A Systematic Review on Augmented Reality Applications in Informal Learning Environments

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Introduction

The widespread availability of portable, interconnected devices with multimedia capabilities and the development of social networking software greatly influence the field of science and information.

The evolution of technology and, more specifically, AR technology contributes greatly to this upward change

Its use is recognized as a lever for increasing the implementation of complex systems in informal learning environments, which support

- dynamically unfolding tours
- browsing of real museums,
- parks, historical landmarks, etc.,

enriching the user experience.

This study aims to investigate the extent to which the available technological capabilities are utilised in the design of **AR** applications for **informal learning** environments.

Background

Learning is the process by which a person cultivates their skills, knowledge, understanding, values, perspectives, feelings, critical thinking abilities

Formal

Non-Formal

InFormal

Background

Informal Learning			
Not Organized and Systematic	Flexible, unstructured, and spontaneous	Individualized rhythm	Occur in any context

Background

Augmented Reality Applications can be used in informal learning environments because

- it is consistent with the pedagogical theories of
  - Situated Learning,
  - Game-based Learning, and
  - Inquiry-based Learning
- can be used to provide personalized information and feedback to the user according to their choices,
- it can be combined with digital interactive storytelling technologies to provide a more immersive experience
- Multiplayer-Collaborative

Related Work

do not consider important factors and affordances of mobile AR applications, examining whether

- it is predicted an appropriate design,
- promoting collaboration between users,
- whether it is allowed to users to contribute to the AR content,
- whether it is included script related features exploiting narration dynamics.

Study	Analysis Dimension	Studies reviewed	Summary of main findings
Stymne, 2020	"Outdoor learning with mobile technology" Review Years: 2004-2019	87	Edu Subjects: Biology, followed by History, Maths etc. Edu Levels: Primary education etc. Technologies: AR the most common one for augmenting the outdoor learning environment Methods of data collection for inquiry learning activities: photos and then taking notes and audio
Petrovich et all. 2018	"AR experiences in informal education" Review Years: 2010-2017	18	Edu Levels: Lyceum, univ students and adults AR effects: better learning effects, motivation, interest on museum content etc. Benefits: Interaction and socialization among participants around tablet or mobile devices
Golff et al.,2018	"AR in STEM in informal learning environments" Review Years: 2003-2017	17.	AR effects: Improve learning and conceptual understanding, more interest and greater engagement, and enhances collaboration among students around devices
Ibanez et all, 2018	"AR in STEM" Review Years: 2010-2017	28	AR effects: Impact on learning, 'positive' sentiments etc Applications' design categories: inquiry- exploration, simulation, games
Dunley & Dede, 2014	"AR in formal & informal settings" Review Years: 2004-2014	19	AR effects: the information augmenting the natural space, facilitates authentic and participatory learning Limitations: the cognitive overload of learners

Research Questions

[RQ1] Do informal learning AR applications for mobile devices promote collaboration and how it is achieved?

[RQ2] Do these AR applications allow the users to contribute (create or change) with new digital content that is accessible to other users?

[RQ3] Do AR applications provide key elements of storytelling?

In parallel, this review considered and analysed four basic characteristics of the reviewed studies such as:

- **[RQi]** the publication date of the study,
- **[RQii]** the AR application users' age group,
- **[RQiii]** the involved scientific subject(s) of related learning activities
- **[RQiv]** the identified learning outcomes of the reviewed studies

