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Exploring a construct model for university makerspaces beyond curriculum

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Abstract
Makerspaces aim to revolutionize the current higher education by providing a means for students to be directly involved in many scientific projects and develop various kinds of skills. While researchers have made progress in understanding different makerspaces and the increase of making in education, the reality is that a specific makerspace may be rather different from many other contexts. As makerspace programs expand around universities in Tianjin, China, it needs a robust framework and a construct model to set the foundation for understanding key makerspace elements beyond curriculum, and to be used for research and verification of these experiences to advance work. Therefore, this paper provides the development and explanation of a construct model of influencing factors for makers in the universities applied beyond curriculum. Methods of questionnaire survey, descriptive statistics, multiple linear regression, and correlation analysis were used to explore the influencing factors of makerspace. The results are as follows: the innovation awareness of the maker subject is positively correlated with teamwork; the innovation awareness and teamwork are positively related to the effect feedback of the makerspace; Activating interest in maker activities is positively related to deep research, putting into practice, and precise creation; deep research has a positive correlation with putting into practice, and putting into practice has a direct correlation with precision creation. In maker resources, Internet resources positively correlate with the sharing of university resources, and Internet resources and university resources positively correlate with enterprise resources. In this paper, a novel theoretical framework and a construct model of makerspaces beyond curriculum offered enables us to analyze future practices and the resulting development of future-making.

Keyword Construct model · Universities · Makerspace · Extra curriculum

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1 Introduction

Higher education is critical to an individual's future success in modern society (Felgueiras et al., 2017). The existence of makerspaces for higher education is designated as carriers of change in the provision of wisdom. It can transform students from knowledge-based learning into creative learning, which promotes freedom of thought, leads to change, and provides creative wisdom. University makerspaces aim at building direct physical prototypes that depend on students, which can be seen in public spaces with academic designs. The purpose of makerspace is to increase students' motivations and interests in learning and innovation, forming co-operations, and fostering entrepreneurship. Therefore, it has the potential to facilitate advanced learning in higher education.

University makerspaces meet all engineering needs based on practices to complement existing theoretical classroom structures. Student makerspaces are very suitable for the curriculum majoring in engineering supported by various aspects but focused on two main concepts: the benefits of building physical models of makerspaces and gaining from informal learning environments (Barrett et al., 2015). Makers may start as beginners. They usually take an active part in using specific tools, gadgets, or programs to testing and refining existing products. At the intermediate level, makers start tinkering with or try other things. At the same time, novice members of the makerspace have never made any suggestions nor built the product into their development designs. At the expert level, students are usually divided into groups starting to fiddle with products or plans that already existed in the past but were left behind. They will begin to develop ideas to innovate so that the product or plan can be reused but differently from the previous one. For this final stage, there will be an autonomous victory and considerations resulting from pioneering activities in makerspaces, which bring unique and innovative results.

Makerspaces across the world have grown significantly over the past few decades, such as Makelab, Bibliolab, Laboratory repair, Hacklab, iFabrica, Repair Cafe, STGO makerspace, Technasium, Techlab, and Techshop (Weinmann, 2014). Each has different goals and uses, combined with informal learning. While researchers have made progress in understanding different makerspaces and the increase of making in education, the reality is that a specific makerspace may be rather different from many other contexts. As makerspace programs expand around universities in Tianjin, China, it needs a robust framework and a construct model to set the foundation for understanding key makerspace elements beyond curriculum, and to be used for research and verification of these experiences to advance work.

As such, the study sought to answer the following questions: (1) How the universities in Tianjin organize their practices and use of resources to support the purposeful implementation of makerspaces? (2) What are the important factors regarding the impact of the makerspaces? (3) What is the relationship between these influencing factors?

Therefore, the paper begins with a brief description of the literature on university makerspaces and develops a theoretical framework and a construct model with the academic purpose for using makerspaces beyond curriculum. After that, the relationship and influence factors of the construct are explored. At last, this paper gives some conclusions and implications.

2 Literature review

2.1 Makerspaces

Makerspaces have several different forms or types and also have different goals and approaches. Most makerspaces are made based on social innovations that existed before and then focus on inclusion. With lifelong learning slogans often used to attract attention, unique and exciting creativity and new artistic and cultural creations are combined with the right portions. Besides, makerspaces provides training to people who have no activity and develop their skills, such as digital and technical skills and entrepreneurship abilities. Makerspaces empower certain groups to be creative in producing products to be marketed. Utilizing makerspaces for the teaching and learning process is possible in any university, thus supporting education to be more innovative, even though it is not the primary goal of the curriculum.

Makerspaces are places for students' creativity that are not just related to the technology area. They can be designed as sophisticated or simple as libraries, of which the main purpose is to support student learning directly. As learning environments, makerspaces facilitate students' critical thinking and creative problem-solving at a high level. The form of solutions to problems may be creative designs, further construction-making, or iterations. Makerspaces are informal physical spaces as part of a community or educational institution used as the spaces for shared creativity (Adams Becker et al., 2016). Makerspaces are spaces intended for students to be creative in making a product in college by using science and technology standards as a guide (Julian & Parrott, 2017). The process of product creation is that students "Do It Yourself" according to their wills and ideas. Nevertheless, there is collaboration from use of digital tools and techniques so that the products can be made to meet standards (Dufva, 2017). Therefore, makerspaces are direct learning spaces for students that can be applied to formal or informal learning.

