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Exploring Twitter Use and Services of Academic Innovation Centers

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Abstract

This study examined the Twitter streams and websites of 36 university innovation centers and identified 14 service categories the centers offered. Exploring the present Twitter use practices of innovation centers and the services the centers provide can inform the design and planning of service offerings at new innovation centers and support training for center staff in the use of this social media platform. In addition, existing innovation centers can benchmark their service offerings against those services. Furthermore, mapping the services the innovation centers offer to the activities in an innovation workflow model can help center managers optimize the information architecture of their websites and resource guides. In this way, students can easily be informed about the help and resources available for each activity or phase of the innovation process. A comparison of the tweet categories identified in the present study with those of academic libraries assembled in a previous study revealed significant overlap, but some differences as well. In contrast to the Twitter accounts of academic libraries, the Twitter accounts of innovation centers did not tweet about their information services even if they offered them. Innovation centers also did not use Twitter to provide Q&A services to their users. Furthermore, innovation centers tweeted not only about the technological resources they provided, but also about the human resources they recruited to serve as student mentors and advisors. Finally, technology use was more mediated in innovation centers than in libraries, and some centers offered their users fee-based assistance from professionals with their 3D design and printing tasks.

1. Introduction

Innovation can be defined as a set of activities that use technologies, data, or both to produce new products, services, workflows, business models, and processes or services (Ayele et al., 2018; Fichman et al., 2014; Nambisan et al., 2017; Zuiderwijk et al., 2014). Universities are presently making significant investments to establish integrated infrastructures to support their students' experiential learning and their innovation and entrepreneurship activities. These efforts and initiatives may take different forms and may be composed of multiple units referred to by different names, including, but not limited to, makerspaces, fablabs, innovation centers, incubators, and accelerators. Here, we refer to this integrated infrastructure collectively as *innovation centers*.

Innovation centers can help students develop design thinking and an innovation mind-set (i.e., curiosity, connections, and creating value; Balz et al., 2019). They provide access to technologies and tools that allow users of those technologies to engage in creative or design activities. These types of technologies range from woodworking and sewing to 3D modeling, printing, engraving, cutting, and robot building (Fourie & Meyer, 2015; Slatter & Howard, 2013). Some of these centers

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have a discipline or area focus and are located and managed by individual colleges or departments. The focus of other centers is interdisciplinary, and they usually operate at the university level. Regardless of the focus and institutional placement of these innovation centers, they need to enable innovation or provide support for innovation activities to be successful and serve as effective instruments for innovation. Hence, it is essential to identify both the innovation activities that take place in innovation centers and the related services these centers provide.

Multiple innovation models have been proposed in the literature. For instance, Ayele et al. (2018) identified six activities involved in the innovation process: planning, ideation, service design, preparation, implementation, and exploitation. Hansen and Birkinshaw (2007), in contrast, proposed a more general model of innovation that included three activities: idea generation, idea development, and diffusion of the developed concepts. Participants in each of these activities will need to know what technology or data they can use and how to use it, how the activity can be completed, and how the output of the activity can be exploited (Wang & Ramiller, 2009). For example, students developing a new recommender web service or mobile app may need to know what open source software libraries are available to use in developing their application, what free open data and knowledge sources are available to use on which to train their application or use as background knowledge, what the quality of those data sources is, and what the relevant literature is to identify the state of the art of this type of application. Finally, students may need know what skills they need for a particular activity, where to seek expert advice, and how to identify and recruit team members with those skills and expertise.

A recent Pew survey confirmed that young adults remain very active consumers of social media. The survey revealed that nearly 80% of younger (18- to 24-year-old) Americans use Facebook and almost half of them use Twitter (Perrin & Anderson, 2019). It is not surprising that social media platforms in general and Twitter in particular have been used by university units, including academic libraries, to promote their services to their target user groups. For example, studies of library Twitter streams have shown that libraries use Twitter (1) to promote campus, library, and community events, library resources and services, and club activities; (2) to promote the library as a community space to receive research support, study, and socialize; and (3) to support Q&A about the library's services and make announcements related to the library's operations (Cuddy et al., 2010; Del Bosque et al., 2012; Stvilia & Gibradze, 2014; Thomas, 2010). Similar to academic libraries, the logs of the Twitter streams of academic innovation centers provide an opportunity to inexpensively identify what services the centers offer and how they communicate with their users about those services via Twitter.