METHOD

Databases

- ERIC
- Science Direct
- Google Scholar
- ACM
- IEEE

Terms

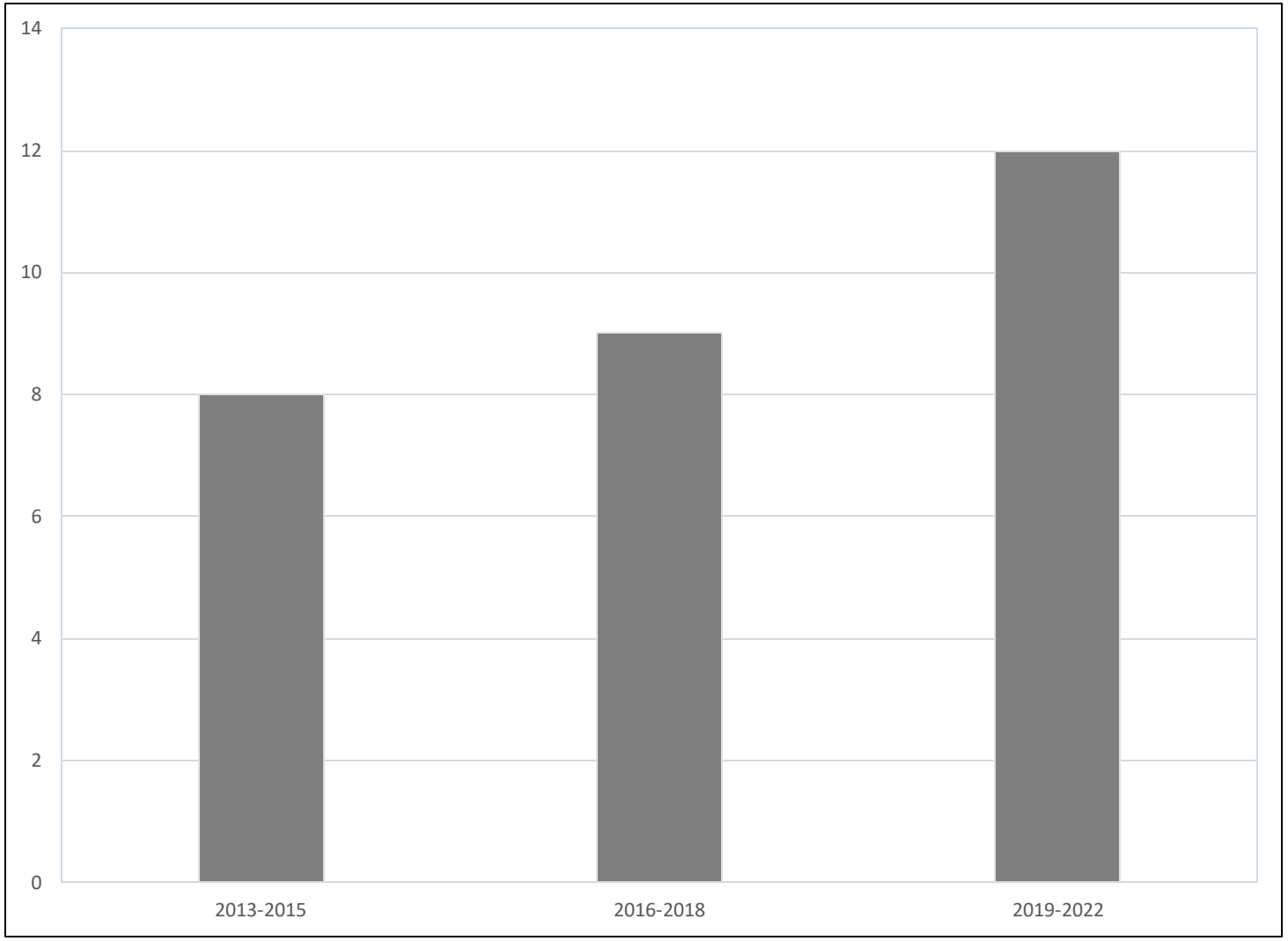
- augmented reality **AND**
- mobile learning **OR** informal learning **OR** storytelling **OR** collaboration