Makerspaces are generally used for the mention of creative spaces that aim as a place for creativity. Some examples of makerspaces include FabLabs, Hackerspaces, and many other makerspaces that appear along with their developments (Geser et al., 2019). A FabLab is a type of makerspace designed in the form of a laboratory that focuses on digital design and fabrication using 3D printing controlled by a computer, laser cutting, and others. Universities usually establish FabLabs as spaces for learning, research, and innovation, where students can directly utilize them with the guidance of tutors. Hackerspaces are makerspaces in the form of various communities that focus on learning computer programming and sharing other open-source software. They expand innovation by combining several open hardware, circuits, electronic components, and existing sensors. Other makerspaces are creative environments established by various local communities in particular domains, including clubs in the university, libraries for study rooms, museums, and other public or civil society organizations that we currently use a lot for its existence. The idea of makerspaces creating governance and regulation becomes more formal in the community.

Some educators have identified the level of synergy between concepts in making makers with the goals of education itself (Gilbert, 2017). A makerspace is a learning space that students use to support the learning process with the direction of a tutor as a companion to create more advanced learning methods. Learning methods in makerspaces emphasize students' activities of experimentation, discovery, creation, and exploration closely related to STEM, which means Science, Technology, Engineering, and Mathematics subjects (Litts, 2015). Students who use makerspaces as learning spaces generally have a high interest in developing their creativity. Meanwhile, in China, creativity is a top national priority. For example, many schools adopt systematic learning approaches based on problem formulation to build more innovative thinking (West-Knights, 2017). Learning methods of creativity have many benefits for universities. They can develop students' mindset, increase their confidence in creating a product (Martinez, 2018), help students prepare themselves to deal with conditions and situations in real life or the world of work (Caballero-Garcia & Grau-Fernandez, 2019). Therefore, Makerspaces highlight more on the mindset of students to create and explore something that comes from their interests, which is the core of learning goals in makerspaces. These makerspaces also aim to help students prepare to practice skills in the twenty-first century, namely underlining STEM learning. Through makerspaces, mentors, tutors, or educators provide direct learning to students to help them think critically, improve their skills, and increase their confidence.

2.2 Makerspaces in universities

Makerspaces in universities have close links with STEM subjects which are the priority subjects on the list of educational systems worldwide. Makerspaces in STEM subjects place learning by obtaining from science to innovate, design, and arithmetic used to shape, develop, and study a particular item or examine artifacts. Students themselves usually choose projects or research objects which are unique. The university provides makerspaces for students accessing quickly, for example, the availability of a place to provide machine tools and an assembly/testing area for objects, CAD laboratories, meeting rooms for discussion, or classrooms. Academic makerspaces are always related to design, innovation, creation, and discovery, which are designated for laboratory rooms, central meeting rooms, and studio rooms. Makerspaces have infrastructure models, programming, and functions that are similar to one another. Every makerspace has its different academic roles, including differences in the focus of objectives, access, and service of their expertise (Wilczynski, 2015). Makerspaces were created to get students directly involved in interactive thinking, creative and critical thinking in solving complex problems (González-González & Arias, 2018).

The structure of makerspace and its staffing service system are critical to preparing students for future professional skills, as is the case with learning goals (Wong & Pratridge, 2016). Lagoudas et al. (2016) conducted a study about the use of makerspaces based on gender and ethnicity, which focused on frequency of use, types of resources use, the impact of using makerspaces on development both professionally and personally, and their effects on confidence to build skills by utilizing existing facilities in makerspaces. Liu (2016) described that focusing on students in classroom learning is very important because learning aims to equip students with the ability to apply ideas, make innovations, find solutions to complex problems, and help students build confidence. Liu (2017) reinforced the results above by further research. The contents emphasize that the learning context of the classroom does include learning goals for the future, improves students' abilities of reading and cognition or skills, and helps students understand functions of tools practice and teaching–learning materials by combining subjects across disciplines. With understanding of the whole context of learning, students will be better prepared for their future. Lin (2016) also mentioned in the results of empirical research that the teacher or educator must be an instructor or mentor who helps students identify problems by holding group work to improve the results of their works as feedback from classroom learning.

The reverse research result was revealed by Martin (2015) that learning methods that only focus on practical tools without developing the value of students' mindset would lead to failure of educational goals. Other researchers also revealed that the learning process activities should focus on developing students' thinking patterns, especially the students' behaviors and attitudes, not only teaching concepts of STEM subjects. Chu et al. (2015) also mentioned that cultivating student's mindset is more holistic than just focusing on developing student's skills and knowledge. It can be done through activities aimed at developing students' perspectives in problem-solving, such as training to increase students' curiosity about the unknown.

The different viewpoints can be concluded from previous studies. The results of the first study describe a good learning method that is using makerspaces to increase the involvement of students in active direct learning or to support a deeper understanding of knowledge. In comparison, the second study results describe that a good learning method is to use makerspaces to support the achievement of educational goals in the twenty-first century. Although the research results are different, they have in common that advanced learning methods used help realize the learning objectives for students.

2.3 Constructs of makerspaces

Activities can work in makerspaces if the individual members have ideas that are supportive and collaborative. The makerspace is a gathering place for students to issue their ideas, which can then be considered materials for developing technology and will eventually create a new team. In their research, Lanci et al. (2018) made a construct model of makers based on student perceptions, the interactions between students, and the learning process. The model above concerns engineering students' motivation, perseverance, ownership, social interaction, knowledge, and professional identity. Students typically do not make or discover anything tangible in the engineering department's standard curriculum until they create a new design and then find it as a learning experience. Lanci et al. (2018) found a new factor that has a major influence on engineering students' interest in improving their learning skills, which is the desire to become entrepreneurs.

