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An Analysis of Front-End Technologies in Higher Education: A Comparative Study of the Largest Universities in the United States and Poland*

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Abstract

This study investigates the front-end technologies used by the largest universities in the United States and Poland to understand how institutions use web technologies to enhance their digital presence. The research addresses a gap in literature concerning comparative analyses of technological adoption in higher education across different countries. The methodology involved analyzing the websites of 50 universities in each country using tools like BuiltWith and Wappalyzer. Key dimensions included the use of JavaScript frameworks, content management systems, and security mechanisms, highlighting adoption trends and differences between the two regions. The findings reveal a shared reliance on stable technologies like jQuery and PHP, with Bootstrap commonly employed for responsive design. Polish universities demonstrate a conservative approach, favoring advanced form-handling tools like Select2, while U.S. universities show greater diversity, adopting modern frameworks like Vue.js and advanced security measures such as HSTS and reCAPTCHA. Despite differences, both prioritize stability over cutting-edge innovation. These results highlight the influence of budget constraints and institutional priorities on technology choices, emphasizing the need for modernization in academic web development to meet evolving user expectations. This study provides a foundation for further exploration of strategies to enhance digital experiences in higher education.

keywords: Front-end technologies in education, university website development, comparative analysis USA-Poland

Introduction

Universities, similarly to other businesses, must compete for customers, where students represent the primary clientele. In this competitive landscape, websites play a pivotal role as they serve as the digital face of institutions, shaping first impressions and facilitating key services. This study seeks to explore the front-end technologies employed by universities in building their websites, with a specific focus on the largest universities in the United States and Poland.

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Existing literature on front-end technologies in higher education reveals a limited body of work, highlighting the need for further research. Studies like those of Bollens et al. (2014) and Estes (2016) emphasize the critical role of responsive web design (RWD) and accessibility standards in enhancing user experience and institutional branding. However, the adoption of modern frameworks such as React, Vue.js, and Angular remains inconsistent, raising questions about institutional priorities and resource allocation. This study bridges the gap by analyzing the technological choices of universities and comparing trends across two different educational ecosystems.

The research hypothesis formulated in the publication was as follows: Due to differences in budget levels between Polish and American universities, the authors expected to find more advanced and modern technologies employed by universities in the United States compared to those in Poland.

Literature Review

(Short) history of front-end frameworks

The history of front-end technologies is a tale of dynamic development, transforming the way web applications are built (Strazzullo, 2023). It all began in 1995 when Netscape created JavaScript, a programming language that introduced interactivity to web pages. A few years later, in 1999, the introduction of XMLHttpRequest enabled the creation of AJAX applications, allowing dynamic content updates without reloading the page(Dinh & Wang, 2020). A major milestone came in 2006 with the release of jQuery, one of the first JavaScript libraries that simplified DOM manipulation and event handling. Its simplicity and compatibility with various browsers quickly made it an essential tool for developers (Odeniran, 2023).

In 2010, Google introduced AngularJS, a framework that revolutionized web application development. Features like two-way data binding and a component-based approach to building user interfaces made it one of the most popular tools of its time. A few years later, in 2013, Facebook launched React—a library that introduced the concept of the Virtual DOM, boosting application performance and changing the way developers approached user interfaces(Singh et al., 2023).

The year 2014 saw the debut of Vue.js, created by Evan You. This lightweight and flexible framework quickly gained recognition for its simplicity and adaptability to different needs. Around this time, technologies supporting scalable application development were also gaining momentum, exemplified by Angular, which was completely rewritten by Google in 2016 and built on TypeScript (Shukla et al., 2023).

That same year, Svelte made its debut, a framework that stood out with its compile-time approach, enabling more efficient applications in browsers. The recent years have seen tools like Next.js (based on React) and Nuxt.js (based on Vue) rise to prominence, offering streamlined solutions for building server-side rendered (SSR) and static site generation (SSG) applications (Jonathan, 2023).

The evolution of front-end development is a story of continuous innovation, enabling the creation of increasingly advanced, interactive, and efficient applications while adapting to the ever-changing needs of developers and users alike.

Research on front-end frameworks used in higher education

When it comes to publications about front-end technologies in higher education, their number is very limited.

