An examination of skill requirements for augmented reality and virtual reality job advertisements

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Abstract
The fields of augmented reality (AR) and virtual reality (VR) have seen massive growth in recent years. Numerous degree programs have started to redesign their curricula to meet the high market demand for people qualified to fill related job positions. In this paper, the authors perform a content analysis of online job postings hosted on Indeed.com and provide a skill classification framework for AR/VR job positions. Furthermore, they present a ranking of the relevant skills for such positions. The paper contributes to the extant literature on curriculum design in degree programs by presenting the popular skills in the AR/VR domain.

Keywords
Augmented reality, virtual reality, skill requirements, content analysis, information systems, curriculum design

According to a Hired.com survey published in 2021 (Hired, 2021), interview requests for jobs related to augmented reality (AR) and virtual reality (VR) had grown by 1400% over the past 12 months. These jobs have been identified as among the top emerging jobs (Perry, 2020). Seventy-four percent of those surveyed by Hired.com agreed that the technologies would have a major impact on the job market within 5 years. The demand for such jobs rose 79% in 2020, partly due to rapid advancements in AR/VR inventions and patents. It has been forecasted that by 2030 over 23 million jobs will be impacted by the two technologies (Thomas, 2021). The same findings were echoed by a Facebook study (Facebook, 2021), which estimated substantial adoption of AR/VR across all industries. Several industries have already begun incorporating AR/VR technologies to enhance customer experiences. For example, Ikea, Lacoste, New York Times, Kate Spade, among others, have leveraged the technologies to aid their marketing delivery channels (James, 2021). Both studies noted that the market demand for AR/VR jobs was prominent and growing. Even though there is a forecasted increase in demand, however, there remains a dearth of skilled professionals. Similar skill shortages exist in other newer information technology (IT) domains as well as in traditional fields like marketing, finance, healthcare and supply chain (Wilson et al., 2017). AR/VR job opportunities are dispersed across a variety of industries. Due to the evolving nature of work and the need for standardization, an enhanced classification of job skills in this domain will make the hiring process more coordinated and efficient. Moreover, the structure provided by such a classification could be utilized in curriculum design.
to address the skill gaps and highlight the relatively important skill sets. Therefore, one of the aims of this research was to develop a comprehensive skill classification framework for AR/VR job positions.

Content analysis was utilized to extract keywords from job postings hosted on Indeed.com to calculate the frequencies of specific skills corresponding to each skill category. In this way, the most critical skills in the dataset were identified based on the relative frequency of each skill for AR/VR jobs. The findings can also aid in curriculum design efforts such that the most valued skill sets are emphasized in the existing analytics curricula. Moreover, existing AR/VR courses can be revised to reflect the currently sought-after software tools and applications.

The job positions examined belong to the professional areas of AR and VR. According to Milgram and Kishino (1994), who developed the initial definition of mixed reality (MR), both domains are defined within the umbrella terms of MR or ‘extended reality’ (XR). Mixed reality merges real and virtual worlds to create new environments. The relationship between AR and VR is summarized by the mapping in Figure 1. On the right MR continuum is VR, in which the user’s entire world is virtual, and on the left continuum is AR, in which the user’s world is only partially virtual (Billinghurst et al., 2015). The three areas superimpose a digital layer (typically through a smartphone or headset) over the physical reality. The individual differences are due to varying levels of superimposition and the relationship between the two layers. Augmented reality enhances an individual’s physical environment by overlaying an interactive 3D virtual object in a real-world environment (Thornton et al., 2012). The technology augments the physical space with a digital presence to enhance customer experiences (Schmalstieg and Höllerer, 2016). Classic examples of AR include Google Glass, Pokemon Go, and Snapchat filters. On the other hand, VR incorporates the highest level of immersive experience and fully immerses the user in a computer-created environment (Goldiez et al., 2004). Virtual reality users typically wear a headset, like Oculus Rift or Microsoft Holoens, to engage in a completely virtual experience. Note that some simple adaptations of VR have been initiated by Google Cardboard using only a smartphone and cardboard. MR or XR allows physical and digital layers to operate in tandem and might involve different combinations of AR and VR. Gaming consoles such as Xbox Kinect rely on human computer interaction (HCI) coupled with gesture recognition and sensors to operate in this domain. The higher-end applications of MR also exist in drone- and robot-assisted surgeries.