Beyond Rubrics (BR) project (Teaching Systems Lab, 2018) is construct-centered and emphasizes embedded (and often playful) assessments and co-design processes for makerspaces. The key constructs, referred to as "Maker Elements", are agency, design process, social scaffolding, productive risk-taking, troubleshooting, bridging knowledge, and content knowledge. The MakEval project identified five key targets based on formal and informal maker educators' survey and interview data: agency, STEM practices, creativity, STEM interest and identity, critical thinking (Maltese, 2018). The MakEval aims to provide educators with suites of tools, such as surveys, rubrics, and observation protocols for each of the different target areas. Makerspaces also support security enhancement programs with online recording methods or instructional movements.

The current constructivist principle emphasizes developments in the fields that lead to STEM using approaches that focus on student engagement in direct learning (Hamir et al., 2015). In constructive makerspaces, the main objective is innovative and student-friendly progress to increase student interest in learning and create collaborative learning conditions. Making a makerspace is done holistically but still bound by constructionism and constructivist theory. For example, it can be seen when students create objects in their research, such as making videos by utilizing slow-motion movement activities, using innovations on the green screens used, or using program improvements to the coding components that exist in applications such as Scratch. All of which are centered on constructionism. Makerspaces have different targets, forms, and systems of approach. Makerspaces have a high level of diversity and heterogeneity, such as structure, arrangement, goals, and learning approaches. The space in makerspaces serves as a meeting room or training room for making, fiddling with the creative construction that each student owns. Makerspaces also offers access to use equipment with high and low technology components, and the community of makers involved will help provide knowledge to students (Dougherty, 2016).

3 The theoretical framework of a construct model for university makerspaces beyond curriculum

University makerspaces aim for students or individuals who have creative ideas to innovate. Students are interested in learning together and discuss the latest prototyping quickly, which can be done using very innovative tools and techniques. The existence of makerspaces stimulates students' curiosity, and students can also use makerspaces as training rooms in making products or works that they want to make.

3.1 Maker subjects

Trends in the use of makerspaces are introduced by various clubs or communities in the educational sphere to attract students' attention, so that enthusiasm to engage in activities is related to STEM subjects and train students to think creatively and critically. Remember, students are a national asset (Hsu et al., 2017). Most colleges and universities are currently investing heavily in efforts to support the creation and use of makerspaces as a form of the facility to support students conducting research, and as a form of participation in efforts to improve the quality of existing education (The White House, 2014). A makerspace is a place that supports students who have high interests and a different sense of curiosity, and it is also a space designated for students who want to collaborate with other students to create a product that is following his/her passion (Oliver, 2016).

Students conducting activities in makerspaces must align their ideas with the circumstances, select the latest topics in the world as a discussion, and combine ideas or thoughts with other students' in the makerspaces group (Bevan et al., 2015). Students who are members of the maker group can make their interests, talents, and abilities to be used as inspiration or capital in their creativity (Kafai et al., 2014). This capital is a supporting tool to increase investment in oneself in carrying out tasks and controlling learning conditions (Martin, 2015). Makerspaces support students to put their ideas into projects and then show them the results of their creations. However, it cannot be avoided if, in the learning process, sometimes students experience failure (Martin, 2015). These failures can be used as a guide or learning materials for students to think critically about how to correct their previous mistakes or failures. Therefore, when students make new mistakes, it is vital to look back at previous mistakes to be used as materials for finding appropriate and practical solutions to deal with new mistakes (McKay et al., 2016).

3.2 Maker activities

Makerspaces have a close relationship with STEM subjects, but this does not rule out that universities integrate makerspaces with other subjects. Students may use makerspaces as part of their classroom learning or outside their classroom. Activities in makerspaces are part of mandatory instructions, which show that activities from planning to conceptualization can produce a product or work of which students can display. Other than engineering or architecture, examples of courses that can be integrated with learning in makerspaces are most interdisciplinary.

In activities of makerspaces, students are disciplined to practice their skills, such as communicating, collaborating and improving their professional abilities as preparation before entering the workforce. Moreover, students are able to create innovative works through collaboration with other students from different majors. The purpose of makerspaces is to facilitate students in creating a concept and then turning it into a work. In addition, the results of activities in makerspaces could be innovative products that might lead to new business. On the other hand, for activities beyond the university curriculum, students are advised to create individual projects or collaborate with clubs and organizations at the university. For example, students can build robots or drones at makerspaces.

Makerspaces can also be a place for teaching activities, seminar rooms or places to hold competitions, but activities in makerspaces must be followed by students because the main goal is to improve their abilities and expand their knowledge. Also, makerspaces are great places for students to practice their low-resolution prototyping skills.

3.3 Maker resources

Maker resources are used as a reference for educators or students to make their makerspaces. Henceforth, these maker resources intend to make it easier for students interested in accessing their curiosity about makerspaces and other things that have a relationship with makerspaces. Maker resources are in favor of helping makerspaces integrated into the university to find out the habits and creation of students at university who use the makerspaces. Maker resources provide services to individual users of makerspaces who need help to achieve the goals in a community that uses makerspaces. Maker resources can also be used to find more detailed information about makerspaces or making makerspaces used in formal education and learning (Vuorikari et al., 2019).

4 Building a construct model for university makerspaces beyond curriculum

The conceptual framework contained in this paper is created to be used as a map or guide for teachers and facilitators who expect to use makerspaces beyond curriculum to be more structured in their making. Makerspaces in universities must have implications for students through instructive instruction to make a device supporting the learning process. Figure 1 shows how the constructs of makerspaces are centered on the perspectives of makers who aim to use makerspaces beyond curriculum.

