# Open-Source Software in Public Schools: A Systematic Review

AP Capstone Research

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**Abstract**

Given that open-source software seems to be advantageous to many businesses, that there is relatively little literature on how advantageous it can be to schools, and that many schools have not yet adopted open-source software, this paper considers the advantages of open-source software and how they impact public schools using a qualitative systematic review. The systematic review was completed through a content analysis. The research followed an established coding process of 6 pieces of current academic literature sourced from various academic databases, surfacing *n=198* instances of 6 codes. Through this, the researcher established six main benefits of open-source software that could appeal to public schools. Out of the benefits identified, the most important were the software's inherent freedom, increased security and transparency, and reduced software expenses. It was found that these main benefits can easily appeal to the needs of public schools and increase their confidence in adopting open-source software. The researcher hopes that, in the future, more schools will adopt open-source software and more quantitative studies will appear to solidify confidence in OSS. It should be noted that this study is limited by the number of studies analyzed (due to time constraints) and the researcher's expertise. This systematic review was not registered in a systematic review database. (Definitions relevant to the abstract are presented in the next section.)

# Introduction

## Definitions

To begin, *software* is "program(s) for a computer" (Merriam-Webster, 2021). More specifically, *proprietary software,* also known as "closed-source software" or "commercial software", are software products "in which all rights are retained by the developer or publisher. They are typically closed-source, meaning the developer does not provide the source code to anyone outside the company. Proprietary programs are licensed to . . . [customers] . . . under specific terms defined by the developer or publisher. These terms often restrict the usage, distribution, and modification of the software" (Christenssson, 2015). An example of proprietary software is the Google Chrome web browser. Conversely, *open-source software*, abbreviated as OSS, is "software with source code that anyone can inspect, modify, and enhance" (Opensource.com, n.d.). Users may generally redistribute or modify the software for any reason and use the software for free. An example of open-source software is the Mozilla Firefox web browser. Based on these contrasting definitions, there is a comparison to be made between these two ways of licensing software.

Open-source software encapsulates software using an open-source licensing model, as defined in the previous section. Since the advent and explosive growth of the World Wide Web in the early 2000s, open-source software has become increasingly popular. It has become a driving force in the software world, with surveys saying that 90 percent or more of all software in the world contains at least some open-source components (Bals, 2021). In other words, without open-source software, the internet and computing as the world knows it would not exist. OSS operates at all levels of the computing hierarchy, from low-level software that communicate

directly with the electrical components in a computer to high-level software where users simply point-and-click to use.

## Literature Review

### Introduction

This study is a systematic review of current literature on the potential benefits of moving to open-source software, applied to the specific needs of public education institutions. This literature review will therefore only be a surface-level review of this literature (which will be analyzed in depth later in this research) and an introduction of important context for this research.

### Advantages & Disadvantages

OSS has a broad set of advantages, but their significance is unclear. Chief among the advantages of open-source software is the reduced cost of using it compared to proprietary software. Large companies such as Amazon.com, Inc. and Sabre Corporation each saved hundreds of millions of dollars by migrating to open-source software (Nagy et al., 2010). Furthermore, OSS helps with security and stability of important line-of-business software. According to Boulanger, the commonplace that open-source software is less stable than proprietary software is rooted in questionable studies funded by proprietary software vendors. In fact, Boulanger suggests that, in many cases, open-source software is more stable and faces fewer defects than proprietary software (Boulanger, 2005). OSS can also support educational values. When schools use proprietary software, teachers act as salespeople for that software, as students need to buy the software themselves in order to access documents and files created by the teacher using that software (Pfaffman, 2008). Also, many people cannot afford such

software, exacerbating the problem of financial inequality in education. Both problems run counter to the principles of readily accessible education and can be mitigated by using OSS, since students would be able to freely use the same software they use in the classroom, if that software is open-source. This summary is, however, a cursory overview of OSS's advantages and does not include all the major advantages that will be identified later in this study.

There are several hidden costs & disadvantages that must be addressed when considering a migration to open-source software (outlined in the following sections). First, as Asay explains, it may be needed to hire consulting services to handle the implementation of, maintenance of, and support for new open-source systems, if the implementing organization lacks the human resources to do so themselves - especially as professionals trained in maintaining open-source systems are relatively scarce compared to professionals trained in maintaining proprietary systems (Asay, 2018). Lost productivity from adjusting to new software and software users' resistance to change must also be considered (Oreški & Šimović, 2012). Educating users about the existence of open-source software is also important, because, as Nagy, Yassin, and Bhattacherjee state, a serious barrier to implementing open-source software is a knowledge gap (Nagy et al., 2010).