Period

- 2012 – 30 April of 2022

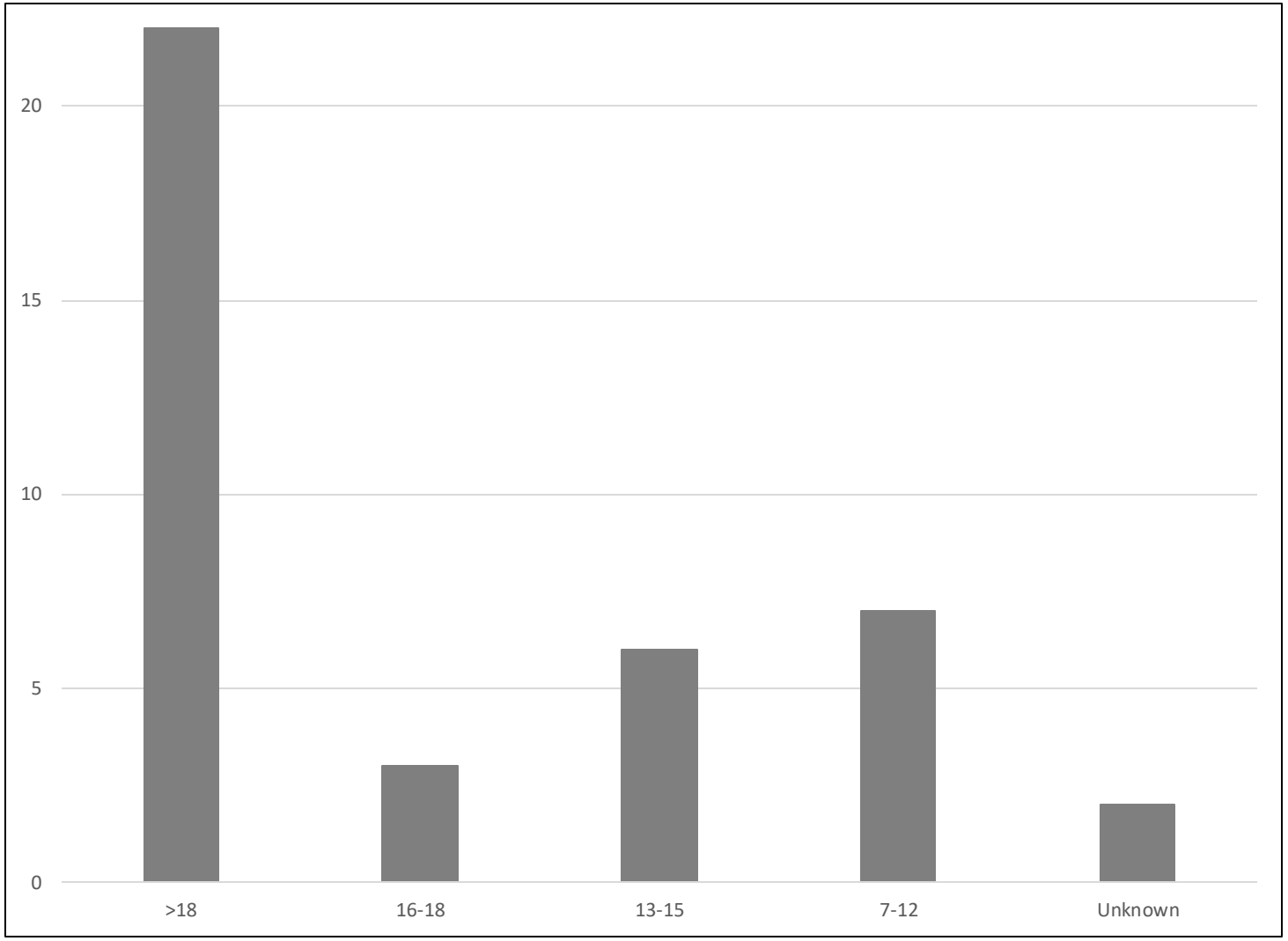
Results

Paper	Age	Subject	Place	Narration	Outcome
Chang (2013)	>18	History	Park	Time Travel	Knowledge Improvement, Interest, Willingness to participate again
Lochrie et al. (2013)	>18	History	City	No	Interest
Chang et al. (2014)	>18	Art	Museum	No	Knowledge Improvement, Satisfaction
Holden (2014)	>18	Foreign Language	City	Mystery Game	Knowledge Improvement, Interest, Willingness to participate again
Pendit et al. (2014)	>18	History	Park	No	Interest, Satisfaction
Sommerauer & Müller (2014)	all	Maths	Museum	No	Knowledge Improvement
Chang et al. (2015)	>18	History	Park	No	Knowledge Improvement, Satisfaction
McMahon et al. (2015)	>18	Navigation	City	No	Knowledge Improvement
Harley et al. (2016)	>18	History	City	No	Knowledge Improvement, Satisfaction
Hsiao et al. (2016)	12-13	Science	Museum	No	Knowledge Improvement
Hu Tsai (2016)		History	Camp	Mystery Game	Prototype
Markouzis & Fessakis (2016)	>18	History	City	Mystery Game with Quests	Knowledge Improvement, Interest Willingness to participate again
Coelho & Costa (2017)		History	Museum	Mystery Game with Quests	Prototype
Juan et al. (2017)	>18	History	Museum	No	Satisfaction
Grevtsova, I. (2017)	> 18	History	City	No	Knowledge Improvement, Interest
Costa et al. (2018)	8-11	Astronomy	Camp	No	Knowledge Improvement, Interest
Sommerauer & Müller (2018)	15-18	Maths	Museum	No	Knowledge Improvement
Chien (2019)	>18	Foreign Language	Park	No	Knowledge Improvement, Satisfaction
Kyza & Georgiou (2019)	7-12	History	Park	No	Knowledge Improvement, Interest
Poitras et al. (2019)	>18	History	Camp	Time Travel	Knowledge Improvement, Satisfaction
Innocent & Leorke (2020)	>18	History	City	Mystery Game	Knowledge Improvement, Interest
Lehto et al. (2020)	all	History	City	Mystery Game with Quests	Interest, Satisfaction
Pombo & Marques (2020)	10-15	Environment	Park	Mystery Game with Quests	Knowledge Improvement, Willingness to participate again
Vicari (2020)	13-15	Astronomy	Museum	Mystery Game with Quests	Knowledge Improvement, Interest
Kennedy et al. (2021)	>18	History	Museum	No	Knowledge Improvement, Interest
Wahyuni et al. (2021)	>18	History	City	Mystery Game with Quests	Satisfaction, Interest
Chen et al. (2022)	11	Science	Museum	No	Knowledge Improvement
Jiang et al. (2022)	>18	History	Park	Mystery Game with Quests	Knowledge Improvement
Nevola et al. (2022)	>18	History	City	Time Travel	Knowledge Improvement