Three aspects of makerspaces, in particular, have a solid connection to the field of education and training. The first aspect is about interdisciplinary perspectives that align with makerspaces. The second aspect is the evidence that when exploring solutions to problems that arise from the surrounding environment, individuals can gain new knowledge and insights through the use of makerspaces. The last aspect is the maker resources made to facilitate learning and practice in the field flexibly. It adjusts to the real conditions experienced by students and with the tutor's assistance in groups, so that the practice in demonstration of the results of the workshop or the tools used becomes more structured.

In the construct model of makerspaces beyond curriculum, the teaching and learning process is encouraged and supported by students' interests and discoveries that occur openly. However, it is still directed by the existing context as guidelines to meet the target learning outcomes wanted within a specific time limit. Informal or structured learning activities provide more opportunities for students to learn together with their peers. Teachers will assess the learning outcomes for these students whether they meet the curriculum or qualification programs that exist in these activities.

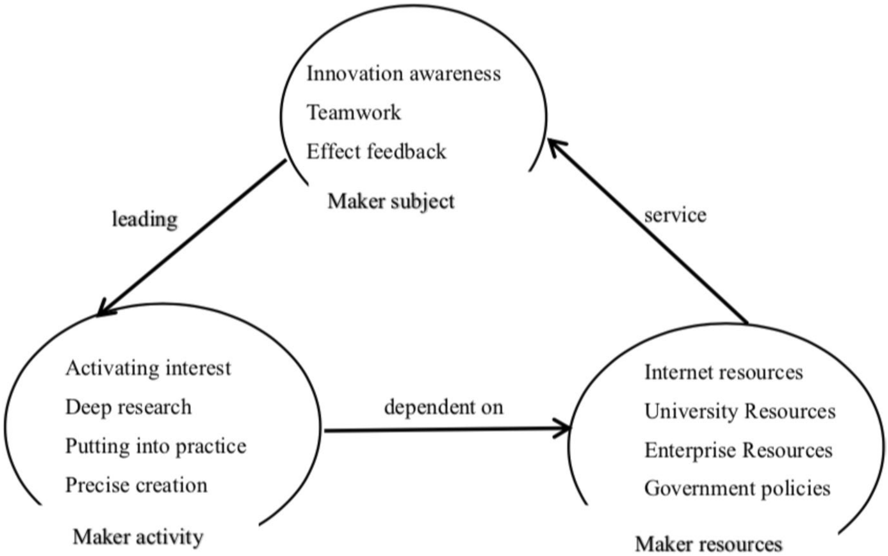

Fig. 1 A construct model for university makerspaces beyond curriculum

5 Methods

5.1 Samples

The sample source for this study is makerspaces of universities such as Tianjin University, Nankai University, Tianjin Polytechnic University, Tianjin University of Technology, Tianjin Normal University, Tianjin University of Science and Technology, Tianjin Foreign Studies University, and Tianjin University of Technology and Education. A total of 330 questionnaires were distributed, and 272 were recovered, with a recovery rate of 82.42%. Excluding 20 invalid surveys, 252 questionnaires were used for data analysis, and the effective rate was 92.65%.

5.2 Instrument

Given that there is no relevant scale or questionnaire for this study, it needs a self-compiled scale. The self-compiled scale adopts a Likert five-point scale, and its analysis of reliability and validity was performed. The questionnaire involves three aspects of makerspaces in universities: maker subject, maker activity, and maker resources, including 11 items, and 44 sub-items, shown in Table 1.

In “Maker subject”, there is a scale from “Very dissatisfied” to “Very satisfied”. As to “Maker activity” and “Maker resources”, there is a scale from “Never” to “A great deal”. The number 1 to 5 is an interval scale.

Table 1 The composition of the questionnaire

Dimensions	Items	Question No
Maker subject	Innovation awareness	1. I love innovation and creation very much, so I participated in the makerspace 2. I have clear goals for what I want to create 3. I can actively encourage myself 4. I have a clear self-evaluation in exploring 5. I have a certain professional knowledge, which has pushed me to further making 6. In addition to class, I have plenty of spare time to participate in making 7. I am not afraid of failure and can persevere in making
	Teamwork	8. My maker team trusts and encourages each other 9. My maker team communicates with each other and makes progress together 10. Teamwork is very helpful for completing the work
	Effect feedback	11. The equipment is of great help to me provided by makerspace 12. The expert guidance is very helpful for me to complete the work 13. Participating in makerspace is very helpful for my innovation abilities 14. I have an entrepreneurial idea after participating in makerspace learning

Table 1 (continued)

Dimensions	Items	Question No
Maker activity	Activating interest	15. My university holds maker competitions
		16. There are successful cases of the maker in my university
		17. My university makerspace proposes some methods to solve practical problems to stimulate interest
		18. My university has publicity activities for makerspace
		19. My university has an incentive mechanism for makerspace,such as an innovation bonus, credit replacement system
		20. My university has displays of finished products for makerspace
	Deep research	21. My university has complete maker courses
		22. I can capture new knowledge, generate new ideas, and explore new approaches in makerspace
		23. My university website has information and resources of makerspace
		24. My university has maker teachers and experts for makerspace
	Putting into practice	25. I can redesign and transform knowledge and activities, such as migrate and remix technologies
		26. I can put innovative ideas into actions such as the prototype, and the aspects of design, construction, and testing may be updated or changed iteratively
		27. My university provides maker equipment for makerspace
		28. My university provides venues for makerspace
		29. My university provides a one-stop service for makerspace
	Precise creation	30. My university provides standards of agile product development, and custom individual service
		31. I can precisely and adaptively fabricate products using automatic, networked and intelligent technologies
		32. My university provides consulting services for makers
		33. My university guides to students in entrepreneurship