## Schools' Software Needs

Schools have a variety of needs regarding software in technology, but reviewing existing literature surfaced five main needs, described in the next five sections. These needs originated mainly from the following sources: (Salinas et al., 2017; Tanner & Johnston, 2013; Tarhini et al., 2019).

### *Financial Constraints*

All organizations, but especially taxpayer-funded ones (such as public schools), have a hard limit on how much money they may spend on technology and software. Overspending, reckless spending, or uninformed spending can lead to significant pitfalls for such organizations. For example, in Western Cape, a low-income province of South Africa, the provincial school district signed a deal with Microsoft to license its software at full price, but later realized that the deal was "completely unsustainable" and "not reasonable" (Tanner & Johnston, 2013). Furthermore, the COVID-19 pandemic & economic crisis has led to steep budget shortfalls at many school districts and other public organizations, further exacerbating the issue; in fact, a survey found that up to 1/3 of all US municipalities find themselves in "difficult financial condition" due to the COVID-19 pandemic (Maher et al., 2020).

***Internal Politics & Culture***

Internal politics are an obstacle in any organization, but especially in an organization like a school, where senior leadership members rely on elections to retain their positions. This can lead to severe friction when looking to create change. For instance, a member of senior management may be especially resistant to change or have some type of vested interest in that organization continuing to use proprietary software. That can make it very difficult for change to occur. An example of this occurring in the context of OSS is in Munich, Germany, which changed between proprietary and open source operating systems for their desktop computers several times, which many people speculate had to do with internal politics, as the changes happened to coincide with changes in the city's leadership (Schaer, 2020). Intriguingly, however, some surveys of IT teachers found that some teachers did not report that internal politics played a part in *their individual* adoption of new software (Salinas et al., 2017).

***Compatibility***

Compatibility is a problem with any organization, but especially in a content heavy organization such as a school. It is important that a new word processing software, for instance, be able to open documents made previously with another word processing software such as Microsoft Word. When considering a migration to any new software, regardless of whether it is proprietary or open source, institutions must consider software compatibility. In other words, they must try to ensure that any new, open-source based systems will be able to read, edit, and interact with any content created using old systems. In the aforementioned example of the provincial school district in Western Cape, "product compatibility was highlighted as the most problematic technological factor owing to the provincial standard being Microsoft" (Tanner & Johnston, 2013).

### *Perceived Performance*

Another issue is perceived performance. Users will always prefer software that *seems* to work well and be secure, including "perception of increased productivity, improvements in the speed of accomplishing tasks, access to resources that are needed to get the job done and the perception that teachers have of how technology contributes toward their student", regardless of how well it actually works (Salinas et al., 2017). The more appealing a new open-source solution seems, the more likely it is that an organization will adopt it and that its users will be willing to use it.

### *Awareness*

Finally, awareness is an issue. Although 80% of governments are using open-source software in some capacity, only a small group of people are aware of exactly what open-source is (Vaughan-Nichols, 2015). Consider asking a relative or a coworker for one example of open-source software – they most likely would not be able to name one, exemplifying the knowledge

gap surrounding OSS. If people are unaware of open-source software, there is no way for them to reap its benefits. Part of the reason for this is that "all the [school officials] . . . have no reason to look at alternative software", making it even more difficult for these people to learn about OSS (Tanner & Johnston, 2013).

**Relevance**

At public school districts, where funds are limited, the potential cost benefits of using open-source software are extremely important: with additional money freed up from spending on software, districts would be able to deliver better programs to students. These benefits are realized at educational institutions that chose to adopt open-source software, including the Keynes High School in Bologna, Italy. This school moved to use open-source software almost exclusively and was allocated 18,075€ to purchase Microsoft Office licenses for its students. Instead, it decided to spend that money on support for open-source software, costing just 6,710€ - roughly ⅓ of the cost of using the proprietary solution Microsoft Office. The extra money was used to purchase computers for students (Lin & Zini, 2008). Also, IT teachers at secondary institutions in Croatia indicated that their main reason for considering open-source software (if they did) was the low cost (Oreški & Šimović, 2012). Furthermore, at this same high school, the implementation of open-source software helped grow the spirit of open collaboration, in that students helped to translate the open-source Apache OpenOffice project, used by millions around the world, to Italian, and established a school-wide blog on which all students and teachers could post. Open collaboration by many people can lead to great success - as evidenced by the success of amateurs in the field of stargazing, who have made significant discoveries in the field, including several planets and moons (Pfaffman, 2008). Finally, seeing as digital literacy is becoming increasingly important in the workforce, schools must promote digital literacy in

students. Using open-source software can help achieve this goal, in that it allows students to explore the internals of the software they use (Red Hat, 2015).