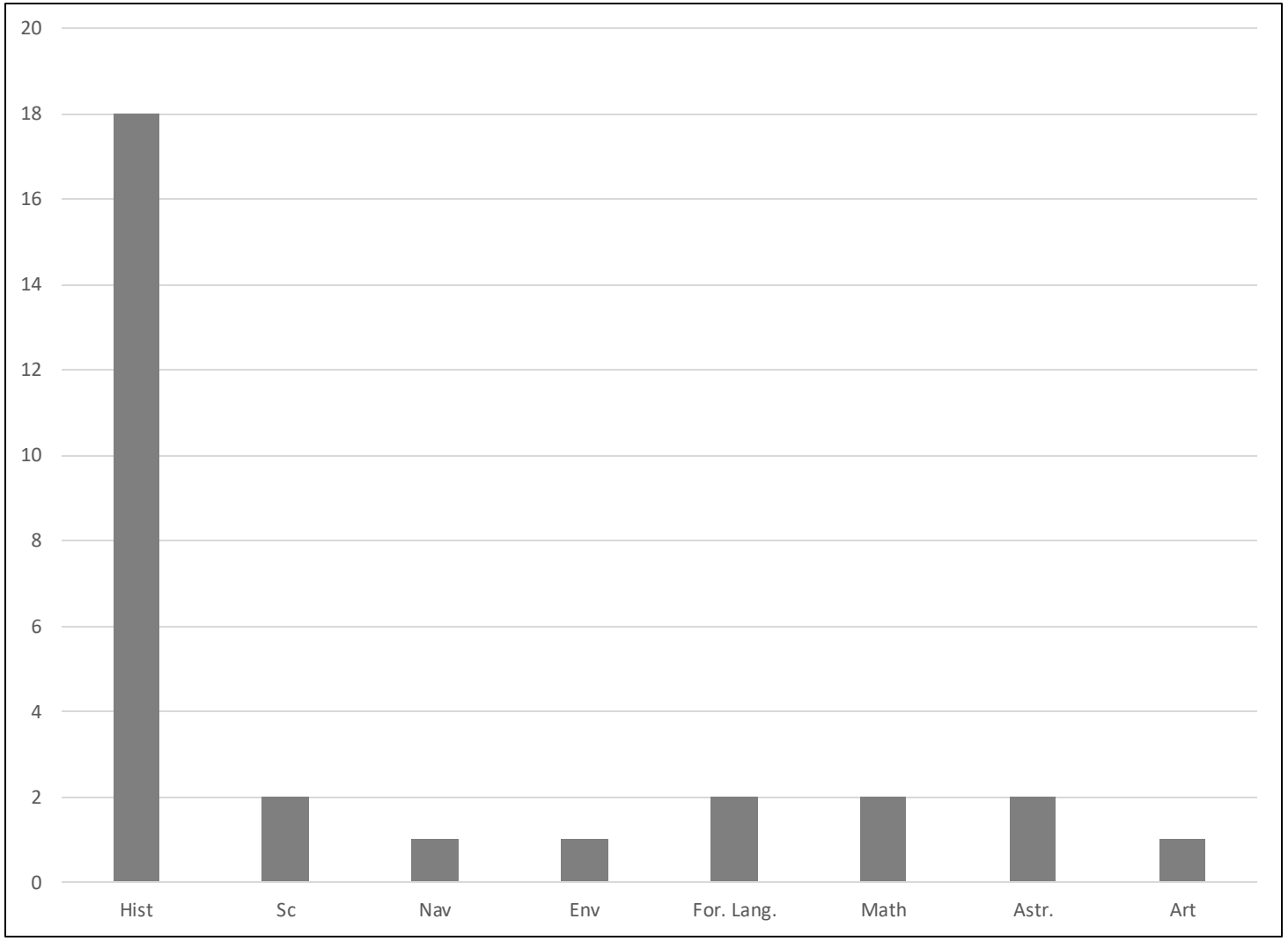
Number of published studies per publication period

