques compared to SGs Learning Analytics



Results: Qualitative analysis

RQ3: Are there defined methodologies for implementing LA in SGs?



Results: Qualitative analysis

- define clear learning goals
- define disered visualization results
- design interventions
- link learning goals and game design
- define variables/objectives to collect the right data
- trace/collect interaction data
- analyze interaction
- visualize results
- evaluate the process through iterations

Results: Qualitative analysis

Methods /Tools for integrating LA in SGs

- embedded tracker component
- Platform-independent base model (PIM)
- Platform-specific model (PSM)
- Knowledge model
- EDGE framework (Engaging Design of Games for Education)
- LMS, MOOCs

- LAM (learning analytic model)
- clustering method
- analytics platform
- game-independent analysis
- game-dependent analysis
- standardized xAPI statements (xAPI-SG)
- Real-time analysis

- LRS for batch analysis
- metrics information and KPIs
- visualization dashboards
- Overlapping model
- ElasticSearch
- Kibana engine
- legal privacy issues compliance

Results: Qualitative analysis

Empirical study	part of EU H2020 SG-related project
	Conectado (SG aims to raise awareness)
	DownTown (aims to train skills)
	First Aid Game (improve students' knowledge)
	2D adventure educational game session
	RumbleBlocks educational game
	Case-Study experiment
	Countrix SG

Results: Qualitative analysis

RQ4: Are there any empirical studies for integrating LA in SGs?

Implemented Tool

- Unknown
- ad-hoc mathmatical model
- SPSS (software for advanced statistical analysis)
- EngAGe (Engine for Assessment in Games)
- DSL (Domain-Specific Language)
- Web services
- Xtext (an Eclipse tool to parse DSL)
- GLEANER framework (LAM &LAS)
- EMERGO SG engine

Developed SG

- CMX (Computer programming)
- CAG (Computer Architecture Game)
- Pilot study (SG GeoFall)
- Lost in Space <XML> game
- Grab the Drink (cross platform SG)
- Kinespell (SG for learning spelling)

SGs' Attributes after LA application

- game design improvement/cofigurable game environment (based on feedback and performancies)
- optimize curricula
- enhance students' progress
- infer conclusion for assisting teaching
- overall monitoring of students
- link educational goals and game design
- game effectiveness
- gender differentiation in learning process
- rewarding system for players
- impact in classroom

CONCLUSIONS

Conclusions

Summary of the thesis

- The traditional educational methods seem insufficient for the digital natives.
- Necessity to enhance curricula with SGs for engaging methods of delivering knowledge
- SGs confront difficulties when applied in educational settings:

  teachers need to know
  - how students interact with game
  - how the learning process occurs
  - whether the desired learning outcomes are obtained

- Solution: SGs + LA
  - A clear, simple and understandable method for teachers to use SGs as educational and assessment tools
  - Standardized methods for integrating LA in SGs

Conclusions

- The scope of data collection reasons varies and shall be defined in an early stage of the game design
  - ✓ To facilitate measurements in knowledge, behaviors, attitudes, and individual progress changes for comparing and contrasting performances and outcomes
- The learning signs have to be collected
  - ✓ To discover whether learning is obtained
- The prediction model shall reveal future learners' performance and knowledge based on learners' present actions and achievements
  - ✓ Learner's profile must be built so as to predict learning outcomes

Conclusions

The application of LA in SGs infer to patterns identification and contribute to the establishment of an expert performance baseline so as to predict learning outcomes

- Behavioral patterns are correlated with learning outcomes.
- The differentiations of expert-novice performance including behavioral profiling contribute to the establishment of an expert's baseline and with the comparison and classification techniques reveal distinction between patterns and finally, lead to the prediction of learning outcomes
- Cluster analysis, correlation analysis, game telemetry and other techniques were used in the reviewed studies for patterns identification.

Conclusions

GA and SGA both aim to maximize the value of player data but SGA has additional purposes of performance estimation, evaluation, and improvement.

- Game industry uses
  - Telemetry methods for non-intrusive interaction data collection
  - Data mining techniques reveals valuable insight
  - Posterior logging analysis to evaluate players' choices, to track in-game bottleneck, to make prediction for players' in-game actions
- Common goals of GA and SGA:
  - Players' preferences assessment, engagement and retention measurement, performance assessment, game design improvement, maximizing the value of player data
- Common techniques:
  - Data mining, posterior logging analysis, metrics associating game and players, telemetry for tracking interaction data

Conclusions

Methodologies for implementing LA in SGs

1. Define clear and realistic learning goals that should be included in game and learning design ➡ shows if the learning actually occurs
2. Game mechanics, structure, objectives, game characters, learning objectives by means of variables must be included ➡ learning evaluation outcomes depend on these variables
3. Define how the interacted data will be traced and collected (embedded tracker component)
4. Analysis
5. Visualization results

Benefits: improvement and validation of SGs' development, SGs' effectiveness, insight and optimization of learning process, learning assessment, prediction of learning outcomes, monitoring and intervention in the classroom, personalized and adaptive player's experience

Conclusions

Empirical studies for integrating LA in SGS

- Unknown implemented tool
- SPSS software for statistical analysis
- Framework for integrating LA in SG

Common approach in the development steps of SGs

- ✓ Link educational goals with game design
- ✓ Improve students' progress

LA provide game improvement, monitoring of the class, prove game effectiveness, optimize curricula in educational settings, provide assessment feedback and have impact in classroom.

A standardized method widely adapted for LA integration in SGs wasn't obvious.

Conclusions

Limitation s of the study

- The majority of the studies concentrate on a theoretical approach of LA in SGs
- A widely adopted approach of integrating LA in SGs wasn't found
- Studies that use SGs as assessment tools for student's evaluation and student's acquired knowledge were limited
- None of the proposed solutions were applied in order to empirically evaluate them
- All the studies that were included were written in English
- Some of the studies that seem relevant for the thesis couldn't be reached due to access restrictions

Future Work

The current thesis could be expanded in reviewing how easily an educator could use SGs incorporating LA with meeting two limitations: he/she isn't a computer science teacher and isn't acquainted with statistical analysis. Which of the tools and methodologies found in the thesis are more suitable and easy to use? Are there automated methodologies for the process?

The End