### Conclusion

There are clearly many advantages to using open-source software that are evident to businesses, and those advantages bear relevance to a public-sector organization like a public school district. Yet, there are many hidden factors in moving to open-source software that are not well-considered in the context of a public-sector education scenario. Therefore, this prompts the question, which advantages should be considered when thinking about a migration to open-source software in public schools? This study will utilize the findings of previous research to surface the various factors that make open-source software advantageous for public schools, describe how those factors are relevant to public schools, and provide a basis upon which future studies regarding the use of open-source software at public school districts may build.

## Methods

### Outline of the Research Design

This research uses a qualitative approach for a systematic review through content analysis. Content analysis was chosen for several reasons: it is the only method usable to analyze existing analyses (i.e. combining the findings of a multitude of studies), it ensures the accuracy of the data by preventing bias from inaccurate results of analyzing a single study as large policy decisions, such as the adoption of OSS, should hardly be made using just one study, and it can demonstrate continuity and change over time, as content analyses can include studies over multiple time periods, as this study does. Furthermore, this research tightly follows the PRISMA 2009 statement for performing meta-analysis and systematic review (Moher et al., 2009). The

PRISMA system features an exhaustive list of content that must be included in a systematic review and has been used by copious other systematic reviews and meta-analyses because it ensures the quality and completeness of compliant research.

This study is designed primarily to inform potential policy decisions on the use of open-source software, whether that is on the level of an individual teacher's classroom or at a large district's Board of Education. A systematic review is the right choice given the abundance of research on the *general* benefits of OSS and the relative scarcity of information regarding its relevance to public schools.

An approach with the following steps was followed to analyze the data:

1. Select literature to use
2. Code the literature
3. Use counts to describe the nature of potential advantages derived from the adoption of OSS and determine which issues are most relevant to public education

**Selecting Literature**

First, relevant literature was selected. This included different studies and articles pertinent to the topic of the advantages of adopting open-source software. The researcher used searches on academic databases/search engines, including EBSCOHost, Google Scholar, Microsoft Academic, and a local university's research databases, using the following keywords: *education, open-source software, factors, qualitative,* and *advantages* to surface relevant and credible literature. The following criteria were followed for all studies included:

- To assure credibility, all literature was required to be peer-reviewed. This was achieved by using relevant filters on each of the databases searched.
- As the researcher is primarily an English speaker, only studies in English were chosen.

- Each study must have been published between 2000 and 2020 to ensure relevance to the current time.
- Each study must have been an empirical study that has a finding concerning one or more of the factors analyzed in this research.

After reading the abstracts of the returned relevant literature, the researcher selected several studies to be used in this systematic review, based on how relevant they appeared to this research. The sources chosen were designed to be as diverse as possible, to minimize the risk of potential widespread bias. A list of literature and their respective rationale for being included (in addition to conformance to the aforementioned criteria) are displayed in Table 1.

**Table 1**

*Literature Selected & Rationale*

| Literature citation | Description | Reason |
|---|---|---|
| **(Oreški & Šimović, 2012)** | This case study considers the reasoning for and against the adoption of open-source software in the ICT (Information communications & technology) classrooms of various schools in Slovenia, based on interviews of ICT teachers. | Considering the input of educators helps reveal specific benefits of OSS that are highly relevant to education. This is the only study the researcher found focusing on teachers' opinions. |
| **(Boulanger, 2005)** | This study examines the difference in security and | The study provides great detail about the theme of |

| | | |
|---|---|---|
| | reliability between OSS and proprietary software. | security and is published in a reputable journal (the *IBM Systems Journal)*. However, it is noted that this study is relatively dated. |
| **(Hwang, 2005)** | The study reviews many different topics with relatively little complexity, making it well suited to the purpose of defining codes for this research. | The study is used to define the themes used to examine the other studies. It was published in the *Michigan Journal of Public Affairs*. |
| **(Lin & Zini, 2008)** | Like Oreški and Šimović, this paper is a case study of the deployment of OSS at an educational institution. Specifically, it focuses on the Keynes High School, a relatively small technical high school, in Bologna, Italy. | Same as Oreški and Šimović. |
| **(Pfaffman, 2008)** | This study describes the benefits of using OSS in individual high school science classrooms. | The paper provides an outstanding overview of specific benefits of OSS for education (rather than |