According to (Bollens et al., 2014), over 70% of surveyed higher education institutions in Portugal reported using Responsive Web Design (RWD) to enhance user experience across devices. Another noteworthy observation was that a significant portion of university website traffic comes from mobile phones. Studies show that mobile traffic accounted for nearly 50% of all visits to university websites, necessitating the adoption of mobile-friendly designs. In terms of front-end technologies used to create websites, the dominant ones included HTML5, CSS3, and Bootstrap. Major challenges faced by universities included budget constraints, which limited the ability to adopt the latest front-end technologies. Another significant issue was ensuring compliance with accessibility standards (such

as WCAG), which posed a challenge for over 60% of institutions. Well-designed websites proved to be a vital element of university marketing. Institutions that implemented RWD observed a 25% increase in user engagement and longer session durations, especially from mobile users. Prospective students were 30% more likely to explore admissions-related content when accessing a responsive website. According to Bollens et al., transitioning to RWD is critical for universities aiming to meet the expectations of tech-savvy students and stakeholders. Investment in responsive and accessible design not only improves usability but also positively influences institutional branding and recruitment. Therefore, universities must prioritize staff training in modern front-end technologies to address skill gaps and ensure sustainable website development.

Another publication dedicated to front-end technologies on university websites is the work of (Estes, 2016), in which the author investigated the adoption of responsive web design (RWD) and accessibility standards among the top 100 U.S. universities. The author analyzed 100 universities from the U.S. News & World Report Rankings (2015) and evaluated their websites on a scale of 0–20 points based on best practices according to WCAG 2.0 and Section 508 standards. The study found that, in terms of responsiveness, 86% of universities scored 15 or higher on the 20-point scale, with an average score of 18.1 (90.5% of criteria met). Additionally, 41% of universities achieved a score of 19, and 32% had a perfect score of 20. Regarding accessibility, universities averaged 25 WCAG errors each. Universities with higher enrollment tended to have fewer accessibility errors; however, higher tuition universities did not consistently show better accessibility. Larger universities demonstrated better adherence to accessibility standards (moderate negative correlation with WCAG and Section 508 errors). In terms of digital inclusiveness, larger universities led in adopting accessibility, likely due to serving a more diverse and larger student population, while smaller universities faced limited options in this area.

The publication by (Bollens et al., 2014) discusses the importance of responsive web design in higher education, emphasizing that responsive university websites enable access from various devices. This is particularly important for students, who are more likely to use smartphones than laptops (68% of high school students have visited university websites on mobile devices). While choosing a university is influenced by factors like knowing someone who studies there and housing conditions, the authors argue that first impressions from using a university's website can impact the decision-making process regarding study choices. Key success factors include consistent design and navigation, usability (easy access to content), and performance (fast loading and optimized multimedia). According to the authors, assembling the right project team is crucial, including designers, developers, content creators, and cloud service providers. Best practices include content inventory, navigation optimization, and regular maintenance.
A significant number of scientific publications describe the popularity of front-end technologies as subjects taught at universities, including works by (Fried, 2003), (Wormald, 2011), (Gretsch et al., 2019), (Chen, 2023), (Allen, 2011). The publication indicates that they significantly improved the competitiveness of students in the market.

Another group of studies discusses the similarities and differences between frameworks, including works by (Skrzypiec & Plechawska-Wójcik, 2023), (Bielak et al., 2022), (Diniz-Junior et al., 2022), (Dymora et al., 2023), (Bogusz et al., 2024).

Methodology

The methodology adopted for this study involves a comparative analysis of the official websites of the 50 largest universities in the United States and Poland. The selection of these institutions ensures a diverse and representative sample, encompassing varying levels of resources, technical expertise, and user demographics.

Analytical tools such as BuiltWith and Wappalyzer were employed to identify the front-end technologies utilized by these websites. These tools provide insights into the frameworks, libraries, and content management systems (CMS) powering the sites. The analysis focused on several key dimensions, including the prevalence of JavaScript frameworks (React, Angular, Vue.js), the use of CMS platforms (WordPress, Drupal), and the implementation of RWD principles.

The study also examined security measures employed by these universities, such as HTTPS adoption, reCAPTCHA usage, and other mechanisms for protecting against cyber threats. The findings were organized into tables for clarity, enabling direct comparisons between the technological landscapes of universities in both countries.