This fact indicates an increasing trend of research interest in the use of AR in informal learning



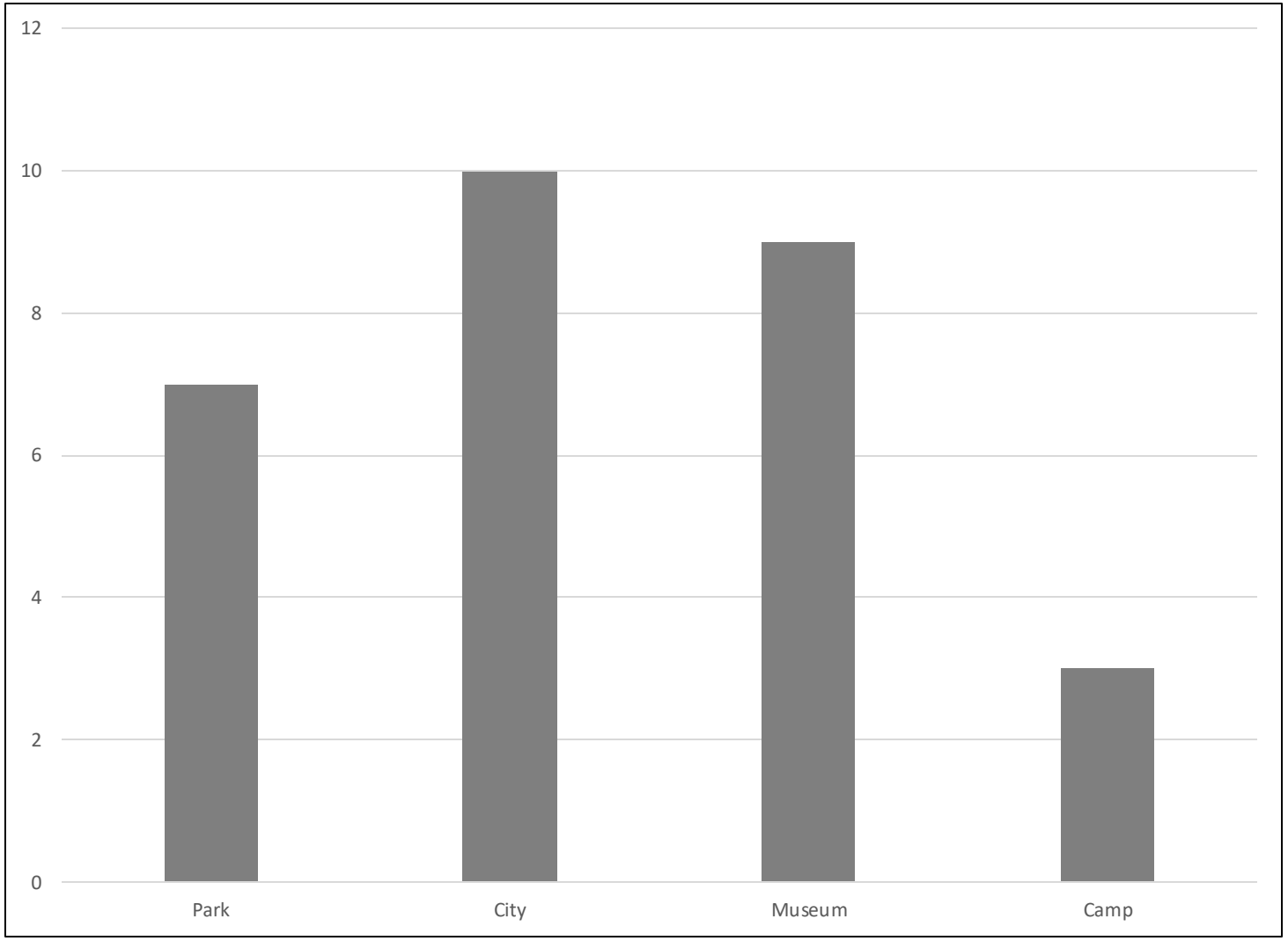
Age distribution of participants in the studies included in the literature review

Analysis of the yielded papers reveals that most of the studies (approximately 53%) concern applications for adults