Interest in AR/VR technologies has grown exponentially since the Covid-19 pandemic (Adi, 2021; Facebook, 2021). In light of this growth an in-depth exploration of the skill requirements needed in this field was conducted. In this regard, the goal of the study was to address the following research questions:

1. Which skills are required for AR/VR professionals?
2. What majors do employers request for AR/VR professionals?
3. What software tools are currently in-demand for such positions?

The authors studied job advertisements in the USA. A breakdown of different skills required for the AR/VR positions was analyzed to provide insights into employers’ expectations. Using the ranked skill categories based on relative frequency, academics can repurpose existing degree programs to highlight the current skillsets required in the job market. The focus of this study is on the “demand side” of the US job market via a descriptive analysis of the job advertisements posted by employers.

The main contributions of the study are:

1. The identification of the key skills needed for AR/VR based on our skill classification framework.
2. An analysis that can assist human resources teams in creating job advertisements in addition to specific current training modules for working professionals in the industry.
3. Academic institutions can also utilize the findings in curricula design efforts. The results may be helpful for the creation of new courses or the restructuring of existing course offerings. Moreover, students interested in related career domains might emphasize the top in-demand skills in their job applications.

The article is organized as follows. First, a literature review on the impact of AR/VR on various disciplines is presented, followed by employers’ perspectives on job requirements. Next, the classification framework, research technique and datasets used for the study are discussed. Thereafter, the results are presented, detailing a ranked list
of the skill categories according to their relative frequency among the total number of jobs. The final section presents our conclusions and outlines future research directions.

**Literature review**

Augmented reality/VR are emerging technologies with a wide range of applications across multiple domains. Over the previous decade, numerous industrial and commercial applications have been envisioned. Various applications of AR/VR have been proposed for robotics, engineering, automotive, aerospace, maintenance and education (Akçayır and Akçayır, 2017; Chi et al., 2013; Doshi et al., 2017; Helin et al., 2017; Mourtzis et al., 2017; Nee et al., 2012). The standard definitions and related taxonomies, along with some successful applications, are surveyed by Billinghurst et al. (2015). The impact of AR/VR on the field of education has been studied by Bacca Acosta et al. (2014). The different pedagogical approaches involved in teaching and training, along with case studies, are detailed by Wang et al. (2018). In terms of STEM learning, a review of the literature on AR/VR is provided by Ibáñez and Delgado-Kloos (2018): similar to the technique used in this study, they use a content analysis through a study of 28 research publications from 2010 to 2017 and also present AR/VR activities that could be used as a part of instructional delivery.

A set of closely related studies was carried out by Fominykh et al. (2019), Fominykh et al. (2020a) and Fominykh et al. (2020b). First, Fominykh et al. (2019) analyzed existing course offerings in AR/VR and conducted a preliminary job market analysis. The study summarized the various teaching methods, learning activities, course objectives and learning outcomes. The authors compiled a list of skillsets based on a first-hand scan of a few job postings followed by a survey of industry professionals. More specifically, the authors’ focus was global and their study examined only the technical skill requirements for 16 US jobs. Given that the biggest players in the AR/VR domain – Apple, Facebook and Google – reside in the USA, an in-depth assessment of the skill requirements needed in the USA was warranted (providing the rationale for using a complete skill classification framework consisting of hard and soft skills to analyze 397 job advertisements in the USA). Fominykh et al. (2020a) and Fominykh et al. (2020b) provided a blueprint for the computer science (CS) curriculum to facilitate AR/VR teaching in universities. They also provided an outline of two AR/VR courses at foundation and advanced levels using 12 groups of skills.