By combining quantitative data with interpretive analysis, this methodology offers a comprehensive understanding of how universities leverage front-end technologies to enhance their digital presence while addressing challenges of usability, accessibility, and security.

Results

The analysis of front-end technologies utilized by the largest universities in the United States and Poland provides valuable insights into the differences and similarities in their technological approaches. By examining the prevalence of specific tools, frameworks, and security measures, this study highlights trends in the digital strategies of these institutions. The findings are summarized in the tables below, showcasing the most commonly used technologies and their distribution across both regions. This comparison aims to identify patterns that align with or challenge the initial research hypothesis, shedding light on how resource allocation and institutional priorities influence technological adoption.

Table 1: Front-end technologies used at the 50 largest universities in the USA

University	website	front-end solutions	security
University of Central Florida	ucf.edu	WordPress, Handlebars, PHP, LazySizes, jQuery, core-js, Bootstrap	
Texas A&M University	tamu.edu	Scrollreveal, jQuery	HSTS
Ohio State University	osu.edu	Vue.js, Socket.io, Nuxt.js, core-js, web-vitals	reCAPTCHA, HSTS
Florida International University	fiu.edu	core-js, Modernizr, jQuery, ZURB Foundation	reCAPTCHA
University of Florida	ufl.edu	WordPress, PHP, AOS, Slick, OWL_Carousel, jQuery, Bootstrap	
University of Minnesota	umn.edu	GSAP, PHP, jQuery, core-js	HSTS
Arizona State University	asu.edu	styled-components, React, PHP, Fastly, Unpkg, jQuery, core-js, Glide.js	
University of Texas at Austin	utexas.edu	GSAP, PHP, ScrollMagic, Modernizr, jQuery, ZURB Foundation	reCAPTCHA, HSTS
Michigan State University	msu.edu	Mustache, GSAP, Microsoft ASP.NET, ScrollMagic, LazySizes, core-js, jQuery, Bootstrap	reCAPTCHA, Imperva, HSTS
Pennsylvania State University	psu.edu	React, Emotion, Next.js, Emotion	HSTS
University of Illinois at Urbana-Champaign	illinois.edu	Ms ASP-NET, SweetAlert, lit-html, lit-element, jQuery, core-js, Bootstrap	
University of Michigan	umich.edu	jQuery	Cloudflare Bot Management, HSTS
University of Washington	washington.edu	WordPress, Backbone.js, PHP, Python, core-js, Underscore.js, jQuery, Bootstrap	
University of Wisconsin-Madison	wisc.edu	HTML, CSS, JS	
Purdue University	purdue.edu	WordPress, PHP, Glide.js, core-js, jQuery, FingerprintJS	HSTS
University of California, Los Angeles (UCLA)	ucla.edu	core-js, jQuery, FancyBox	reCAPTCHA
University of California, Berkeley (UC Berkeley)	berkeley.edu	WordPress, AngularJS, jQuery, PHP	Cloudflare Turnstile
University of Southern California	usc.edu	WordPress, GSAP, PHP, Swiper, LazySizes, core-js, jQuery	HSTS
University of North Carolina at Chapel Hill	unc.edu	WordPress, Java, PHP, Swiper, core-js, jQuery	HSTS
University of Arizona	arizona.edu	PHP, jQuery, core-js, Bootstrap	HSTS
University of Houston	uh.edu	AOS, Modernizr, jQuery, Bootstrap	
University of South Florida	usf.edu	Microsoft APS.NET, jQuery	
University of Maryland, College Park	umd.edu	PHP, jQuery, Bootstrap	
Indiana University Bloomington	indiana.edu	jQuery, Modernizr, jQuery, ZURB Foundation	reCAPTCHA, HSTS
University of Georgia	uga.edu	Vue.js, AOS, core-js	HSTS
University of California, San Diego (UCSD)	ucsd.edu	Stick, jQuery, Bootstrap	HSTS
University of California, Irvine (UCI)	uci.edu	jQuery, Bootstrap	HSTS
University of California, Davis (UC Davis)	ucdavis.edu	PHP, lit-html, lit-element, jQuery	HSTS
University of Colorado Boulder	colorado.edu	PHP, jQuery, Flickity, core-js, Modernizr	HSTS
University of Pittsburgh	pitt.edu	GSAP, PHP, Swiper, core-js, jQuery	HSTS
University of Alabama	ua.edu	WordPress, PHP	HSTS
University of Kentucky	uky.edu	PHP, jQuery	