Although a significant body of research exists on makerspaces and innovation centers, understanding is limited regarding what services university innovation centers provide to students and how the centers use social media to promote those services. Assembling and sharing the repertoire of services supported by innovation centers campus-wide can guide libraries, other units on campuses, and universities as wholes that are planning to establish a new innovation center. This repertoire can also inform existing innovation centers in benchmarking and expanding their existing service offerings. Academic library communities too call for research that would inventory the innovation resources available campus-wide and how the resources are used (Association of College & Research Libraries, 2018, p. 49). Their objective is to develop information services to enhance students and faculty's access to those resources. This exploratory study contributes to the above needs by addressing the following research question: What services do university innovation centers provide to their students?

2. Literature Review

A sizable body of literature exists on makerspaces in different disciplines. Innovation centers such as makerspaces can facilitate both innovation and entrepreneurship (Lindtner et al., 2014; Yu et al., 2016). It is important to identify the skills needed for successful innovation and entrepreneurship and design effective pedagogies for training student innovators and entrepreneurs. Although the innovation and entrepreneurship curricula are related, they may place different priorities on

different skill sets. Whereas the entrepreneurship curriculum may emphasize management skills, such as how to write a business plan, the innovation curriculum may prioritize leadership skills, such as creative ideation, risk taking, persuasive communication, teamwork, networking, and enhancing intrinsic motivations for innovation (Selznick & Mayhew, 2018; Swayne et al., 2018). Students need to learn how to identify a client's needs, define the problem, design a project that addresses the problem, communicate effectively, defend their project to the client, and manage the life cycle of the project, including its budget and timeline (Balz et al., 2019; Forest et al., 2014; Lanci et al., 2018). Makerspaces provide shared, free, or low-cost access to technologies to prototype and make things (Gershenfeld, 2005; Kohtala & Bosqué, 2014), but these maker technologies can be challenging and intimidating for novice or casual makers to operate. The centers need to provide their users with training in how to design and manufacture things. Sheridan et al. (2014) examined learning activities in three nonacademic makerspaces and identified five types of learning activities: solo and group projects, feedback forums, workshops, and open-ended play.

Students may have different objectives and motivations for engaging in innovation activities. One of the main motivations can be altruism—the desire to help others (Balz et al., 2019). The literature shows that maker activities can be shaped by the needs of local communities. They may help local businesses, organizations, community institutions, or charities develop solutions to social problems, manufacture parts for expensive equipment, or train and mentor unemployed persons in digital manufacturing to help them obtain certifications and jobs (Taylor et al., 2016). Other motivations could be the students' desire to grow professionally and personally through experiential learning; solve real-world problems; feel more autonomous and independent; or enhance their design, making, problem-solving, communication, teamwork, and project management skills. Some students might simply want to receive academic credit, socialize, and make friends (Balz et al., 2019; Lagoudas et al., 2016).

Similar to FOSS (free and open source software) projects, designing and making innovative products can enhance the reputation of makerspaces, communities, and even the nations represented by the makers of those products (Avle & Lindtner, 2016). In addition, making things can enhance makers' well-being and their feelings of accomplishment and empowerment (Taylor et al., 2016). Makerspaces can enhance the users' entrepreneurship skill learning and self-efficacy by providing them with opportunities for peer scaffolding and coaching, as well as product exploration and public validation (Hui & Gerber, 2017; Ladner, 2015; Sun et al., 2015). Confidence in oneself or one's self-efficacy is essential for both successful innovation and entrepreneurship (Chen et al., 1998).

Innovation is a problem of identifying an unmet need and developing a solution for it or developing a novel solution for a previously identified need that is more effective or efficient than the existing ones. Thus, innovation is a search process within the need and solution spaces. Ideation is the initial phase of the innovation process. Innovative ideas often are incremental, old, or borrowed from other domains. Innovative ideas and solutions can be modularized and generated by combining and recombining existing design solutions and modules (Nambisan et al., 2017). Innovators need effective mechanisms for searching and retrieving ideas and solutions from different domains, including ones that are distant from the problem domains targeted by their innovations (Swanson, 1986; Yu et al., 2016). Innovation centers need to provide access to tutorials and guides not only for their maker technologies, 3D model databases, and design and prototyping software, but also for their design problem and solution databases.

Innovation often involves teamwork. Innovators may need different expertise to design, implement, and bring their innovative products or services to the market. Crowdsourcing platforms such Upwork allow individuals to identify and recruit virtual teams of skilled freelance workers from around the world. The spatial, temporal, social, and cultural diversity of these distributed teams enables more competition and choice; it also leads to challenges in the articulation and coordination of innovative work, quality assurance, and team motivation (Nambisan et al., 2017). To help student innovators and enhance their learning through and engagement in innovation and entrepreneurial activities, innovation centers may need to implement similar expertise identification and matchmaking services but with a local scope. It is

important to identify and share the expertise and skills of individual students so that they can be recruited for project teams that need their expertise and knowledge (Balz et al., 2019).