Augmented reality/VR can be considered among the digital skills needed for success in the workplace of the future. The technical and soft skillsets needed for Industry 4.0 were analyzed by Saari et al. (2021). In addition to Industry 4.0, other relevant fields are business analytics, data analytics and big data. Many studies have explored the employer’s perspective through a skill-based analysis of job postings. For instance, Debortoli et al. (2014) analyzed the difference between big data and business intelligence job positions using a skill classification framework based on a Latent Semantic Analysis of the job descriptions. The authors concluded that for each position both business domain and technical skills were valued. Gardiner et al. (2018) studied 1216 job advertisements having “big data” as part of their title. The authors found that analytical skills and soft skills were highly valued for such positions in addition to technical skills. Lovaglio et al. (2018) collected information and communication technology (ICT) and statistical job advertisements in Italy between June and September 2005. The authors concluded that statistical positions required more technical and computing skills than soft skills. Verma et al. (2019) utilized a skill classification framework for related job categories like Business Analyst, Business Intelligence Analyst, Data Analyst and Data Scientist using a content analysis of 1235 job advertisements. The results indicated that skills such as decision making, organization, communication and data management were essential for success in these professions. More recently, Anton et al. (2020) analyzed the skill requirements for three related occupations: data science and engineering, software engineering and development, and business development and sales. A mixed-methods approach was employed in conjunction with text mining of scientific literature. Similar to other studies, the authors presented the important soft and hard skills required for these positions.

The use of online job portals for collecting job-related information is not novel. However, the difference from Fominykh et al. (2019) and related studies is that the complete dataset in this study is collected from the most popular job database in the USA, namely Indeed.com. In this way, this paper explores the local market needs of AR/VR professionals specific to the USA. Fominykh et al. (2019) and Fominykh et al. (2020a) included a small global sample of around 100 job listings with only 16 job positions within the USA. As a result, a large number of skills were classified as rare since they appeared only in one or two advertisements. In contrast, we analyzed around 400 job advertisements collected over a 6-month period. Therefore, a significant difference in this study lies in the amount of data collected and the more extended period covered. On the other hand, Fominykh et al. (2019) and Fominykh et al. (2020a) employed a very small data collection window of about a week. Theoretically, our skill classification framework consisted of both soft skills and hard technical skills. However, the skill categories of Fominykh et al. (2019) included only technical skills.

This study supplements and builds on the extant literature by proposing a new skill classification framework for
AR/VR jobs. Given the high demand and evolving nature of the field, an in-depth analysis of the required skills was merited. Therefore, our goal was to study an important job category in the Industry 4.0 era.

Research methodology

Skill classification framework

In this section, the skill classification framework used for AR/VR job postings is presented. Job postings were analyzed and keywords identified. The keywords were used to determine which job postings belonged to each skill category. Lists of skill categories developed by Fominykh et al. (2019) and Verma et al. (2021a, 2021b) were used as a starting point. Additional skill categories were included to further reflect the needs in the AR/VR domain. The additional categories were identified through an in-depth content analysis of the skill requirements found in 50 AR/VR job postings. Based on the findings, the skill categories and subcategories were updated. Three independent raters were utilized to determine the reliability score of the proposed categorization framework. The alpha coefficient of the intercoder reliability measure was 0.91. An alpha coefficient has a range from zero to one, with a lower score indicating greater disagreement among raters and a higher score indicating greater agreement. A score of greater than 0.9 is generally considered reliable (De Swert, 2012). The final list of skill categories and subcategories, along with sample keywords were detailed (see Table 1).

Research technique. For this research project, job postings from Indeed.com, the most popular job search site across the USA, were utilized. Web scraping was the primary source of data collection. The data were extracted during June–December 2020. The results of a web search on Indeed.com based on the titles of “AR” and “VR” were gathered. After downloading the job postings through Python, each job description was split up into keywords using content analysis – a tool for analyzing words in a document and identifying patterns in a text (Neuendorf, 2016). The text was divided into various categories in order to summarize the skill requirements for the studied job positions. Note that each of these individual keywords of the text fits into a specific category and subcategory given by the skill classification framework described in the previous section. This allowed us to measure the required skills for each job posting. In this way, aggregate measures were developed for the relative importance of each skill category (see Figure 2).

Next, each component of the technique was detailed. The first component was the web scraper. Python was utilized to build the web scraping tool. It was entirely dependent on the existing Indeed Application Programming Interface (API). The API requires job title, location and time period as input arguments. The specific search query based on job titles was conducted during the specific time period. The output was an XML file consisting of the job title, job URL, location, company, posting date and a job summary. The job summary field provided a very high-level summary of the job description but did not contain all necessary information; thus, the job URL became critical for our approach because the job summary field of the API did not contain important information such as software development kits (SDKs), programming languages, graphical design tools and specific hardware. To address the lack of relevant information, the actual job postings corresponding to the URLs provided by the API were downloaded.