University	website	front-end solutions	security
University of Tennessee, Knoxville	utk.edu	WordPress, PHP	reCAPTCHA
University of Iowa	uiowa.edu	PHP, jQuery, core-js, Bootstrap	ClickCease
University of Kansas	ku.edu	PHP	HSTS
University of Oklahoma	ou.edu	Backbone.js, Java, Underscore.js, core-js, jQuery	Facebook_Login
University of Nebraska-Lincoln	unl.edu	PHP, RequireJS, GSAP, jQuery, core-js	
University of South Carolina	sc.edu	TwinPics, core-js, AOS, Modernizr, jQuery, Instant_Page, FancyBox, ZURB Foundation	
University of Missouri	missouri.edu	PHP, jQuery, Instant.Page, Bootstrap	HSTS
University of Connecticut	uconn.edu	WordPress, PHP, LazySizes, core-js, jQuery	
University of Massachusetts Amherst	umass.edu	PHP, LazySizes, Swiper, jQuery, core-js	
University of Virginia	virginia.edu	PHP, Swiper, core-js, Modernizr, jQuery	
University of Utah	utah.edu	PHP, jQuery, core-js, AOS, OWL_Carousel	HSTS
University of Illinois at Chicago (UIC)	uic.edu	GSAP, Vue.js, core-js	HSTS
University of Cincinnati	uc.edu	Java, web-vitals	HSTS
University of Louisville	louisville.edu	Handlebars, Lodash, core-js, Twitter_typeahead.js, jQuery, PHP, USWDS, Bootstrap	
University of Oregon	uoregon.edu	PHP, jQuery, core-js, Slick	reCAPTCHA, HSTS
University of Nevada, Las Vegas (UNLV)	unlv.edu	PHP, jQuery, Animate.css, Bootstrap	reCAPTCHA, HSTS
University of New Mexico	unm.edu	Backbone.js, Underscore.js, jQuery, Bootstrap	
University of Hawaii at Manoa	manoa.hawaii.edu	WordPRess, GSAP, PHP, core-js, jQuery	reCAPTCHA

The analysis of Table 1 shows that the dominant technologies used for creating websites at the largest universities in the USA were: jQuery (42/50 universities), PHP (30/50), core-js (28/50), Bootstrap (15/50), and WordPress (11/50). Modern frameworks such as React, Vue.js, and Angular were not particularly common (used by 2, 3, and 1 university, respectively). Similarly rare were Next.js and Nuxt.js, each used by only one university.

This is rather surprising, as considering the budgets of these institutions, the expense of modernizing a website would not seem to be a significant burden. However, the reasons might be purely practical—minimizing the risk of severe losses in the event of a hacking attack and questioning what financial gains hackers could achieve by breaching a university website.

It is also intriguing that these universities have computer science departments, which evidently do not create their websites, as modern front-end technologies are certainly taught in their courses.

Table 2: Front-end technologies used at the 50 largest universities in Poland

No	University	website	front-end solutions	security
1	Uniwersytet Warszawski	www.uw.edu.pl	WordPress, GSAP, AngularJS, PHP, prettyPhoto, core-js, Modernizr, jQuery	
2	Uniwersytet Jagielloński w Krakowie	www.uj.edu.pl	Java, Bootstrap, YUI, Moment.js, Underscore.js, OWL_Carousel, Modernizr, jQuery, FancyBox, AlloyUI	
3	Politechnika Warszawska	www.pw.edu.pl	PHP, Skrollr, prettyPhoto, jQuery, Isotope, Bootstrap	
4	Uniwersytet Wrocławski	www.uni.wroc.pl	WordPress, React, PHP, Select2, Moment.js, jQuery, Bootstrap	HSTS
5	Uniwersytet Gdański	www.ug.edu.pl	PHP, jQuery, Bootstrap	
6	Uniwersytet Adama Mickiewicza w Poznaniu	amu.edu.pl	PHP, Swiper, Moment.js, LazySizes, core-js, Moernizr, jQuery	HSTS
7	Politechnika Wrocławska	www.pwr.edu.pl	Select2, Modernizr, core-js, jQuery	
8	Uniwersytet Łódzki	www.uni.lodz.pl	Angular, Zone.js, PHP, Select2, PhotoSwipe, jQuery, core-js	reCAPTCHA, HSTS
9	Uniwersytet Śląski w Katowicach	www.us.edu.pl	Angular, Zone.js, PHP, TypeScript, Select2,	reCAPTCHA, HSTS