Employing skilled educators as mentors may be an essential part of training student innovators. In addition, students may need mentors if they want to work on a project that requires knowledge that no existing classes offer. A faculty member who has that expertise and is willing to work with a student can act as a mentor and guide the student through the project (Balz et al., 2019). Mentors can help students overcome the challenges of learning new technologies by assigning them maker projects designed according to education theories and best practices and by guiding them through the use of those technologies (Somanath et al., 2017).

Securing funding is another major need of student innovators and innovator teams. Students may need the help of innovation centers to obtain funding, especially if their projects are of a humanitarian nature or if they do not have immediate commercial potential. As a part of acquiring funding, innovation centers may need to evaluate the criticality and technical feasibility of the projects students propose (Balz et al., 2019).

Students may use different resources and spaces found in innovation centers. The list of those resources and spaces may include, but is not limited to, conference rooms; electronic and 3D fabrication resources, such as 3D printers, lathes, mills, and laser cutters; and data analytics and design software (Lagoudas et al., 2016; Nambisan et al., 2017). Innovation centers can provide spaces for social interaction beyond the maker activities. Maker technologies can serve as attractors for new members, but opportunities for socialization can help retain them and grow communities around the makerspaces (Taylor et al., 2016). Many makerspaces are run by volunteers, including student volunteers and clubs. Makerspaces and innovation centers need not only to maintain their hardware and software, but also to build and maintain their user communities, including welcoming and training new members and identifying and assigning formal or informal work roles (Kohtala & Bosqué, 2014; Toombs et al., 2015). Note that in addition to belonging to the local community of users of an innovation center, makers can be members of global, interest-based maker networks, often designed or supported by a specific maker platform (Freeman et al., 2018; Morreale et al., 2017). They can network and share their designs, knowledge, and expertise with other makers around the world (Kohtala & Bosqué, 2014).

Having an active community around an innovation center can elevate the need for external mentors and advisors who can provide peer support, mentoring, and knowledge sharing. Hudson et al. (2016) distinguished between makerspaces and print centers. The latter focuses on 3D modeling and printing, operated mostly by paid operators, and may lack community aspects, such as peer support in learning and sharing knowledge and expertise. Furthermore, casual users of 3D technologies may be more extrinsically motivated and outcome driven. Compared with enthusiast makers, they may also face more barriers in their use of microfabrication technologies and may require more assistance from and mediation by the center operators and advisors.

3. Study Design

To address the research question specified in the Introduction, we analyzed the content of Twitter streams of 36 innovation centers at universities categorized as Doctoral Universities: Highest Research Activity (DUHRA) in the Carnegie Classification of Institutions of Higher Education (2015). To qualify for selection, a center had to have a student component. That is, the center had to support the maker, innovation, or entrepreneurship activities of students. University units that focused solely on technology transfer or faculty research commercialization were not considered for this study. Finally, the center had to have an active Twitter site. Out of the 115 DUHRA universities, only 36 had an innovation center that met these selection criteria (see Table 1). To identify these centers, we searched the Web domains of the universities by using “innovation,” “center,” “hub,” “maker,” and “hacker” as keywords. In addition, we used the list of

makerspaces and innovation centers published in a previous study of makerspaces (Barrett et al., 2015) to supplement and triangulate the list of centers identified through the Web search.

Table 1

Twitter accounts and websites of innovation centers used in the sample.

University name	Twitter user name	Website
University of Cincinnati–Main Campus	1819innovation	http://www.engr.utexas.edu/research/innovation-center
Carnegie Mellon University	CMUIDeATe	https://ideate.cmu.edu/
Brandeis University	deisinnovation	http://www.brandeis.edu/innovation/
Emory University	EmoryTechLab	https://it.emory.edu/studentdigitallife/study_production_spaces/tech-lab/index.html
Georgia Institute of Technology	GTInvention	https://inventionstudio.gatech.edu/
Georgetown University	gumakerhub	https://www.library.georgetown.edu/makerhub
George Washington University	GWInnovate	https://innovation.gwu.edu/
University of New Mexico–Main Campus	ia_unm	http://innovationacademy.unm.edu/
Colorado State University	idea2product	https://idea2product.net/
The University of Texas at Austin	Innovate_UT	http://www.engr.utexas.edu/research/innovation-center
Boston University	innovatebu	http://www.bu.edu/innovate/
The University of North Carolina at Chapel Hill	innovateUNC	https://innovate.unc.edu/
The Ohio State University	Innovation_Cntr	https://www.ohio.edu/research/innovation/
Duke University	InnovationCoLab	https://colab.duke.edu/
Harvard University	innovationlab	https://innovationlabs.harvard.edu/
Princeton University	kellercenter	https://kellercenter.princeton.edu/
University of Utah	LassondeInst	https://lassonde.utah.edu/
Massachusetts Institute of Technology	MIT_Innovation	https://innovation.mit.edu/
University of Mississippi	msstateecenter	https://ecenter.msstate.edu/
North Carolina State University at Raleigh	NCStateENT	https://entrepreneurship.ncsu.edu/