The downloading procedure was also completed programmatically using Python, leading to the local storage of HTML files. Each HTML file contained different elements stored under different tags. The benefit of using the Indeed.com API output was that the final webpage followed a consistent design. Therefore, the job descriptions were always found using a specific tag. Thus, the development of the parser could be streamlined. In turn, the parser extracted the job description for each downloaded HTML file. The job description field was crucial since it contained important data points such as job type, major, related work experience and required software tools. Furthermore, the parser eliminated all unnecessary keywords from consideration, like a, an, the, in and for, and special symbols like quotation marks and semicolons. The parser is paramount for the success of natural language processing projects involving content analysis (Neuendorf, 2016). The residual words were individually recognized as unigrams: the two-closest and three-closest unigrams were considered as bigrams and trigrams respectively. These n-grams were critical to our technique because the keywords belonging to each skill category (detailed in Table 1) were directly matched with the n-grams.

The parsed text in the job description tag was inputted to a frequency analyzer that counted whether the text contained specific keywords belonging to each category and subcategory of our skill classification framework. Recall that the associated keywords for each skill category are listed in Table 1. If any keywords belonging to a specific skill were present in the job description, the authors declared that the associated skill category was required for a specific job posting. This method was repeated for each job posting and each skill category. Combining all the outcomes, the number of jobs for which a specific skill category was required were calculated. This characterized the frequency of occurrence of each skill category for each job title. In this way, the relative importance of each skill category for AR/VR job title was determined. Note that the relative importance of each skill category was directly provided by the relative frequency (given by the frequency count divided by the total number of jobs). The relative frequency was
Table 1. Classification framework.

| Skill category        | Skills                  | Keywords                                                                 |
|-----------------------|-------------------------|--------------------------------------------------------------------------|
| Communication         | Written                 | Copywriting, editing, blogging, content creation, story ideation         |
|                       | Verbal                  | Verbal, oral, cold calling                                               |
|                       | Presentation            | Present, presentation, report                                            |
|                       | Generic                 | Responsible, determined, competitive, witty, success-oriented            |
| Employee attributes   | Motivation              | Motivated, ambition, willingness to learn, delivering result, continuous |
|                       | Time management         | Time management, timely manner, prioritize time, deadline-driven         |
|                       | Detail-oriented         | Attention to detail, eye for detail, accuracy, precision                 |
|                       | Attitude                | Can do, go-getter, self-learner, self-directed, positive attitude        |
|                       | Independence            | Independence, without supervision, autonomous                           |
|                       | Adaptability            | Adaptable, flexible, multitasking                                        |
|                       | Confidence              | Confident, decisive                                                      |
|                       | Other                   | Funny, smiling, high-energy, reliable, proactive                         |
| Occupational attributes| Programming            | Python, C#, C++, VB, Excel macros, PERL, C, java, visual basic, VB.NET,  |
|                       | Software design         | principles                                                               |
|                       | XR SDKs                 | UIKit, AVFoundation, core motion, core ML, CloudKit, SiriKit, StoreKit,  |
|                       | Asset design            | ARKit, ARCore, AR foundation, MRTK, WebXR, CoreMedia, CoreAudio,         |
|                       | UI/UX design            | Interaction, studying users, XR experience, UX design, interaction design |
|                       | 3D software             | Maya, houdini, blender, 3Ds max, Arnold, RenderMan, cycles, three.js,    |
|                       | Game engine             | Maya and Cinema4D, Direct3D, MAYA, 3D MAX, autodesk 3D, autodesk 3ds max, |
|                       | XR hardware             | HTC VIVE, varjo HMD, microsoft hololens, rift, VIVE, gear VR, oculus rift, |
|                       | Performance tools       | VTune, XPerf/GPUView, valgrind, instruments, performance profiling,      |
|                       | 2D software             | Adobe sketch, illustrator, FIGMA, CAD, CAM, adobe illustrator, autodesk,   |
|                       | Graphics rendering      | Metal, HLSL, GLSL, animation effects, VFX, computer graphics, imaging    |
|                       | Mathematics             | Geometry, linear algebra, 3D math, 3D geometry, vector math, vector      |
|                       | Sensors                 | EEG, fMRI, fNIRS, EMG, MTF, SNR, human interface, HCI, haptic, hand      |
|                       | Cloud tools             | AWS, google firebase, azure, server                                     |
|                       | Project management      | Project management, PERT, CPM, PERT/CPM, change management, project      |
|                       | General hardware        | Hardware, architecture, devices, printer, storage, desktop, PC, server,  |
|                       | Decision making         | Reporting, analysis, modeling, design, problem-solving, implementation,  |
|                       | Interpersonal           | Team management, collaboration, cooperation, networking, client          |
|                       | Problem solving         | Problem solving, troubleshoot, conflict resolution, solve issue, critical |
|                       | Creativity              | Creative, out of box, storyteller                                       |
|                       | Process design          | Design process, improve process, continuous improvement, operations      |
| Administrative        | Administrative          | Issue management, posting schedule, product launch, social calendar      |