No	University	website	front-end solutions	security
			PhotoSwipe, jQuery, core-js	
10	Uniwersytet Marii Curie-Skłodowskiej w Lublinie	www.umcs.pl	Select2, jQuery, core-js, jQuery	reCAPTCHA
11	Politechnika Gdańska	pg.edu.pl	PHP, Splide, Moment.js, jQuery, core-js, Bootstrap	
12	Uniwersytet Mikołaja Kopernika w Toruniu	www.umk.pl	PHP	HSTS
13	Akademia Górniczo-Hutnicza w Krakowie	www.agh.edu.pl	PHP, PhotoSqipe, jQuery	HSTS
14	Uniwersytet Szczeciński	www.us.edu.pl	WordPress, Handlebars, PHP, wpBakery, Preact, FancyBox, Moment.js, jQuery, Animate.css, Bootstrap	
15	Uniwersytet Opolski	www.uni.opole.pl	PHP, jQuery, prettyPhoto	
16	Politechnika Krakowska	www.pk.edu.pl	PHP, Bootstrap, SoundManager, core-js, jQuery	
17	Uniwersytet Ekonomiczny w Krakowie	www.uek.krakow.pl	PHP, AOS, Hammer.js	Facebook.Login
18	Uniwersytet Zielonogórski	www.uz.zgora.pl	Moment.js, Select2, jQuery, Bootstrap	
19	Politechnika Śląska w Gliwicach	www.polsl.pl	WordPress, GSAP, Backbone.js, PHP, mOxie, Flickity, core-js, Underscore.js, Swiper, jQuery, Clipboard.js, Bootstrap	
20	Uniwersytet Rzeszowski	www.ur.edu.pl	PHP, core-js, Select2, jQuery, ZURB Foundation	reCAPTCHA, HSTS
21	Uniwersytet Kardynała Stefana Wyszyńskiego w Warszawie	www.uksw.edu.pl	WordPress, PHP, core-js, OWL_Carousel, Lightbox, jQuery, DataTables, Bootstrap	reCAPTCHA, HSTS
22	Uniwersytet w Białymstoku	www.uwb.edu.pl	Swiper, Moment.js, Select2, jQuery, Bootstrap	
23	Uniwersytet Medyczny w Łodzi	www.umed.lodz.pl	Swiper, Moment.js, Select2, jQuery, Bootstrap	
24	Uniwersytet Ekonomiczny w Katowicach	www.ue.katowice.pl	PHP, core-js, Slick, Lightbox, jQuery, Bootstrap	reCAPTCHA, HSTS
25	Politechnika Poznańska	www.put.poznan.pl	PHP, jQuery, DataTables, Bootstrap, jsDelivr	HSTS
26	Uniwersytet Pedagogiczny w Krakowie	www.up.krakow.pl	GSAP, PHP, core-js, jQuery, Bootstrap	
27	Uniwersytet Przyrodniczy w Poznaniu	www.up.poznan.pl	PHP, lit-html, lit-element, jQuery, Bootstrap	Facebook.Login
28	Uniwersytet Technologiczno-Przyrodniczy w Bydgoszczy	www.utp.edu.pl	Swiper, jQuery, jsDelivr	HSTS
29	Wyższa Szkoła Bankowa w Poznaniu	www.wsb.pl	PHP, LazySizes, jQuery, FrancyBox, core-js	reCAPTCHA, HSTS
30	Akademia Sztuk Pięknych w Warszawie	www.asp.waw.pl	WordPress, GSAP, PHP, Swiper, lit-html	
31	Uniwersytet Kazimierza Wielkiego w Bydgoszczy	www.ukw.edu.pl	TypeScript, PHP, Moment.js, jQuery, Bootstrap	
32	Uniwersytet w Toruniu	www.umk.pl	PHP	HSTS
33	Politechnika Lubelska	www.pollub.pl	Moment.js, core-js, Select2, jQuery, Bootstrap	
34	Uniwersytet Medyczny w Gdańsku	www.gumed.edu.pl	Lightbox, Modernizr, jQuery, Bootstrap	HSTS
35	Politechnika Częstochowska	www.pcz.pl	Swiper, Moment.js, core-js, Select2, jQuery, Bootstrap	
36	Uniwersytet Łódzki	www.uni.lodz.pl	Angular, Zone.js, PHP, TypeScript, Firebase	reCAPTCHA, HSTS
37	Akademia Morska w Szczecinie	www.am.szczecin.pl	CodeIgniter, PHP	
38	Politechnika Świętokrzyska	https://tu.kielce.pl/	WordPress, PHP, wpBakery, Swiper, core-js, Underscore.js, OWL_Carousel, jQuery, Animate.css, Bootstrap	
39	Uniwersytet Warszawski (Wydział Nauk Ekonomicznych)	www.wne.uw.edu.pl	PHP, jQuery	
40	Wyższa Szkoła Informatyki i Zarządzania w Rzeszowie	www.wsiz.rzeszow.pl	WordPress, Backbone.js, PHP, jQuery, Underscore.js	
41	Akademia Wychowania Fizycznego w Warszawie	www.awf.edu.pl	React, PHP, lit-html, lit-element, Lodash, Modernizr, jQuery	