Table 1 (continued)

Dimensions	Items	Question No
Maker resources	Internet resources	34. My university has a virtual maker community (such as QQ, WeChat group) on the school website 35. My university has the display of relevant works on the website 36. My university website launches the situation of maker competitions 37. There are network supports for maker activities
	Government policies	38. I understand the government's preferential policies for university students' innovation and entrepreneurship 39. I understand the government's relevant policies of the makerspace development plan
	Enterprise resources	40. The company helps the maker understand market demands 41. There are technical co-operations among my university's makerspace and enterprises
	University resources	42. There are the utilizations of maker resources among different universities 43. There are relevant regulations on the realization of openness and orderly management of makerspaces for different universities 44. My university has the maintenance of related equipment in the makerspace

Table 2 Reliability of the questionnaire

Element	α	Element	α
Innovation awareness	0.868	Precise creation	0.728
Teamwork	0.836	Internet resources	0.726
Effect feedback	0.811	Government policies	0.636
Activating interest	0.811	Enterprise resources	0.603
Deep research	0.781	University resources	0.721
Putting into practice	0.803		

Table 3 KMO and Bartlett's test

Kaiser–Meyer–Olkin Measure of Sampling Adequacy		0.926
Bartlett's Test of Sphericity	Approx. Chi-Square	5969.694
	df	946
	Sig	0.000

5.2.1 Reliability analysis of the scale

Regarding the reliability α, the first acceptable coefficient is $0.7 \leq \alpha < 1$, and it is considered that a more considerable α value is better. At present, in the related studies of pedagogy, psychology, management, and medicine, the reliability coefficient widely used is $0.6 \leq \alpha \leq 0.9$ (Bhatnagar et al., 2014; Eum et al., 2007; Morgan et al., 2004; projectguru, 2019). It is believed that too high a reliability is not necessarily a good thing. A high value means that there are redundancy remaining or invalid items (Taber, 2018). In this study, $0.6 < \alpha < 0.9$ shown in Table 2 has inherent consistency and reliability.

5.2.2 Validity analysis of the scale

The content validity of the questionnaire was analyzed by factor analysis shown in Table 3. According to KMO (Kaiser–Meyer–Olkin), the closer the KMO value is to 1, the more suitable it is for factor analysis. The KMO value obtained from the analysis results in Table 2 is 0.926, indicating that it is suitable for factor analysis. The null hypothesis of Bartlett's test of sphericity is that the correlation coefficient matrix is the identity matrix and the Sig. Value is 0.000 less than the significance level of 0.05. Therefore, rejecting the null hypothesis indicates a correlation between the variables, and it is suitable for factor analysis, meaning that the questionnaire has good content validity.

Table 4 Descriptive statistical analysis of the data

Variables	M	SD	N
Innovation awareness	3.3690	0.782	252
Teamwork	3.6706	0.913	252
Effect feedback	3.4732	0.836	252

Table 5 Correlation between variables

		Innovation awareness	Teamwork	Effect feedback
Innovation awareness	Pearson correlation	1		
	Sig. (2-tailed)			
Teamwork	Pearson correlation	0.753**	1	
	Sig. (2-tailed)	0.000		
Effect feedback	Pearson correlation	0.740**	0.803**	1
	Sig. (2-tailed)	0.000	0.000	

6 Analysis and results

6.1 Maker subjects

6.1.1 Descriptive statistical analysis

Table 4 shows the mean and standard deviation of the three variables in the maker subject. The mean of every variable is more significant than 3 and less than 4, which indicates that the satisfaction of the maker subject is between “general” and “agree” reflecting that the maker subject is not positive about innovation.

6.1.2 Analysis of correlation

Bivariate analysis is required to understand the correlation between variables in the maker subject. Table 5 shows that all correlation coefficients have reached a significant level, indicating that the two variables are closely related.

6.1.3 Regression analysis

The study used multiple linear regression analysis to explore further the causal relationship between the feedback of the maker subject’s innovation development effect and its influencing factors. Regression analysis was performed using teamwork and effect feedback as dependent variables and influencing factors as independent variables. Table 6 shows the statistical analysis results.

As shown in Table 6, the difference in the impact of innovation awareness on teamwork is highly significant ($p < 0.01$). There is a significant linear relationship

Table 6 Results of regression analysis of variables

Dependent variable	Enter Equation Variable	R^2	F	B	β	T	P
Teamwork		0.567	326.908				0.000
	Innovation awareness			0.879	0.753	18.081	0.000
Effect feedback		0.687	273.274				0.001
	Innovation awareness			0.335	0.313	5.816	0.000
	Teamwork			0.519	0.567	10.528	0.000

between the two. The regression equation established is teamwork = 0.753 × innovation awareness; innovation awareness and teamwork have a significant difference ($p < 0.01$) for effect feedback, indicating a significant linear relationship between the variables. The regression equation was established as follows: effect feedback = 0.335 × innovation awareness + 0.519 × teamwork.