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|---|---|---|
| | | focusing on more extraneous themes like cost savings, etc.). Also, the author (Pfaffman) has substantial experience with education research, and the paper is published in the *High School Journal*, a reputable education journal. |
| **(Ven et al., 2008)** | This study surveys IT employees at various Belgian organizations about the use of OSS to determine their main reasons for doing so. | In general, benefits to a business are also applicable to public sector organizations, especially financial benefits. This study is also published in the reputable *IEEE Software* journal. |
| **(Waring & Maddocks, 2005)** | This study examines the possibility of using OSS to replace expensive and underperforming proprietary systems in various British public agencies. It notes the positive aspects that push this | This study provides a good overview of factors that are more important to public sector organizations (which is important, as this research focuses on public education). It was published in the |

| | | |
|---|---|---|
| | consideration, as indicated by British IT professionals, while also ruling out those that are generally considered relevant but were not. | *International Journal of Information Management*. |

**Coding the Literature**

The analysis of the chosen literature follows the coding framework established in (Brown et al., 2003). Coding, as defined by Linneberg, "is the simple operation of identifying segments of meaning in your data and labelling them with a code" (Linneberg & Korsgaard, 2019). It uses this coding framework to look for six themes in the analyzed literature. Some themes were derived from the main topics in Hwang, 2005, a study that provides a general overview of the advantages of open-source software in the context of the public sector. These were *Reduced software expenses, Security and transparency* (note that reliability, as one of the pillars of security in information technology, also goes into this category), *Durability and interoperability,* and *Reducing software piracy*. Note that the fifth category mentioned in Hwang, *increased national sovereignty*, is not used in this research as sovereignty from foreign software vendors is not relevant to a public school district, the subject of this research. Two more categories, *inherent freedom* and *fostering community* were established by the researcher following the coding of the studies because the researcher observed several related codes that were not similar to the 4 codes derived from Hwang (Hwang, 2005). More details on each of these categories' meanings are available in the Results section.

Each of the selected studies were analyzed and interpreted to determine which of the previously mentioned theme(s) it supports, in three serial stages. In the first stage, the researcher identified specific codes observed while reading the literature, while the subsequent stages merged similar themes together, eventually culminating with each identified code being categorized into one of the five themes. Note that the researcher only coded items that were believed to be relevant to the topic of inquiry - not *any* theme emerging in the literature. A map of the coding process is available in Appendix A. Note that abstracts, titles, any highlights (i.e., enlarged quotes of text available elsewhere in the paper), headings, and subheadings were not considered in the coding process, as they often repeat content already existing elsewhere in the literature and can therefore introduce bias. Tables and figures, however, were included, as they typically contain unique content not available elsewhere in the piece. Furthermore, one text fragment identified as a code could only contain one code. In other words, a text fragment that could be classified as more than one code was only identified as one code by the researcher.

**Counts to Analyze the Literature**

According to Morgan, quantifying qualitative data, like the studies analyzed in this research, is necessary to properly analyze it (Morgan, 1993). So, based on the coding process, the frequency of each theme in each analyzed piece of literature was counted. Based on the sum of the frequencies, a percentage for each theme was calculated, which was then used to establish the most prevalent issues in the reviewed literature. Sums and percentages for the occurrences of each theme are available in Table 2**,** while the raw data (consisting of the number of occurrences of each theme in each analyzed piece of literature) is available in Appendix B**.**

Finally, those themes were compared with the issues relevant to educational institutions specifically. A final ranking of the themes in order of importance as relevant to education was created, which is displayed in Table 3 of the Results section.

## Results

Results of this research include two different sets of information. First is the distribution of concern about open-source software in the technological community (as derived from the content analysis outlined in Methods), available in Table 2. This data is used to identify the most prominent advantages of leveraging OSS in different organizations. The second set of information is a list of advantages that public sector & educational institutions find when using OSS in general. This list is unranked because concerns for public sector/educational institutions can vary between organizations, while the first set of data is globally generalizable. It is important that this study considers the needs of all public educational institutions, and a ranked list could exclude the needs of certain organizations.

**Table 2**

*Prevalence of Each Theme*

| Theme/code name | Instances | Percentage |
|---|---|---|
| **Reduced software expenses** | 40 | 20.2% |
| **Security and transparency** | 41 | 20.7% |
| **Durability and interoperability** | 13 | 6.5% |
| **Reducing software piracy** | 4 | 2.0% |
| **Inherent freedom** | 83 | 41.9% |

| | | |
|---|---|---|
| **Fostering community** | 18 | 9.1% |
| **Total** | **198** | **100%** |

Based on the data in Table 2, the *inherent freedom* category was the most important advantage in the analyzed literature, with a plurality of 41.9% of codes. The studies analyzed, in particular Lin and Zini, placed great emphasis on the importance of the free licenses that open source software uses (Lin & Zini, 2008). These licenses allow the organizations to freely modify the software to fit their needs (for proprietary software, this would require a royalty and/or licensing payment to the software vendor) and validate the software for security and integrity. It also means anyone may use such software for any reason and glean lessons from previously published OSS when building new software.