(continued)
reported as a percentage count (see Table 2). These data are employed in the next section to establish the relative importance for different skill categories.

### Results

Job titles containing the phrases “AR” and “VR” were obtained between July and December 2020 were obtained from Indeed.com. A large sample size of 397 was the target for data analysis. The top five states where the jobs were located were identified (see Table 3).

Most of the current interest in AR/VR technologies is from the IT sector. As is evident from the results, most of the jobs are located in California’s Silicon Valley. Denver in Colorado has also emerged as an upcoming entrepreneurial hub for newer technologies. IT giants like Facebook, Apple, Google, and Amazon have propelled interest in AR/VR technologies, especially in the metropolitan areas of San Francisco.

The required majors for the job positions were systematically extracted using regular expressions in content analysis, which allows matching of strings like Graphic Design in a specific neighborhood of the complete text of the job description field. To accomplish this, complete sentences in the job description of each job posting were used. More specifically, keywords in the neighborhood of information pertaining to majors like BS, BA, Bachelor’s, etc. were examined. These matched keywords belonging to related majors in the AR/VR field, such as CS, Fine Arts, and IT (see Table 4).

In Table 4, the percentage column for each skill category does not sum up to 100% because each job posting might accept multiple majors, like a Bachelor’s in CS or in Machine Learning. It was clear that the various engineering majors were more desirable for AR/VR professions, given the technical nature of the job. The conventional degree programs in mathematics and CS were still valued for AR/VR jobs.

Next, a breakdown of the skill requirements for the AR/VR job positions was carried out. The five most common skill categories required were sorted from high to low in terms of the number of job advertisements in which at least one skill associated with the skill category was present (see Table 2). The top five skills associated with each skill category were also identified. These skills were similarly ranked with respect to their relative frequency (expressed as a percentage count). For this purpose, the number of job positions associated with a specific skill was divided by the total number of job postings.

The research project identified 38 skills structured into 10 different skill categories for AR/VR professions (see Table 1). While the literature provided some insights regarding AR/VR professions (Fominykh et al., 2019; Fominykh et al., 2020a, 2020b), the authors carried out a thorough analysis of hard and soft skills centered on extensive empirical data. The occupational skills were assigned the highest priority for AR/VR job postings and the user interface/user experience (UI/UX) design skill sub-category was ranked at the top. This included designing user experiences while keeping in mind the constructs of accessibility and HCI. In this way, people with varying abilities should be able to use the end product seamlessly.

Employees were also expected to be familiar with various design concepts, like New Product Introduction (NPI), Design for Manufacturing (DFM) and Design for Assembly (DFA). These concepts typically exist in engineering

### Table 1. (continued)

| Skill category   | Skills     | Keywords                                                                 |
|------------------|------------|--------------------------------------------------------------------------|
| Analytical       | Analytical | Insight, identify trend, summarize finding, analyze trend, synthesize information, draw conclusion, propose solution, google analytics, arcgis, GIS, QGIS, data analytics, business analytics |
| Research         | Research   | Data gathering, data collection, data reporting, monitor trend, monitor performance |
| Numeracy         | Numeracy   | Financial management, bookkeeping, accountancy                            |
| Foreign language | Foreign language | Spanish, French, German, Italian, Chinese                              |

Figure 2. Summary of research technique employed. Figures 1 and 2 supplied in separate PPT files.
Table 2. AR/VR results.