University name	Twitter user name	Website
University of Notre Dame	ndideacenter	https://ideacenter.nd.edu/
New York University	nyumakerspace	http://makerspace.engineering.nyu.edu/
University of Oklahoma–Norman Campus	ouinnovationhub	http://www.ou.edu/innovationhub
The University of Chicago	polskycenter	http://polsky.uchicago.edu/
The Pennsylvania State University	PSUmaker	https://makercommons.psu.edu/
Rice University	Rice_OEDK	http://oedk.rice.edu/
Rutgers, The State University of New Jersey	rumakerspace	https://makerspace.rutgers.edu/
Syracuse University	SUMakerSpace	http://makerspace.syr.edu/
University of Maryland at College Park	terrapinworks	https://terrapinworks.umd.edu/
Northwestern University	theGarageNU	https://thegarage.northwestern.edu/
Vanderbilt University	thewondry	https://www.vanderbilt.edu/thewondry/
University of California, Berkeley	InventCITRIS	https://invent.citris-uc.org/
University of Illinois at Urbana-Champaign	UIMakerLab	https://makerlab.illinois.edu/
University of Kentucky	uky_ic	https://www.engr.uky.edu/students/student-success/maker-spaces
The University of Tennessee–Knoxville	UTK_ICS	https://ef.engr.utk.edu/wp/ics/
The University of Wisconsin–Madison	uwmadmaker	https://making.engr.wisc.edu/

The data were collected and processed by using the Twitter API (application programming interface) with the twitter4j Java libraries[2] and additional Java and Python codes developed by one of the authors. The data were harvested on November 26, 2018. The temporal scope of the data collection was limited to the last 3 years, including 2016, and the number of tweets harvested from each site was limited to up to 100 of the most recent tweets.

The initial data set comprised 3,039 tweets. After removing duplicates and tweets bearing little content, such as brief acknowledgments of users thanking the center for information or services provided (e.g., “welcome”), brief comments on someone else’s tweet (e.g., “lol”), and short encouragements (e.g., “keep going”), the data set was made up of 2,174 tweets. Next, we analyzed the data set for the service types referenced in these tweets. If a tweet contained URLs

[2] https://github.com/yusuke/twitter4j.

referencing external sources such as a webpage, YouTube video, or another blog or microblog, we analyzed those sources as well so that we could disambiguate and interpret the content of the tweet more accurately. To develop a coding scheme for the content analysis, we selected a random subset of 220 tweets from the data set and analyzed it for service topics using the open-coding approach. To generate the subset, we used the random sample generation utility of the IBM SPSS (Version 23) software. We compared our individual lists of codes, aggregated, and mapped them. Fifty-five service topics were identified in the first round of the comparison. These 55 topics were then inductively aggregated into 12 more general categories of services (Bailey, 1994). These 12 categories constituted the coding scheme we used to code the data set. Each researcher coded half of the data set independently. To evaluate the intercoder reliability, we recoded another random subset of 220 tweets (i.e., ~10% of the data set). The kappa statistic for the intercoder reliability of the subset was 0.89, which qualifies as a good agreement level (Carletta, 1996). We discussed and resolved the cases on which we disagreed, and then updated our code assignments for other similar cases in the complete data set. In addition to the Twitter streams, one author examined the contents of the centers' websites following the same coding protocol.

4. Findings

The content analysis of the Twitter streams of innovation centers yielded 12 categories of services, and the analysis of the centers' websites yielded 2 additional service categories (see Table 2). We used the Labeled Latent Dirichlet Allocation (LLDA) to generate word profiles for the categories. The LLDA allowed us to identify latent topic models in the data set that corresponded to the service category codes or tags assigned to individual data cases or tweets in the manual content analysis. In addition, the LLDA could handle multiple topic codes assigned to data cases, and according to the literature, could generate more accurate topic models than other supervised learning methods, such as support vector machines (Ramage et al., 2009). Table 3 shows the word profiles for the 14 service categories generated by applying the LLDA to the data set. Each profile included the top 50 terms ranked by their probabilities for that topic. We adapted Nakatani Shuyo's Python implementation of the LLDA[3] to generate the profiles.

Table 2

Service categories.