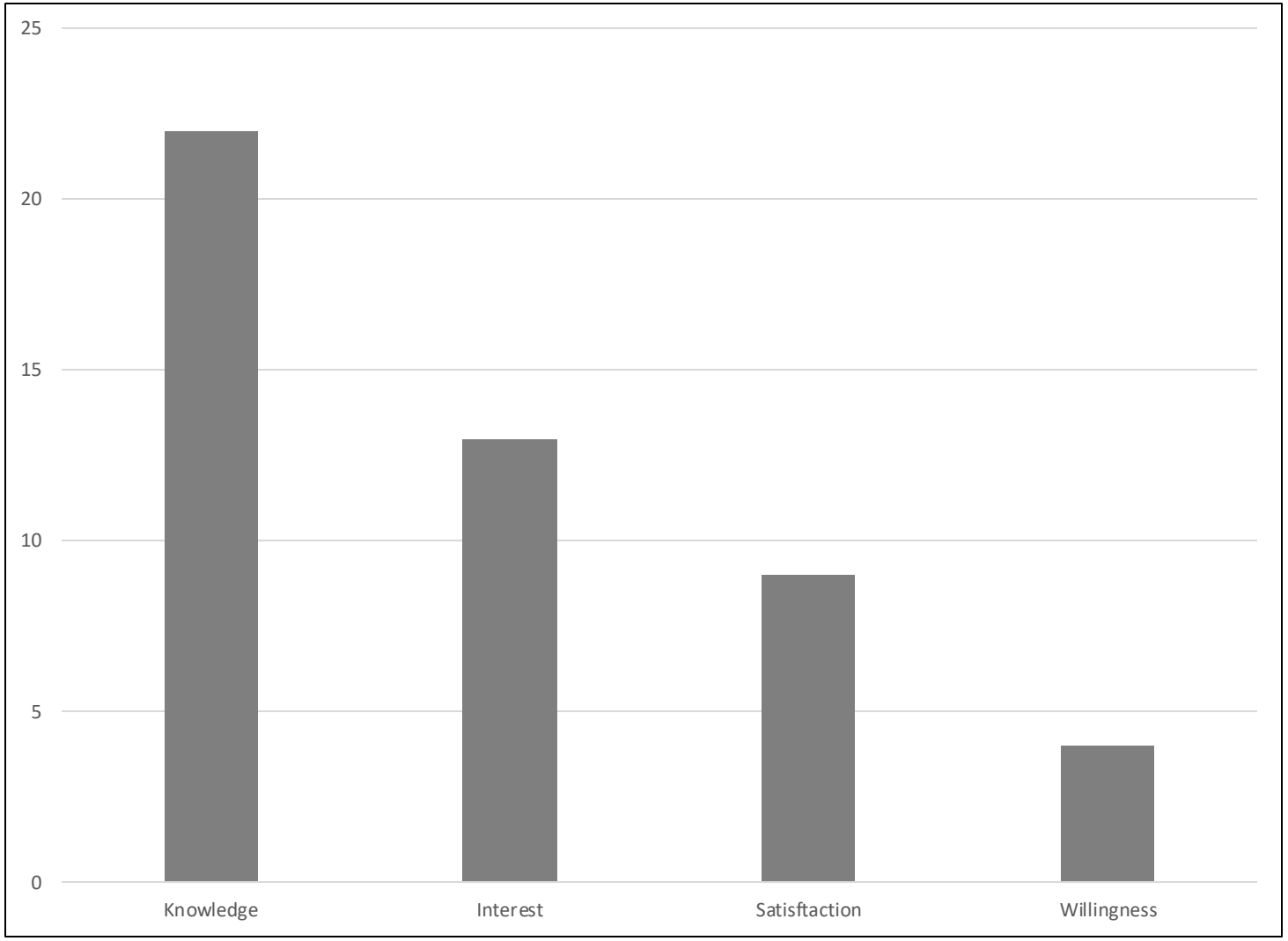
Scientific subject of studies included in the literature review

History (information about historical sites, archaeological sites, etc.) is included in more than half of the studies