Following this, the next advantage is *security and transparency,* representing 20.7% of codes. Many organizations in the analyzed studies, along with computer-based analysis of software, observed greater reliability and fewer security issues (and other programmer-induced software faults) in open-source software, which can be attributed to the fact that most open-source code is extensively peer reviewed by community members. Because of this, organizations also found that issues are resolved more quickly and more competently by open-source teams, compared to proprietary software vendors, who must be blindly relied upon for patching when vulnerabilities are discovered.

The next advantage is *reduced software expenses* with 20.2% of codes. While there is an obvious short-term financial benefit in that most open-source software is free to download and use under any scenario (due to their open licenses), there is also a long-term benefit. All analyzed

studies investigating financial benefits noted that, in the long term (i.e., total cost of ownership), open-source software costs less than proprietary software, all factors considered.

*Fostering community* represented 9.1% of codes. This factor was particularly significant in studies concerning OSS at schools, while it was mentioned less often in studies concerning corporations. In particular, Lin and Zini had a great focus on how users of OSS at a school can work together to form a community that contributes to open-source projects. It specifically mentions a group of students who collaborated to translate the open source office suite Apache OpenOffice to Italian (Lin & Zini, 2008). Other studies also mentioned how anyone can create and consume online resources and help for open-source software and that communities blossom from this collaboration.

Following further after *reduced software expenses* is *durability and interoperability,* representing 6.5% of codes. Most codes under this category relate to reported ease of use and the fact that using OSS avoids lock-in. More marginally, this is also related to the idea that OSS can be used on older hardware compared to proprietary software (especially in the realm of desktop operating systems). Generally, all these factors help ensure that systems built on OSS can be used for longer and more easily compared to systems built on proprietary software.

Lastly, *reducing software piracy* represented 2.0% of codes. There was relatively little discussion about the idea that the fact that OSS is free means it is unnecessary to pirate or otherwise illegally use or obtain software.

**Table 3**

*Concerns Affecting Public Schools' Adoption of New Technologies*

| | |
|---|---|
| **1** | Financial constraints |
| **2** | Organizational internal politics & culture |

| | |
|---|---|
| **3** | Compatibility |
| **4** | Perceived performance: security, reliability, and quality |
| **5** | Awareness of OSS |

Evaluating the general concerns around technology in public education, as explained in the literature review, led to 4 technological factors from 3 sources: (Salinas et al., 2017; Tanner & Johnston, 2013; Tarhini et al., 2019). The data for this is available in Table 3. It should be noted that narrower factors were combined into broader factors (e.g., government awareness and teacher awareness were both combined to the *awareness* category). Having these factors allows the researcher to compare between the general benefits of OSS and the general priorities in the context of technology for public education. Seeing as there is a degree of subjectivity, the relationship between the data in Table 3 and the data in Table 2 will be reported later in this paper.

## Discussion

### Interpretation of Results

The researcher will discuss the most significant factors (as specified in Table 2) in the next sections, in relation to the factors addressed in Table 3.

### Inherent Freedom

Inherent freedom was discovered to be the most important benefit of OSS. *Since open-source software is open-source*, it can be highly appealing to organizations. The flexibility afforded by OSS licenses are particularly interesting to public education, as public educational institutions often have technological needs that differ drastically from those of traditional private

commercial organizations. With greater agency to truly build solutions that fit their organizations, public education can fill all their needs. Inherent freedom, however, particularly fits the public education needs of organizational politics & perceived performance: By constructing a tailor-made solution, IT professionals can more easily satisfy their organization's needs and appeal to employees' perceptions of the software, as custom-built software will naturally fit an organization's workflow better, making the technology experience more appealing to end users.

**Security and Transparency**

Security is undoubtedly one of the foremost concerns of any organization. This is particularly important in public education, where stringent regulation like the Family Educational Rights and Privacy Act (1974) mandates the protection of privileged student information, which is now often stored on school IT systems (Family Educational Rights and Privacy Act, 1974). In other words, security defects originating from low quality proprietary software is something that is untenable for public schools. In fact, "the White House identified privacy in education as a flashpoint for big data policy concerns" (Polonetsky & Tene, 2015). In this way, the increased security, faster patching, and elimination of blind trust in a software vendor derived from open-source solutions appeals to public education's perceived performance needs. By adopting OSS, especially for critical systems containing privileged information, public educational institutions can be confident that their information will remain secure and compliant with current and future privacy legislation.