Topic	Frequency	%
1. Educate	617	28.4
2. Showcase	556	25.6
3. Community Building	357	16.4
4. Competitions	260	12.0
5. General News	209	9.6
6. Operations Updates	153	7.0
7. Network and Matchmake	83	3.8
8. Incubate Startups	69	3.2
9. Technology	67	3.1
10. Festivals	61	2.8

[3] https://github.com/shuyo/iir/blob/master/lda/llda.py.

11. Internships and Job Placement	53	2.4
12. Expert Consultation and Mentorship	20	0.9
13. Document Library		
14. Fee-based 3D Design and Printing		

Note. The last two service categories were identified through an analysis of the centers' websites.

The most frequently occurring category was Educate. Innovation centers tweeted about different teaching and learning activities they supported, including maker and entrepreneurship classes and workshops. This category also included invited talks, panels, and roundtables at which successful entrepreneurs, startup leaders, and venture capitalists shared their experience and advice. The centers also used Twitter to share news about new technologies; funding sources; bits of entrepreneurship technology; related wisdom and advice; references to podcasts, blogs, and other publications that provided more detailed stories, how-to guides, and advice for starting and managing a business; and examples of how a particular technological innovation was monetized.

The second most frequently occurring category was Showcase. This category included tweets showcasing the achievements of the innovation centers, such as being featured in a news media story; showcasing the technologies at the centers, such as 3D printers, scanners, and laser cutters; and showcasing student projects that used those technologies. This category also included stories showcasing the success of student and alumni innovators and entrepreneurs and the achievements of the center staff. These included, but were not limited to, winning a hackathon or an award, launching a startup company, securing venture funding, delivering an invited talk, or serving on an expert panel.

The category Community Building included tweets intended to build or maintain a community around the centers. Subtypes of this category were tweets congratulating student makers and entrepreneurs on their achievements, such as winning a hackathon or pitch competition, starting a business, or thanking different groups critical to the centers' success. These included students who used the center facilities; participated in or organized innovation and entrepreneurship competitions; and staff, partners, donors, experts, advisors, and high-profile visitors (e.g., university presidents, celebrities, successful entrepreneurs). This category also included activities that were directly aimed at building community around the centers. Examples of this subtype were tweets inviting students to the centers' open houses and orientation sessions; organizing holiday, maker, t-shirt design, and game parties; and offering raffle incentives in exchange for liking or following the centers' social media sites.

The Competitions category combined tweets that announced or reported on various innovation or entrepreneurship competitions organized by the centers, their partners, industry, and national or international organizations that promoted innovation and entrepreneurship among students. These included *Shark Tank*-style pitch competitions, hackathons based on various technologies, societal and environmental problems and challenges (e.g., poverty, human trafficking), and grant and award competitions.

The General News category comprised tweets reporting news of a general nature not directly related to center activities. This category included news tweeted by the centers about various campus events, activities, and achievements (e.g., music performances, charity drives, faculty grant or award recipients, the university or college rising in a national ranking); broader community updates (e.g., information about the economic climate of a city or a region; impact of an entrepreneurship promotion project); and scientific discoveries.

The Operations Updates category combined tweets about day-to-day operations of the centers, such as announcements about the hours of operation, building closures for holidays or maintenance, job vacancies, and operational arrangements related to specific events (e.g., how to get to the event). This category also included tweets reporting on the status of a

specific technology or technologies at the center (e.g., a 3D scanner, the center's website or e-mail system) and disseminating links to event calendars and bulletins.

The next six tweet categories were less frequent. The Network and Matchmake category included tweets about the services and events that explicitly provided student innovators and entrepreneurs with opportunities for networking and matchmaking with other students with different skill sets and knowledge, alumni, and more established and experienced innovators, entrepreneurs, and venture capitalists. Examples of such events were technology-specific meetups, Friday socials, workshops, talks, and receptions. The Incubate Startups category combined tweets reporting on services of startup incubators and accelerators. As the profile shows, this category included services from some of the other categories in the typology (e.g., Educate, Competitions), although the tweets in this category reflected a more planned and comprehensive approach to the promotion of student innovation and entrepreneurship (e.g., providing startup phase-specific advising, funding, and infrastructure support). The Technology category included tweets referencing design and microfabrication technologies the centers provided, such as 3D printers, scanners, laser cutters, and CAD (computer-aided design) software. It is important to note that the main topics of most of the tweets in this category were not the technologies themselves but the services that used those technologies, such as workshops and courses on the technologies, or the showcasing of products made with those technologies. Hence, this category shared tweets with the Educate and Showcase categories. The Festivals category referenced large innovation and entrepreneurship events, such as innovation or entrepreneurship festivals, fairs, exhibitions, months, weeks, or days. These activities constituted other shorter events and activities included in the other categories (e.g., talks, workshops, competitions). The tweets in the Internships and Job Placement category reported on various practical training opportunities and job placement help the centers provided to students. These included placing students in internships with startups and industry partners, organizing job fairs, and providing career advising. The least frequently occurring tweet category was Expert Consultation and Mentorship. This category comprised tweets that referenced center services that helped students find experts and mentors and that obtained their consultation and advice to bring the students' innovative or entrepreneurial ideas to fruition.