| Skill category     | Skill                        | Percentage count (%) |
|--------------------|------------------------------|----------------------|
| Occupation         | UI/UX design                 | 95.48                |
|                    | Software design principles   | 90.36                |
|                    | Asset design                 | 71.07                |
|                    | Graphics rendering           | 64.47                |
|                    | Programming                  | 57.87                |
| Employee           | Time management              | 64.41                |
|                    | Motivation                   | 31.91                |
|                    | Attention to detail          | 26.40                |
|                    | Independence                 | 22.84                |
|                    | Other                        | 11.42                |
| Communication      | General                      | 60.91                |
|                    | Verbal                       | 42.61                |
|                    | Written                      | 24.87                |
|                    | Presentation                 | 12.69                |
| Interpersonal      | Team management              | 50.76                |
|                    | Personal                     | 29.95                |
|                    | Creativity                   | 24.87                |
|                    | Other                        | 15.74                |
| Analytical         |                              | 39.09                |
| Administrative     |                              | 21.83                |
| Research skills    |                              | 18.27                |

Table 3. Geographical distribution of AR/VR jobs.

| Rank | US state (percentage count of AR/VR jobs) |
|------|-------------------------------------------|
| 1    | CA (90.20%)                               |
| 2    | CO (5.33%)                                |
| 3    | MA (2.10%)                                |
| 4    | NY (1.13%)                                |
| 5    | TX (0.32%)                                |

Table 4. Majors required for AR/VR jobs.

| Rank | Major (percentage count of AR/VR jobs) |
|------|----------------------------------------|
| 1    | Engineering (65.48%)                   |
| 2    | Computer science (39.09%)              |
| 3    | Machine learning (27.41%)              |
| 4    | Mathematics (21.32%)                   |
| 5    | Architecture (15.23%)                  |

activities and strengthen the connection of AR/VR with Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM). Thus there was an overwhelming need for majors with an engineering background in these job postings, as illustrated in Table 4. The next ranked subcategory was that of traditional software design principles. Thus, successful employees have a concrete understanding of software engineering principles such as object-oriented programming, product lifecycle management and security protocols. Employees should also be able to perform traditional software developer tasks, including debugging, testing, documentation and source control. They should therefore be proficient in DevOps, which involves the combination of software development activities with business operations. Asset Design is the next prioritized skill subcategory, dealing with video production or simulation in order to develop a prototype or proof of concept to meet clients’ requirements. These activities typically involve content creation through storytelling aided by VFX animations or some other 3D modeling software. A list of 3D modeling software was also captured separately through a skill subcategory defined in Table 1. The relevant results in the form of a sorted list based on the percentage occurrence of the 3D modeling tools are presented in Table 5.

These findings established that the marketplace was dominated by commercial software from Autodesk (see Table 5). The only open-source offering was Blender, in fourth place. These in-demand tools could be utilized at the
course level to enhance student learning experiences and prepare them for success in the AR/VR industry. The next critical skill category was Graphic Rendering. This exercise involves tracking, lighting, rigging and mapping objects in scenes through the use of algorithms relying on deep learning and reinforcement learning. At a fundamental level, this skill assumes familiarity with visual effects using features and spatial imaging, sometimes achieved by using a shader programming language to adjust the levels of light, darkness and color. Both High Level Shading Language (HLSL) and OpenGL Shading Language (GLSL) are written in a C-like language. The AR/VR job positions are technical in nature and place emphasis on computer programming skills. The top five programming languages in order of relative occurrence in the job advertisements were identified (see Table 6).

These findings identified C-like languages as the most common. Given that the popular game engines Unity and Unreal are built on C-type languages, this observation was trivial. Moreover, Android and iOS application development requires knowledge of Java and Swift programming languages, respectively. Python is needed for deep learning and reinforcement learning for advanced imaging applications in the graphical rendering pipeline. Basic data management skills using SQL are also in-demand.

Augmented reality/VR development is facilitated by SDKs designed by Apple, Google and Facebook. Apple utilizes popular frameworks like ARKit and RealityKit, while Google’s service is called ARCore. Facebook’s immersive experiences are created through AR Studio. Traditional AR/VR job positions also entail game development on web, desktop or mobile environments. The web-based framework for AR/VR is called WebVR or WebXR, a Javascript application that allows interaction with various AR/VR devices. A ranked list of the relative frequency of these AR/VR specific hardware devices was drawn up (see Table 7).