**Reduced Software Expenses**

Financial constraints were identified as one of the concerns affecting public school adoption of technology. Fortunately, the financial benefit was discovered as one of the most

significant advantages of OSS. As elaborated on before, open-source software is cheaper to operate in the long term compared to proprietary software. In order to enhance the value-per-dollar of the technology services they can deliver to students and staff, public schools should consider replacing expensive proprietary systems with open-source alternatives.

**Fostering Community**

The fostering of community around and with OSS can appeal to the needs of organizational internal politics as well as the awareness of OSS. Organizational leaders may see the extensive help resources freely available for OSS as a boon for their information technology support teams. Furthermore, developers and other contributors form a community around the work for their relevant software. When they join organizations, they can spread their knowledge about OSS to that organization. To a lesser degree, it may also appeal to the perceived performance of OSS. When users have a community of people to fall back on when help is needed, or a group of users to collaborate with on open source, they may come to see the software as easier to use.

**Other Factors**

Seeing as the other factors (*reducing software piracy* and *durability and interoperability*) constitute less than ten percent of code occurrences, they do not represent enough of the advantage of using OSS to warrant further consideration in the context of public education.

**Implications**

It is important to note that the implications of this research should be limited to those established in this section. While this research is designed to act as a policy recommendation, no decision, regardless of size, should be made using only this research, without the support of

additional quantitative analyses in this field. The researcher hopes that future quantitative research in this field will be possible because of their provided framework.

Although many governments and other public institutions already use open-source software extensively, many continue to lag behind the private sector (Marson, 2005). Part of the reason why governments and schools are slow to adopt OSS is because of a lack of confidence in its benefits. Seeing as this study helps demonstrate the benefits of open source for public educational institutions, the researcher hopes that greater OSS adoption will be achieved in this sector in the future. Also, the COVID-19 pandemic may also affect OSS adoption: organizations have placed greater focus on their IT infrastructure since many services and functions have moved online due to the pandemic, meaning organizations may spend more time researching prior to making IT decisions, allowing them to potentially surface OSS solutions. Furthermore, relating to the economic strain placed on organizations due to the COVID-19 pandemic's resultant economic downturn, technology analysts have observed that "organizations turn to open source in tough economic times because it helps them reduce costs and improves their ability to innovate" (Vaughan-Nichols, 2020). As demonstrated in this study, OSS provides a low-cost, high-quality alternative to proprietary software that would enable organizations to spend their increasingly limited IT budgets more efficiently. For these reasons, the researcher expects to see adoption of OSS increase rapidly in the near future.

**Limitations**

While this study was conducted with a good-faith effort to make it as accurate as possible, there are some limiting factors that may affect the actual accuracy of this study. Chief among these is the fact that this study is a qualitative systematic review. According to Petticrew, this study could serve as a framework for future quantitative studies, but it cannot establish the

existence of very specific factors in the adoption of OSS, nor could it establish a cause-and-effect relationship between factors (Petticrew, 2015). In other words, this study could *suggest* something, but not *prove* something.

Also, due to time and resource constraints, such as having other work and obligations, the effect of COVID on school hours and operation, the short length of the AP Research course, and the lack of a second coder to collaborate with (as some other systematic reviews have), the researcher was only able to analyze six studies. As a result, there could be some errors, perhaps stemming from a bias that is present in all six studies, errors in one or more of the analyzed studies, or from the researcher not choosing the absolute best studies for this research. The timeframe of these studies was also limited to the earlier part of the timeframe defined in the studies' selection criteria in the Methods section, which is relevant because the technology world shifts unusually fast compared to other sectors. Additionally, because 4 of 6 codes were derived from (Hwang, 2005), bias in that source could decrease this study's accuracy.

Finally, the researcher is not an expert in systematic review and coding. While choices in this study were justified with other research and examples as much as feasible, there remains the possibilities of errors or inaccuracies in the research design, which could affect the results or their accuracy.

## Applications

In this section, viable explanations will be offered to address how each technological factor (as expressed in Table 3) can be appealed to by the advantages of OSS (as displayed in Table 1) by synthesizing the analysis earlier in this paper.