Finally, the last two service categories were identified through the analysis of the centers' websites. The Document Library category comprised the innovation centers' library of policy guides, maker tutorials for different equipment, links to 3D modeling software, 3D model databases, innovation and entrepreneurship literature, and do-it-yourself (DIY) blogs and magazines. Some of the centers also provided a fee-based printing service where professionals helped students with their 3D design, scanning, and printing projects.

Table 3

Term profiles of the service categories.

Category	Term profile
Educate	learn, student, innovation, workshop, business, register, entrepreneurship, startup, event, founder, ideate, company, security, printing, build, session, impact, class, story, program, host, customer, venture, center, cyber, resource, library, create, course, skill, creative, healthcare, network, apply, solution, world, video, design, career, start, panel, success, opportunity, development, series, discussion, idea, startuplife, information, technology
Showcase	innovation, student, print, check, startup, learn, today, feature, create, design, 3dprinting, project, research, team, congrats, entrepreneurship, great, showcase, space, excite, working, company, center, entrepreneur, engineering, making, makerspace, demoday, global, university, community, maker, cutter, first, idea, technology, state, event, laser, resource, experience, award, story, article, people, program, support, education, product, amaze

Category	Term profile
Community Building	student, today, thank, welcome, great, innovation, event, happy, check, follow, night, print, ideate, center, makerspace, friday, congratulations, everyone, learn, opening, enjoy, halloween, community, host, bring, friend, sharing, excite, giveaway, campus, proud, coming, maker, visiting, amaze, summer, entrepreneurship, visit, retweet, design, grand, feature, connect, experience, winner, partner, orientation, session, attend, coffee
Competitions	pitch, student, competition, challenge, startup, learn, event, apply, innovation, prize, hackathon, register, team, entrepreneur, program, venture, grant, award, chance, hack, idea, alumnus, weekend, launch, health, impact, application, innovative, congrats, technology, happening, ready, deadline, global, solution, traffic, working, group, project, business, getting, pizza, start, winning, registration, shark, problem, ideate, wildfire2018, hacking4freedom
General News	innovation, student, state, learn, award, today, launch, college, business, project, first, research, university, check, support, study, institute, grant, science, expand, performance, learning, graduate, entrepreneur, music, company, national, apply, international, campus, technology, faculty, impact, initiative, design, future, school, video, rank, feature, library, teacher, announce, million, country, ranking, community, public, ideate, funding
Operations Updates	student, close, makerspace, interest, today, center, hours, design, email, bulletin, monday, happy, event, sorry, break, thanks, weekly, innovation, welcome, follow, deadline, summer, passion, request, update, print, great, system, shuttle, project, university, website, working, tomorrow, operate, inconvenience, services, campus, check, details, reopen, instagram, register, movein, reminder, user, holiday, normally, extend, hire
Network and Matchmake	network, event, connect, entrepreneurship, innovation, startup, team, entrepreneur, interest, social, lunch, community, host, investor, celebrate, woman, business, workshop, maker, start, register, student, conference, share, summit, innovator, makerspace, talent, experience, keynote, ticket, enjoy, halftime, refreshment, create, technology, problem, collaboration, founder, university, meetup, leading, club, idea, discussion, proposal, opportunity, check, conversation, venture
Incubate Startups	apply, startup, application, program, entrepreneur, company, venture, student, innovation, deadline, space, incubator, support, launch, start, opportunity, resource, unlock, accelerator, community, chance, milestone, cohort, accept, worldchanging, submit, biotech, member, state, catalyst, entrepreneurship, looking, starting growing, funding, training, stage, unique, guidance, register, focus, wayfinder, grant, learn, graduate, world, commit, idea, network, coworking
Technology	printer, learn, workshop, makerspace, student, 3dprinting, cutter, maker, model, fusion, design, sewing, blockchain, react, campus, gigabot, tormach, engraver, studio, build, center, extruders, switch, augment, electronics, driver, process, mobile, academic, system, innovation, internet, tinkercad, apply, experience, public, bring, friend, phone, development, skill, arrive, debate, moodlebox, justice, education, raspberry, enormous, designathon, create3d
Festivals	student, innovation, learn, event, startup, today, check, apply, design, register, entrepreneurship, entrepreneur, great, program, center, business, company, tomorrow, print, pitch, workshop, start, application, opportunity, create, makerspace, tonight, university, month, project, state, community, innovative, idea, happy, venture, excite, team, world, challenge, innovator, science, space, entrepreneurial, founder, award, campus, coming, thank, host