The most popular device identified was Oculus Rift, followed by HTC Vive and Microsoft Hololens. Due to the high initial investment cost in hardware for developing an AR/VR course, these findings could serve as a guideline to help institutions select the most appropriate AR/VR hardware. The desktop game development is primarily performed on two game engines: Unity and Unreal. Unity is a proprietary software developed by Unity Technologies, while Unreal is a commercial software developed by Epic Games. Based on our dataset, we observed that Unity (59.55%) was more popular than Unreal (40.45%). Overall, the current job listings demand more technical expertise in commercial software tools from corporations like Autodesk, Unity, etc.

Employee traits have also started to become more important for success in the workplace. First, as noted in Table 3, the Employee skill category was less valued than the

| Table 5. 3D modeling software for AR/VR jobs. |
|---|---|
| Rank | Software (percentage count of AR/VR jobs) |
| 1 | Autodesk Maya (23.26%) |
| 2 | CATIA (22.93%) |
| 3 | Autodesk VRED (20.41%) |
| 4 | Blender (9.30%) |
| 5 | Autodesk ReCap (4.65%) |

| Table 6. Programming languages for AR/VR jobs. |
|---|---|
| Rank | Programming language (percentage count of AR/VR jobs) |
| 1 | C/C++/C#/Objective C (32.72%) |
| 2 | Java (10.49%) |
| 3 | Python (8.95%) |
| 4 | SQL (5.25%) |
| 5 | Swift (4.63%) |

| Table 7. Hardware devices for AR/VR jobs. |
|---|---|
| Rank | Hardware devices (percentage count of AR/VR jobs) |
| 1 | Facebook Oculus Rift (33.05%) |
| 2 | HTC Vive (19.13%) |
| 3 | Microsoft Hololens (17.39%) |
| 4 | Samsung Gear (9.57%) |
| 5 | Varjo VR (7.83%) |

Occupational attributes. In the Employee skill category, time management was the most in-demand: especially in the current business climate, time management skills are crucial. Employees with a focus on achieving deadlines in a timely manner are sought after in a fast-paced and dynamic workplace. The next ranked skill was motivation: higher levels of motivation are typically associated with lifelong success in any profession. The next skill in the list was attention to detail, which is regarded as an indicator of organized and attentive professionals who are essential to the success of any firm. The next key soft skill was independence. Independent workers typically complete assigned activities with minimal supervision: these individuals are regarded as proactive and take the initiative to own and complete their assigned projects. Note that these employee attributes are valued for success in any job. These skills could be incorporated into course offerings to adjust the curriculum appropriately.

Another important skill category concerns basic communication skills. The most frequent generic skills included keywords corresponding to responsibility and determination. Thus, taking the initiative and dealing with stressful situations were considered as success factors in a fast-paced work environment. On closer inspection, verbal, written and
presentational skills were also valued in these job positions, which entail understanding client requirements and typically modeling them through 3D software. Hence, various inputs from multiple team members need to be gathered and employees are expected to analyze the aggregate results. Therefore, verbal and writing skills are more in-demand. Presentational skills are also vital for AR/VR specialists since the modeling phase usually involves various meetings and brainstorming sessions with different teams.

Interpersonal skills were valued too. These skills typically relate to cooperation and collaboration in a team-based environment. Personality and creativity attributes were also highly valued, because, in various settings, individual deliverables were assigned to each team member. Additionally, creativity is paramount in the art design field, which has many parallels with AR/VR. The analytical and research skill categories target individuals who are analytical thinkers and can use rational judgment to understand and resolve clients’ requirements. The long-term growth of a company is contingent on individuals with sound judgment. The creativity or innovation skillset pertains to the artistic side of the individual, in tune with the arts design aspect of the job. Lastly, the analytical skillset coincides with the problem-solving mindset of the individual, which is necessary for the long-term growth of a firm. It is well known that all strategic problem-solvers benefit from a sound understanding of the business processes to increase the effectiveness of deployed solutions. Thus, employees are supposed to have an essential knowledge of the holistic product lifecycle, which necessitates an understanding of product design, supply chains and marketing channels. Moreover, various routine administrative tasks are expected to be handled by AR/VR specialists.