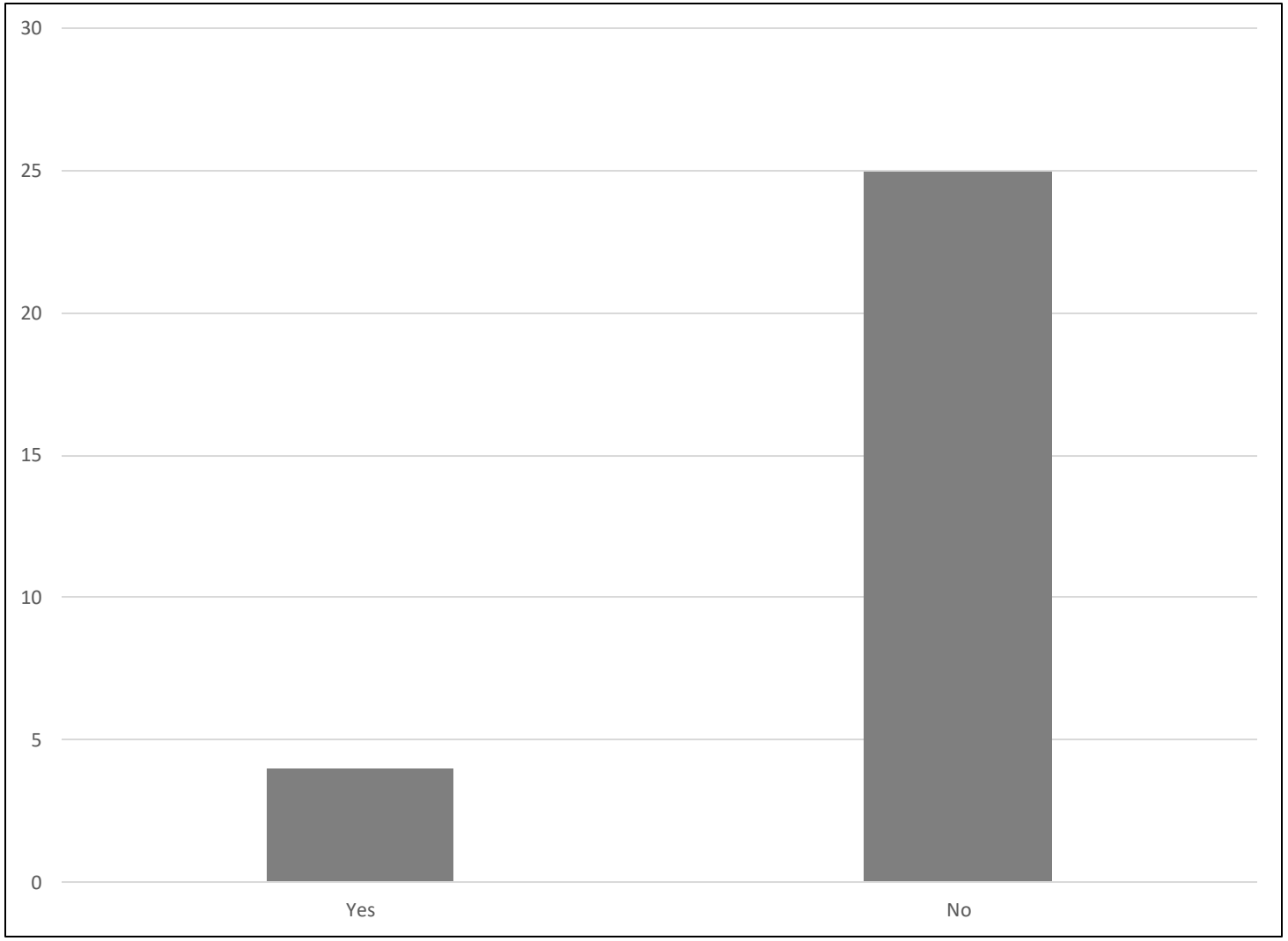
Implementation space of studies included in the literature review

Urban areas such as entire cities are the spaces mentioned in most studies. An almost equal percentage of studies concerns museums



Results of studies

- ***Knowledge****: whether users improved their knowledge of the scientific subject mediated through the application*
- ***Interest****: whether the application succeeded at retaining a high level of interest amongst the users and whether the users actively participated without their involvement seeming boring*
- ***Satisfaction****: whether users enjoyed the application and positive emotions were elicited), Interest*
- ***Willingness****: whether users acquired a positive attitude towards AR and would like to use similar applications again in the future*