7 Research results

The innovation awareness of the maker subject has a positive impact on teamwork. The stronger the innovation awareness of the maker subject, the more conducive to teamwork. The effect feedback of maker subject on innovative development is affected by the two factors of innovation awareness and teamwork. Innovative ideas are not isolated but come from a network of supplemental ideas, indirect concepts, basic assumptions, logic, and many possibilities. A good team is conducive to developing an idea into a large number of ideas, and innovation is a fusion of cluttered ideas.

7.1 Maker activities

7.1.1 Basic assumptions

Maker activity can better reflect the maker concept of innovation, practice, open-source sharing, and the spirit of digital artisans. Figure 2 shows the path model of its influencing factors.

Hypothesis 1 (H1): Activating interest can facilitate deep research.
Hypothesis 2 (H2): Activating interest can put students into practice.
Hypothesis 3 (H3): Activating interest can help students create precisely.
Hypothesis 4 (H4): Deep research on interesting topics will encourage students to put into practice.
Hypothesis 5 (H5): Deep research on interesting topics will encourage precise creation.
Hypothesis 6 (H6): Putting into practice is conducive to precise creation.

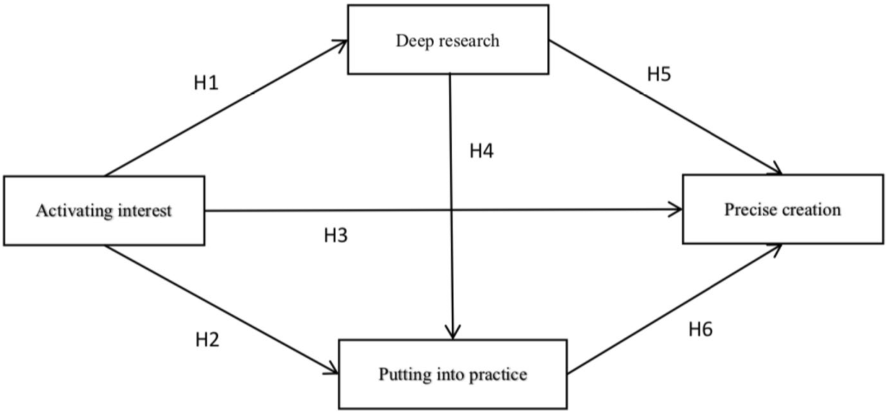

Fig. 2 Path model of influencing factors of maker activities in universities

7.1.2 Descriptive statistical analysis

Descriptive statistical analysis is used for variables affecting creativity in maker activities shown in Table 7. The mean of every variable is greater than 3 and less than 4, which indicates that the status of maker activities is between "Yes" and "There are some" reflecting the weak continuity of maker activities.

7.1.3 Analysis of correlation

Firstly, a bivariate analysis is performed on the four variables for the purpose of understanding the relationship between the two variables, and then the statistical data are analyzed according to the correlation, as shown in Table 8. The coefficient of bivariate correlation $p<0.01$,indicates that there is a high correlation between the two variables: between deep research and activating interest, the correlation coefficient $r=0.672$, $p=0.000<0.01$; between putting into practice and activating interest, $r=0.649$, $p=0.000<0.01$; between putting into practice and deep research, $r=0.683$, $p=0.000<0.01$; between precision creation and activating interest, $r=0.674$, $p=0.000<0.01$; between precision creation and deep research, $r=0.634$, $p=0.000<0.01$; between precise creation and putting into practice, $r=0.771$, $p=0.000<0.01$.

Table 7 Mean and standard deviation of variables

Variables	M	SD	N
Activating interest	3.3108	0.70061	252
Deep research	3.2123	0.77791	252
Putting into practice	3.3984	0.68495	252
Precise creation	3.4444	0.66604	252

Table 8 Correlation between variables

		Activating interest	Deep research	Putting into practice	Precise creation
Activating interest	Pearson correlation	1			
	Sig. (2-tailed)				
Deep research	Pearson correlation	0.672**	1		
	Sig. (2-tailed)	0.000			
Putting into practice	Pearson correlation	0.649**	0.683**	1	
	Sig. (2-tailed)	0.000	0.000		
Precise creation	Pearson correlation	0.674**	0.634**	0.771**	1
	Sig. (2-tailed)	0.000	0.000	0.000	

7.1.4 Regression analysis

Multiple linear regressions are used to study the causal relationship of an influencing factor in maker activities for analysis. Deep research, putting into practice, and precise creation were used as dependent variables, and their influencing factors were used as independent variables for statistical analysis, as shown in Table 9.

When deep research is used as the dependent variable and activating interest is used as the independent variable, $F=206.396$, $p=0.000<0.01$. It is considered that there is a linear regression relationship between deep research and activating interest, and $\beta=0.672>0$ ($p=0.000<0.01$). It shows that activating interest can promote the behavior of deep research, verified the hypothesis H_1, and got the regression equation: deep research $=0.672\times$ activating interest.

When putting into practice is used as the dependent variable, and activating interest and deep research are used as independent variables, $F=141.239$, $p=0.000<0.01$. It is believed that there is a linear regression relationship between

Table 9 Results of regression analysis for variables

Dependent variable	Enter Equation Variable	R^2	F	B	β	t	p
Deep research		0.452	206.396				0.000
	Activating interest				0.672	14.366	0.000
Putting into practice		0.531	141.239				0.000
	Activating interest				0.346	5.906	0.000
	Deep research			0.369	0.450	7.675	0.000
Precise creation		0.650	153.376				0.000
	Activating interest			0.251	0.265	4.880	0.000
	Deep research			0.076	0.088	1.564	0.119
	Putting into practice			0.524	0.539	9.819	0.000

putting into practice and activating interest and deep research, and activating interest $\beta = 0.346 > 0$ ($p = 0.000 < 0.01$), deep research $\beta = 0.450 > 0$ ($p = 0.000 < 0.01$), indicating that both activating interest and deep research can promote the behavior of putting into practice, verified hypothesis H_2 and hypothesis H_4, and obtained the regression equation: putting into practice = 0.346 × activating interest + 0.450 × deep research.