No	University	website	front-end solutions	security
42	Politechnika Opolska	www.po.opole.pl	WordPress, TypeScript, PHP, jsDelivr, Swiper, jQuery, Isotope, core-js, Bootstrap	Facebook.Login
43	Wyższa Szkoła Prawa i Administracji w Warszawie	www.wspa.pl	WordPress, PHP, lit-html, lit-element, LazySizes, Isotope, core-js, Swiper, jQuery	reCAPTCHA
44	Akademia Leona Koźmińskiego	www.kozminski.edu.pl	TypeScript, PHP, LazySizes, core-js, Slick, Select2, jQuery	HSTS
45	Akademia Humanistyczna w Pułtusku	www.ah.edu.pl	WordPress, Vue.js, Nuxt.js, Node.js, PHP, jsDelivr, LazySizes, core-js, Select2, jQuery	reCAPTCHA
46	Uniwersytet Rolniczy w Lublinie	www.up.lublin.pl	blocked because of trojan suspicion	
47	Uniwersytet Zielonogórski	www.uz.zgora.pl	Moment.js, Select2, jQuery, Bootstrap	
48	Politechnika Rzeszowska	www.prz.edu.pl	PHP, Swiper, jQuery	
49	Uniwersytet Szczeciński	www.us.edu.pl	WordPress, Handlebars, wpBakery, PHP, Preact, FancyBox, Moment.js, jQuery, Animate.js, Bootstrap	
50	Uniwersytet Łódzki	www.uni.lodz.pl	Angular, Zone.js, PHP, TypeScript, Firebase, Select2, PhotoSwipe, jQuery, core-js	reCPATCHA, HSTS

The analysis of Table 2 shows that the following front-end technologies dominated at Polish universities: jQuery (44/50), PHP (38/50), Bootstrap (24/50), and core-js (22/50). Popular frameworks such as React, Vue.js, and Angular were used in only a few cases (2, 1, and 4 respectively).

Conclusions

The analysis of front-end technologies used at universities in the United States and Poland highlights certain significant similarities and differences in their approaches to building websites.

The most commonly used technology among universities in both the United States and Poland is jQuery, appearing in 42 out of 50 cases for the USA and 30 out of 50 for Poland. This confirms the enduring popularity of this library, despite its reputation as being somewhat outdated in the front-end development world. Universities rely on it primarily due to its ease of implementation and extensive technical support base. PHP, used in 30 out of 50 cases in the USA and 38 out of 50 for Poland, is another frequently employed back-end language, often integrated with WordPress (which appeared at 11 universities in the USA and 12 in Poland).