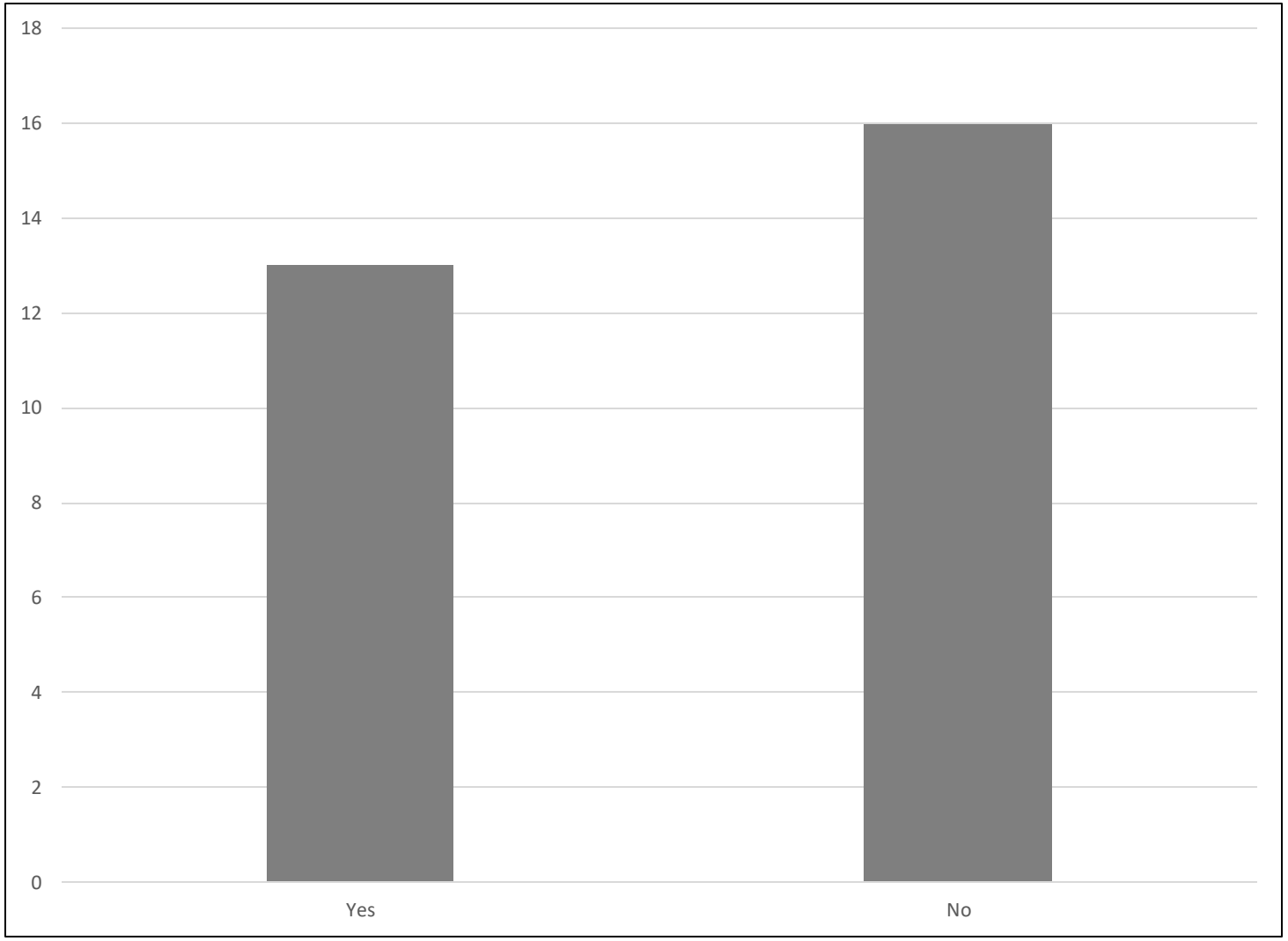


Promote collaboration through AR device

- ***role-playing games*** *: where each player has their own digital role based on which the appropriate information is displayed on the device. Players with different roles had to work together to complete their missions*
- ***Simple Communication****:simply enabling the exchange of messages or digital material without, however, this communication being necessary for the proper use of the application*

Users' ability to create or edit digital content

Only 1 study allow intervention in the content (e.g. after obtaining approval from the application administrators).



Incorporate digital storytelling

- *Time Travel (3)*
- *Mystery Game (3)*
- *Mystery Game with Quests (7)*

Research Questions

[RQ1] - Do informal learning AR applications for mobile devices promote collaboration

- **NO**

[RQ2] - Ability of AR applications for mobile devices to allow users to create new digital material accessible to other users

- **NO**

[RQ3] - The existence of scripts and plots in AR applications for mobile devices

- **55%** of applications did not include a script
- **45%** the activity was part of a story

Conclusions

The study of the research questions showed that **collaboration**, as well as **the creation of new digital material**, are features that are generally absent from these applications

As for the **script**, this feature is found in several applications (40%) as it constitutes a key motivator for users.

A lack of sufficient **pedagogical** consideration to fully exploit the available technological developments, maybe the absence of powerful features from AR applications

Conclusions

next research challenge might be

- the use of appropriately designed collaborative functions,
- the study of the impact of AR applications on shared contributions of digital materials
- the learning outcomes and the user motivation

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