When precise creation is used as the dependent variable, and activating interest, deep research, and putting into practice are used as independent variables, $F = 153.376$, $p = 0.000 < 0.01$. It is believed that precise creation has a linear regression relationship with activating interest, deep research, and putting into practice, and activating interest $\beta = 0.265$ ($p = 0.000 < 0.01$), deep research $\beta = 0.088$ ($p = 0.119 > 0.05$), and putting into practice $\beta = 0.539$ ($p = 0.000 < 0.01$), indicating that both activating interest and putting into practice can promote creative behaviors of maker activities, rejected hypothesis H_5, verified hypotheses H_4 and H_6, and obtained the regression equation: precise creation = 0.265 × activating interest + 0.539 × putting into practice.

The results of multiple regression analysis showed that the relationship between deep research and precise creation is $t = 1.564$, and $p = 0.119 > 0.05$, indicating that the relationship between the two variables was not significant, so the invalid path was removed: deep research → precise creation. Therefore, a path analysis model is established based on the standard regression coefficient β (path coefficient) obtained in the regression analysis, as shown in Fig. 3.

7.1.5 Correction of the path model

The path model test uses Amos 21.0 to evaluate the model's fitting degree, and the revised fitting value is shown in Table 10. The index fitting degree used in the measurement is assessed. In essence the ratio of chi-square to the degree of freedom (CMIN/DF) is $2.465 < 3$, goodness-of-fit index (GFI) is $0.995 \geq 0.9$,

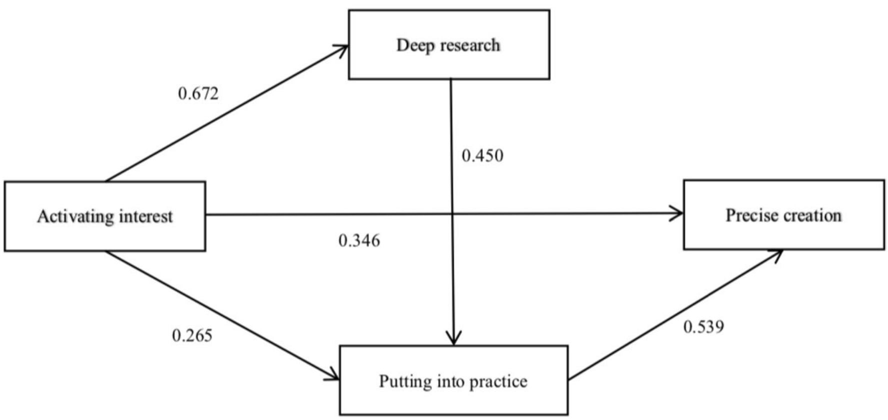

Fig. 3 Path Analysis of factors affecting university maker activities

Table 10 Modified model and data fitting results

Fitting index	CMIN/DF	GFI	RMSEA	NFI	CFI	IF	TLI
Results	2.465	0.995	0.076	0.996	0.998	0.998	0.985
Recommendations	< 3	≥ 0.9	≤ 0.1	≥ 0.9	≥ 0.9	≥ 0.9	≥ 0.9

root-mean-square error of approximation (RMSEA) is 0.076 ≤ 0.1, normed fitting index (NFI) is 0.996 ≥ 0.9, comparative fit index(CFI) is 0.998 ≥ 0.9, incremental fitting index (IFI) is 0.998 ≥ 0.9, and Tucker Lewis index (TLI) is 0.985 ≥ 0.9. Each fitting index of the research path model has reached the recommended index, indicating that the research model has a high degree of fit, and the revised path model is shown in Fig. 4.

In this study, path analysis is used to test theoretical hypotheses, and hypothesis test results of the model are shown in Table 11. The test results show that all path coefficients are significant at the level of $p < 0.05$. The path coefficient level between factors that activating interest, deep research, putting into practice, and precise creation represents the strength of the relationship.

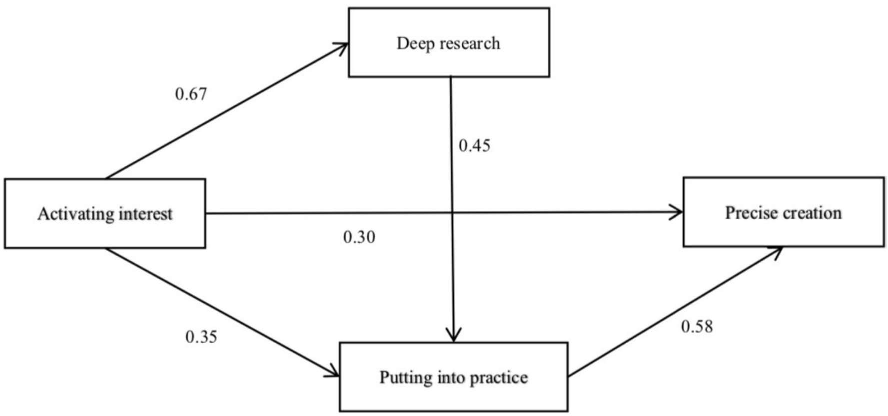

Fig. 4 Adjusted results of the path model

Table 11 Test results of the research hypothesis model

Hypothesis	Relationships	Path coefficient	P	Test result
H1	Activating interest → Deep research	0.67	0.000	supporting
H2	Activating interest → Putting into practice	0.35	0.000	supporting
H3	Activating interest → Precise creation	0.30	0.000	supporting
H4	Deep research → putting into practice	0.45	0.000	supporting
H6	Putting into practice → Precise creation	0.58	0.000	supporting

7.1.6 Results

Test results of the model show that activating interest is the most important determinant of innovation and development in maker activities. Activating interest directly affects accurate production and indirectly affects precise creation through deep research and putting into practice. This discloses that the more interested the maker team is in the innovative process, the more willing to create. At the same time, if the maker team is interested in the innovative process, the more they are willing to conduct deep research and putting into practice, the more precise creation can be achieved.