The Bootstrap framework was used 15 times among U.S. universities (out of 50 analyzed) and 24 times among Polish universities, highlighting its importance in creating responsive user interfaces. An alternative, ZURB Foundation, appeared 7 times in the USA and once in Poland.

Core-js was present in 28 cases in the USA and 22 cases in Poland, indicating a need for support for older browsers. Modern frameworks (the youngest technologies listed in the table, created respectively in 2013 for React and 2014 for Vue.js) such as React and Vue.js were used less frequently, suggesting that universities do not widely invest in rebuilding their websites using the latest technologies. Instead, they focus on stability and proven tools like jQuery and PHP. For both Poland and the USA, React appeared twice in the tables, while Vue.js appeared 3 times in the USA and once in Poland. Angular was present once for universities in both the USA and Poland.

An outstanding feature in the table of Polish universities is the frequent use of Select2 (15 cases), indicating a greater emphasis on advanced form handling.

The data presented in the tables show that both in Poland and the USA, university websites rely on stable and well-documented technologies. jQuery and PHP dominate in both cases, confirming their universality. Bootstrap is

equally popular, underscoring the importance of responsiveness in web design. The presence of core-js reflects attention to compatibility with various browsers.

Polish universities seem more conservative in their choice of technologies. Select2 is more commonly used in Poland, suggesting a greater focus on advanced form functionalities. Meanwhile, the U.S. shows greater diversity in modern frameworks, such as Vue.js and Next.js. In the USA, three universities used Microsoft ASP.NET, while none of the 50 largest universities in Poland adopted this framework.

Universities, regardless of country, prefer stable and proven technologies. Polish academic websites, however, appear more traditional compared to their American counterparts. Modern frameworks are used sporadically, while tools like jQuery, PHP, and Bootstrap dominate. Website modernization may represent a potential development direction for both groups, especially in the context of increasing user demands for functionality and modernity.

The analysis of security technologies used at universities shows that the most frequently employed technology in the USA was HSTS. This mechanism ensures that communication between the browser and the server occurs exclusively via the HTTPS protocol, protecting against man-in-the-middle attacks. HSTS was used by 35 universities in the USA and 20 universities in Poland. The second most popular technology was reCAPTCHA, which protects against bots and automated attacks.

Relatively rare technologies, used by only 5 universities in the USA and none in Poland, included Cloudflare Bot Management and Turnstile. These are modern tools that provide advanced protection against bots. Cloudflare also supports content loading optimization.

Occasionally, Facebook login appears, indicating integration of websites with social media. This approach can enhance user convenience but introduces additional data protection challenges.

In some cases, Wappalyzer detected no security technologies on university websites. This either indicates a lack of security measures or the non-implementation of modern protection mechanisms, which poses potential risks for users. Another possibility is the use of custom configurations or technologies implemented at the server level.

The research hypothesis assumed that differences in budgets between universities in the USA and Poland would result in a greater use of modern front-end technologies in the United States. The results of the study partially confirmed this hypothesis, as U.S. universities demonstrated greater diversity in the adoption of modern technologies (e.g., Vue.js, Next.js, reCAPTCHA) compared to the more conservative approach of Polish universities, which more frequently employed advanced tools like Select2. However, both groups of universities showed a strong reliance on older, stable technologies such as jQuery, PHP, and Bootstrap.

Limitations of the study

This study has several limitations that should be considered when interpreting the findings. First, the analysis is limited to the 50 largest universities in the United States and Poland, which may not fully represent the technological landscape across all higher education institutions in these countries. Smaller universities or specialized institutions may employ different approaches to website development that are not captured in this study.

Second, the data were collected using tools like BuiltWith and Wappalyzer, which, while reliable, may not detect all technologies employed on a website, particularly if they are custom-built or implemented in ways that these tools cannot identify. Additionally, the study focuses exclusively on front-end technologies, without a deeper exploration of back-end systems or organizational factors that might influence technology choices.

Lastly, the study does not account for the specific contexts or strategic decisions behind each university's technological adoption. Factors such as institutional goals, historical infrastructure investments, or varying interpretations of what constitutes "modern" technology could all impact the results. These limitations suggest the need for further research to gain a more comprehensive understanding of technology adoption in higher education.

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