Discussion

Educational programs involving AR/VR are falling behind market demand and are failing to produce the graduate numbers required. To fill this skills gap and meet demands, universities need to upgrade their curricula and include the courses needed to educate future AR/VR experts. We intend to shed light on the required hard and soft skills needed for AR/VR developers to be successful and competitive in this fast-growing marketplace. The findings of this paper can be used as a guideline for educational institutions wishing to develop specialized courses or fast-track certificates targeted at specific skill categories or sectors of the job market. In all degree programs, any change to the changes. In all degree programs, any change to the changes.

A possible strategy for universities in responding to the more complicated technical demands of the industry is to develop specialized courses or fast-track certificates targeted at specific skill categories or sectors of the job market. However, if the number of essential skills continues to evolve, universities may have severe challenges in adapting to the changes. In all degree programs, any change to coursework requires multiple levels of committee approval, which inhibits the adoption of the teaching of critical skills in a timely manner. On a similar note, it is worth noting that job market analysis provides a lagging indicator of the required skills for the workplace. At any rate, continuous...
education for workforce development should be a high priority, given that technology is constantly evolving, especially in all areas of IT.

It is also important to mention that degree programs include many topics other than technical skills. Soft skills have typically been critical in all areas of IT; however, this study shows that these skills are becoming increasingly important for AR/VR jobs. Soft skills that should be added to the curriculum to enhance graduate employability include communication, delivering presentations, writing, team management, project management, critical thinking and interpersonal relationship development.

The study findings have other implications. First, instructors for technology-related courses should try to establish a partnership with industry, so that they can remain current with the evolving skill requirements of the AR/VR domain. Second, universities should promote student internships that closely complement student skills with industry requirements.

Conclusions and future research

This paper analyzes the skill requirements of AR/VR jobs in the USA. The study employed content analysis to develop a ranking of the required skill categories. The study found that occupational skills were most valued, were technical in nature and that there was an emphasis on UI/UX design, software design, asset design and graphics rendering skills. The job advertisements also assigned importance to interpersonal and communication skills.

The study identified and ranked skills currently required for AR/VR positions. The results could be utilized in two different ways. First, degree programs in, for example, CS and Fine Arts could repurpose their existing curricula related to AR/VR. Hence, this paper could benefit associated undergraduate and graduate degree programs. Second, the findings could be used by human resource departments to identify qualified AR/VR professionals. More specifically, human resources teams could design well-structured and consistent job descriptions to increase the effectiveness of their recruitment strategies.

This study highlights the need for further research. In particular, surveys should be designed and administered to students and employers to determine which skills are more valuable in relation to the industry standards. Additionally, follow-up studies regarding required skills should be administered frequently in order to monitor evolving skillsets. Finally, survey data from employers regarding valued skills and competencies should be integrated with this job market analysis. Having investigated the AR/VR job market, a natural extension is to compare the results with existing IS curricula: we are hopeful that this will provide interesting insights into gaps between employers' expectations and demand on the one side and course curricula and universities’ supply of graduates on the other. For instance, Mobarak (2021) investigated the extent to which advertised degree programs offered by South African universities addressed the skills and knowledge requirements of employers. This comparison could then be evaluated by experts from industry and academia in order to ascertain the implications for IS curricula. It would also be insightful to repeat the study regularly or to compare it to historical data and/or former studies to monitor changes over time.

While this study extends the current body of knowledge on skill requirements for AR/VR professionals, there are limitations. As we gathered job postings in the USA, the data are, to some extent, country-specific. The data were collected from a leading international online job portal and the collection period was 6 months, inclusive of the impacts on the job market of the Covid-19 pandemic. Involving more job search engines and having a different and/or longer collection period might be a promising area of investigation. This study could be easily generalized to other countries and industry verticals. With the approach being generic, future studies might compare the findings to those for other regions or industries. There have been various successful attempts in this direction: for instance, Stewart (2021) examined 130 job advertisements in Australia and determined the most relevant specific and generic skills required by employers in the field of environmental sciences.

Finally, future research could investigate the effects of job localization in some specific US states on different skill requirements. This would involve studying the job postings in a specific geographical region, allowing local employers and universities to benefit from the relevant findings. An additional research direction could involve the analysis of the existing curricula of degree programs in the AR/VR domain in the USA. In this way, the findings of the current study could be used in conjunction with the coursework of related degree programs. By identifying the existing skill gaps between academic programs and local industry needs, specific recommendations related to curriculum design could be made.

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