### Financial Constraints

Given that the financial benefits of OSS were the 3rd most important advantage as identified earlier in this research, the use of open-source software can substantially alleviate financial worries public education institutions may face. Although governments like the United States have already made significant headways in OSS adoption, other governments, both national and local, should still consider expanding OSS adoption in the public sector, potentially through new statutes.

**Internal Politics & Culture**

According to a report in the Harvard Business Review, one of the most important things to do to overcome this barrier is to "win hearts and minds by emphasizing how the new technology benefits the organization and makes employees' lives easier" (Knight, 2015). In other words, the benefits of OSS as demonstrated in this study can be used to prove to possibly politically opposed organization members, especially members of leadership who are more influential, how the adoption of OSS can really benefit the organization, enhancing confidence in implementing new OSS systems.

**Compatibility**

This study was inconclusive regarding whether compatibility and interoperability is a significant advantage of OSS, so further research will be required to determine how open-source software can appeal to this need, perhaps through another content analysis focusing only on this factor.

**Perceived Performance**

Perceived performance easily compasses the two biggest advantages of open-source software as identified in this research: its freedom and its high security and reliability. This

research already demonstrated that these two benefits are extremely well known and important to organizations considering OSS.

**Awareness**

Given the extensive benefits of OSS as discussed in this study and given the importance of these benefits to organizations as discussed in this section, it is reasonable to conclude that awareness of open-source software will only increase over time. Eventually, awareness should no longer be a significant concern for organizations.

**Future Recommendations**

Future research into open-source software that may or may not include schools should focus on more clearly establishing how exactly the use of OSS benefits schools. While this study focused on a qualitative analysis to establish the general benefits of OSS for public education, future studies could focus on one specific domain of OSS's advantages (e.g., financial, freedom, etc.) and perform a detailed *quantitative analysis* to assert OSS's benefits more definitively for schools.

**Conclusion**

This study addressed the advantages of open-source software as specifically applied to public schools. Through a systematic review through content analysis, this study discovered that several advantages are prevalent regarding OSS adoption in general, and that these factors help satisfy the main needs public education institutions face when looking for new technology. Previous studies have only examined the benefits of OSS in general for businesses, while this study newly discovered how OSS can satisfy the needs of public education. It is clear that open-source software is a huge resource for public education waiting to be tapped. By gaining an

understanding of how it can benefit public schools, organizations will be able to adopt OSS more confidently.

## Funding

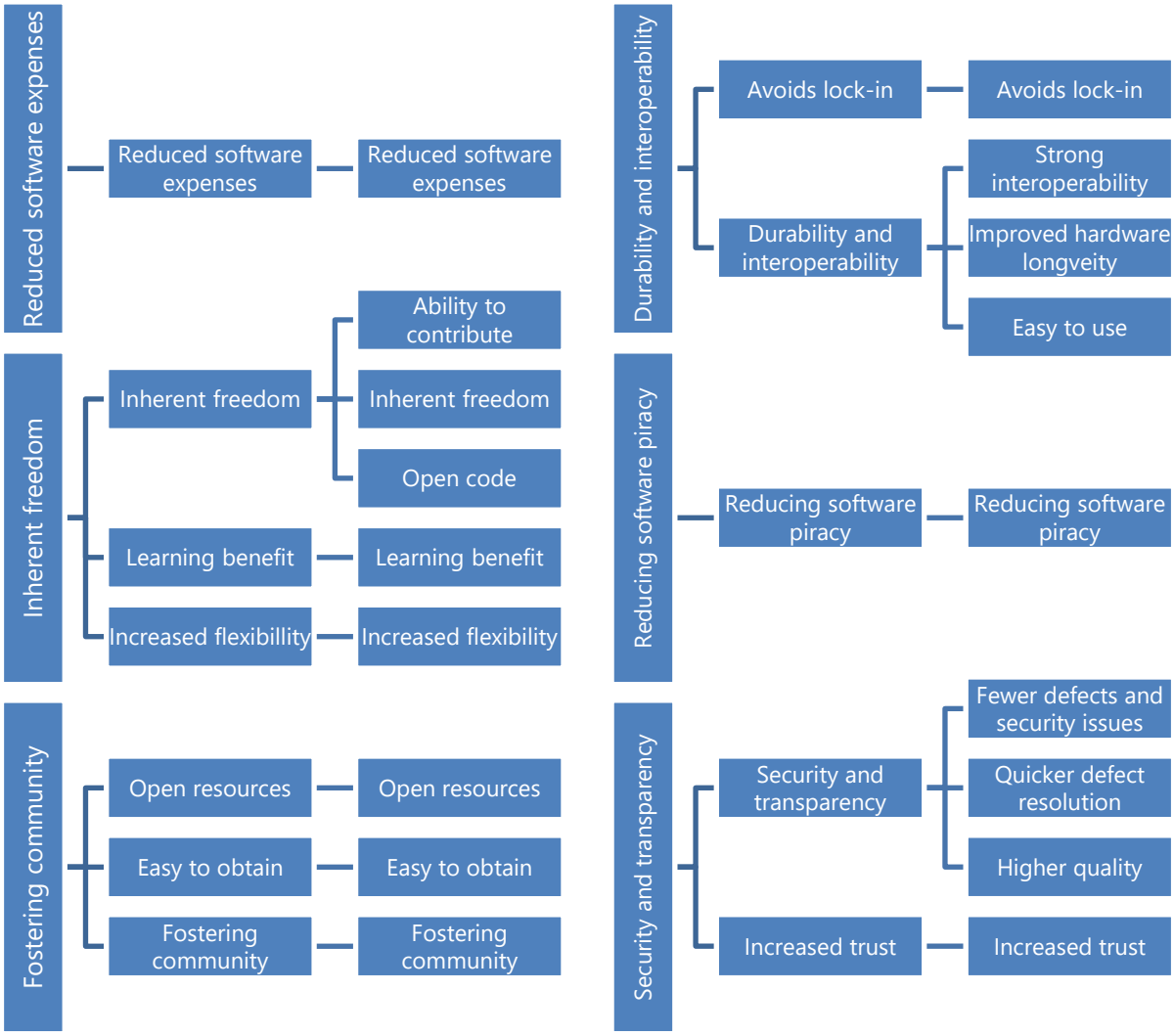
No external funding was used for this research. All data was derived from freely available journals and databases.