Category	Term profile
Internships and Job Placement	student, apply, program, intern, startup, company, host, great, internship, learn, opportunity, summer, experience, connect, business, science, portfolio, diverse, technology, application, employment, industry, immersion, fellow, google, leadership, lecture, career, center, system, posting, looking, event, build, course, spring, deadline, uplift, staff, potential, leading, individual, colab, participate, challenge, entrepreneurial, need, practice, society, identify
Expert Consultation, Mentorship	expert, advisor, entrepreneur, basic, register, investor, legal, diagnostics, student, submit, mentoroftheweek, looking, insurance, feedback, advice, welcome, technology, resource, tapping, strategy, million, 'unstuck', start, guidance, industry, attention, residence, community, alumnus, discussion, taking, energy, consult, try, innovation, interest, collaborator, bring, founder, team, need, sessions, private, include, protection, precision, question, happy, field, diagnostic
Document Library	machine, innovation, design, video, tutorial, print, model, policy, software, power, instructions, user, guide, maker, project, supervisor, allow, create, parts, appropriate, build, check, computer, overview, university, download, approach, practice, learn, support, filament, supervision, resource, tool, equipment, change, cutter, staff, community, hours, place, clothing, embroidery, modeling, initiative, member, development, file, exercise, entrepreneurship
Fee-based 3D Design and Printing	service, design, printing, material, professional, services, online, scanning, offer, information, available, print, campus, request, account, please, equipment, faculty, quote, rates, price, minimum, contact, require, student, payment, supervise, prototyping, things, nozzle, accept, nanoscribe, credit, charge, digital, biomaterials, engineering, university, program, times, staff, question, email, model, surcharge, holder, submit, private, research, support

Note. Includes the top 50 terms for each category. The last two categories were identified through an analysis of the centers' websites.

5. Discussion

This study examined the Twitter streams and websites of 36 innovation centers to identify a set of services the centers provided. Through content analysis of the Twitter streams, 12 service categories were identified. The most frequent categories were Educate and Showcase. Not all the tweet themes reflected services directed to its user and stakeholder groups, however. For example, some of the tweets in the Operations Updates category, such as job advertisements for staff positions at a center, were not considered services directed to the center's user groups, but rather to support the overall operations of the center.

The analysis of the centers' websites helped identify two additional service categories: (1) Document Library, and (2) Fee-based 3D Design and Printing. It is noteworthy that the centers did not explicitly tweet about these services. They advertised different orientation and safety training events on Twitter but did not reference the policy guides and equipment tutorials used in those trainings. Similarly, the centers that offered fee-based 3D design and printing services did not tweet about those options.

The conceptual mapping of the service categories to the activities in the innovation model proposed by Ayele et al. (2018) showed that each of the service categories could support multiple activities (see Table 4). The services in the Educate category, such as courses and workshops, are relevant to any part of the innovation workflow. Innovation centers may showcase students engaged in innovation design, implementation, or exploitation activities, which in turn can inform other students who lack that experience about those activities and demystify them. Establishing and maintaining an active

community around an innovation center can enable peer support, learning, mentoring, and knowledge sharing. Hence, the Community Building category can indirectly support innovation design, preparation, implementation, and exploitation activities. In the same way, the rest of the service categories can be mapped to the activities in the model. Mapping the services to the activities in the innovation workflow model can help managers of innovation centers optimize the information architecture of their websites and resource guides and easily inform students about the help and resources available for each activity or phase of the innovation process. It can also help the innovation center identify possible gaps in its service offerings for each innovation activity or opportunities for new services.

Table 4

Innovation activities supported by the service categories.

Topic	Activities
1. Educate	Planning, Ideation, Design, Preparation, Implementation, Exploitation
2. Showcase	Design, Implementation, Exploitation
3. Community Building	Design, Preparation, Implementation, Exploitation
4. Competitions	Ideation, Design
5. General News	Ideation
6. Operations Updates	Design, Preparation, Implementation
7. Network and Matchmake	Planning, Ideation, Design, Preparation, Implementation, Exploitation
8. Incubate Startups	Design, Preparation, Implementation, Exploitation
9. Technology	Design, Preparation, Implementation
10. Festivals	Ideation, Design, Implementation
11. Internships and Job Placement	Planning, Ideation, Design, Preparation, Implementation, Exploitation
12. Expert Consultation and Mentorship	Design, Preparation, Implementation, Exploitation
13. Document Library	Planning, Ideation, Design, Preparation, Implementation, Exploitation
14. Fee-based 3D Design and Printing	Design, Preparation, Implementation

Note. The last two service categories were identified through an analysis of the centers' websites.