## Appendix A

An Analytical Map of the Coding Process

The map demonstrates a hierarchy of the codes surfaced by the researcher. On the leftmost level of the hierarchy chart are the most general codes (i.e., codes that surfaced from the third stage of coding), while codes get more specific moving to the right. The codes in the center column originated from the second stage, and the codes on the rightmost (third) column of the hierarchy are the most specific codes, i.e., the ones that originated from the first stage of the coding process.

**Figure A1**



## Appendix B

Frequency of Occurrence of Themes in each Analyzed Literature

**Table B1**

| Theme | (Oreški & Šimović, 2012) | (Boulanger, 2005) | (Lin & Zini, 2008) | (Pfaffman, 2008) | (Ven et al., 2008) | (Waring & Maddocks, 2005) |
|---|---|---|---|---|---|---|
| **Reduced software expenses** | 4 | 3 | 3 | 4 | 5 | 21 |
| **Ability to contribute** | 1 | 8 | 12 | 2 | 1 | 0 |
| **Knowledge / learning benefit** | 1 | 1 | 11 | 4 | 2 | 0 |
| **High quality** | 2 | 6 | 0 | 0 | 3 | 4 |
| **Inherent freedom** | 3 | 1 | 3 | 4 | 0 | 3 |
| **Open code** | 0 | 5 | 2 | 1 | 3 | 2 |
| **Increased flexibility** | 1 | 1 | 3 | 0 | 5 | 3 |
| **Fewer defects / security issues** | 0 | 8 | 0 | 0 | 0 | 3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Fostering community** | 0 | 0 | 11 | 0 | 0 | 0 |
| **Quicker defect resolution** | 0 | 6 | 0 | 1 | 1 | 0 |
| **Increased trust** | 0 | 2 | 0 | 0 | 4 | 1 |
| **Open resources** | 0 | 2 | 2 | 11 | 0 | 0 |
| **Avoids lock in** | 0 | 0 | 0 | 0 | 2 | 3 |
| **Reducing software piracy** | 1 | 0 | 3 | 0 | 0 | 0 |
| **Easy to use** | 0 | 1 | 2 | 1 | 0 | 0 |
| **Improved hardware longevity** | 1 | 0 | 1 | 1 | 0 | 0 |
| **Easy to obtain** | 2 | 0 | 0 | 0 | 0 | 0 |
| **Strong interoperability** | 1 | 0 | 0 | 0 | 0 | 0 |
| **Security & transparency** | n/a | n/a | n/a | n/a | n/a | n/a |
| **Durability & interoperability** | n/a | n/a | n/a | n/a | n/a | n/a |

*Note: Security & transparency and durability & interoperability themes are all n/a because they were not identified as part of the first-stage coding process but rather created during the second stage merging procedure. Some theme names are abbreviated to improve the table's readability.*

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