Our previous study of academic library tweets identified nine categories of tweets (see Table 5; Stvilia & Gibradze, 2014). A comparison of the tweet categories from the present study with those from the 2014 study showed that all the present tweet categories could be mapped onto the Event category from the previous study, with the exception of Operations Updates and Technology. That is, most of the tweets posted by innovation centers referenced various kinds of events. The Resources category was another category that frequently overlapped the set of categories in the present study. This finding was not surprising given that innovation centers offered services enabled by their resources, even though the types of resources differed. Academic libraries tweeted mostly about information resources they curated or provided access to, whereas innovation centers tweeted not only about the technologies they provided access to, but also about the human resources needed to complete the activities they supported or were involved with. The resources they tweeted about included, but were not limited to, business and technical experts serving as mentors and advisors to student innovators and

entrepreneurs, venture capitalists funding new startups, laboratory space and equipment for projects and startups, and data sets used in hackathons. The analysis of the websites showed that some of the centers also maintained online libraries of policy documents, innovation and entrepreneurship literature, tutorials, links to 3D modeling software, model databases, and DIY blogs and magazines, although they did not tweet about those types of resources.

The other matched categories from the study of academic libraries were Community Building, Operations Updates, Study Support, Survey, Staff, and Club. Clubs were mentioned in the context of recruiting members and building student communities around innovation centers, for their roles in organizing hackathons and other competitions, and for supporting student networking. Study support for experiential learning was assumed when innovation centers tweeted about organizing technology workshops and providing their spaces for innovation- and entrepreneurship-related courses. In addition, delivering study support was presumed when innovation centers advertised their meeting rooms in user recruitment and community building tweets. Notably, innovation centers did not directly advertise the use of their physical spaces for studying and the availability of study support services in the way academic libraries did in the 2014 study (e.g., posting updates on the number of sites available; announcing stress management services available during finals week).

Table 5

Comparison of tweet categories between the present study and Stvilia and Gibradze (2014).

	Stvilia and Gibradze (2014)								
Present Study	Event 28.3%	Resources 22.7%	Community Building 12.9%	Operations Updates 11.4%	Study Support 8.6%	Q&A 6.6%	Survey 3.9%	Staff 2.9%	Club 2.5%
Educate 28.4%	x	x			x		x		
Showcase 25.6%	x	x							
Community Building 16.4%	x	x	x		x				x
Competitions 12.0%	x	x							x
General News 9.6%	x								
Operations Updates 7.0%		x		x			x	x	
Network and Matchmake 3.8%	x	x							x
Incubate Startups 3.2%	x	x							
Technology 3.1%		x							

Festivals 2.8%	x	x		x
Internships and Job Placement 2.4%	x	x		
Expert Consultation and Mentorship 0.9%	x	x		

6. Conclusion

In this study, the Twitter streams and websites of 36 university innovation centers were examined, and 14 service categories that the centers offered were identified. Exploring the present Twitter use practices of innovation centers and identifying the services they provide can inform the design and planning of service offerings of new innovation centers and aid in training the center staff in the use of this social media platform. In addition, existing innovation centers can benchmark their service offerings against these services. A comparison of the tweet categories identified in the present study with the categories of tweets by academic libraries assembled in a previous study (Stvilia & Gibradze, 2014) revealed significant overlap, but some differences as well. In contrast to academic libraries, innovation centers did not tweet about their information services even if they had them. Innovation centers also did not use Twitter to provide their users with a Q&A service. Furthermore, innovation centers tweeted not only about the technological resources they provided, but also about the human resources they recruited to serve as student mentors and advisors. Finally, technology use in innovation centers was more mediated than in libraries. Some centers offered their users fee-based professional assistance with their 3D design and printing tasks.

This study has a limitation: Its findings are based solely on the content analysis of the Twitter streams and websites of 36 DUHRA universities. The use of documentary data sources such as Twitter streams enables researchers to collect data about an organization's activities that may span multiple years. In addition, Twitter streams and website content-based data do not have the recall-related bias that data generated through self-reports (e.g., surveys, interviews) may have. However, the data sources used in this study provided only the information the centers chose to share through these particular media; hence, they may not have fully reflected the centers' service offerings. Furthermore, the findings of this study may not be generalizable to innovation centers affiliated with non-DUHRA universities, which may have different resource structures and educational priorities.

To amplify and triangulate the findings of this study, we will conduct a future research-related study using different sources of data, such as interviews and a survey, to examine the information and technology needs of students who participate in innovation center activities and events. Another fruitful future research direction could be to investigate students' priorities for using the set of services identified in this study. Such results would help new innovation centers set their priorities and determine which services to offer first.

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