Deep research has no direct positive effect on precise creation but indirectly affects precise creation by putting into practice. The reasons are as follows: firstly, in-depth analysis of the key elements of creativity violates the growth conditions of the project; secondly, analyzing the project to find out the pain points is unable to build the connectivity; finally, the depth and breadth of the problem is insufficiently understood, and the precise creation is abandoned.

Putting into practice has a positive effect on precision creation. Research shows that when the maker team is putting into practice, errors will occur in practice, and mistakes promote the collaborative development of the team. How to control and guide this development is the key to achieve precise creation. Therefore, the more the maker team puts into practice, the more beneficial it is to achieve innovation.

7.2 Maker resources

7.2.1 Descriptive statistical analysis

The mean and standard deviation of the four variables are listed in Table 12. The mean of each variable is greater than 3 and much less than 4, which is enough to reflect that the overall maker resources of universities have a disadvantage.

7.2.2 Correlation analysis

Correlation analysis was first performed on the four variables for a preliminary analysis of the correlation between the two variables. The results are shown in Table 13. The bivariate correlation coefficient $p<0.01$ indicates that there is a significant correlation between the two variables. Between university resources and network resources, the correlation coefficient $r=0.684$, $p=0.000<0.01$; between enterprise

Table 12 Mean and standard deviation of each variable

Variables	M	SD	N
Network resources	3.4511	0.506	252
University resources	3.4511	0.506	252
Enterprise resources	3.4524	0.550	252
Government policies	3.3492	0.587	252

Table 13 Correlation between variables

		Network resources	University resources	Enterprise resources	Government policies
Network resources	Pearson correlation	1			
	Sig. (2-tailed)				
University resources	Pearson correlation	0.684 **	1		
	Sig. (2-tailed)	0.000			
Enterprise resources	Pearson correlation	0. 563**	0. 692**	1	
	Sig. (2-tailed)	0.000	0.000		
Government policies	Pearson correlation	0.593**	0. 613**	0.617 **	1
	Sig. (2-tailed)	0.000	0.000	0.000	

resources and network resources, $r=0.563$, $p=0.000<0.01$; between enterprise resources and university resources $r=0.692$, $p=0.000<0.01$; between government policies and network resources, $r=0.593$, $p=0.000<0.01$; between government policies and university resources, $r=0.613$, $p=0.000<0.01$; between government policies and enterprise resources, $r=0.617$, $p=0.000<0.01$.

7.2.3 Regression analysis

Multiple linear regression analysis explores the causal relationship between the maker resources and its influencing factors. Regression analysis was performed using university resources, enterprise resources, and government policies as the dependent variables and influencing factors as independent variables. The results are shown in Table 14.

Table 14 Results of regression analysis for four variables

Dependent variable	Entry into the equation	R^2	F	R	β	T	P
University resources		0.468	220.028				0.000
	Network resources			0.702	0.684	14.833	0.000
Enterprise resources		0.494	121.342				0.000
	Network resources			0.601	0.577	9.327	0.007
	University resources			0.180	0.168	2.719	0.000
Government policies		0.485	77.869				0.017
	Network resources			0.300	0.272	4.285	0.000
	University resources			0.218	0.203	2.793	0.006
	Enterprise resources			0.335	0.324	5.059	0.000

The impact of network resources on university resources has a significant difference ($p < 0.01$), and there is a significant linear relationship between the two. The regression equation established is university resources = 0.684 × network resources; network resources and university resources The difference in impact on enterprise resources is extremely significant ($p < 0.01$), indicating a significant linear relationship between the variables. The regression equation is established as follows: enterprise resources = 0.577 × network resources + 0.168 × university resources. Network resources, university resources, and enterprise resource have a significant impact on government polices ($0.01 < p < 0.05$), indicating that there is a linear relationship between the variables. The regression equation is established as follows: government policies = 0.272 × network resources + 0.203 × university resources + 0.324 × enterprise resources.

7.2.4 Results

Research shows: network resources in the maker environment positively impact university resources sharing, indicating that the richer the innovation resources in the network, the better the resources flow between universities; network resources and university resources positively impact enterprise resources; The flow, update, and collision of network resources and different universities' resources will affect the adjustment of enterprises resources; network resources, university resources, and enterprise resources have a positive impact on government policies, that is, because of maker resources with uncertainty, diversity, inclusiveness and constant fluidity, the control and guidance of relevant government policies can properly promote innovation and development.

8 Discussions

This paper aims to show a construct model of makerspaces in universities that implement it beyond curriculum and how the university applies it. In this case, it involves various fields, such as deep knowledge of planning techniques, insights about organizations in universities, knowledge of makerspaces, and other parties. They collaborate with them in making makerspaces. The paper categorizes from various perspectives while building a construct model of the makerspaces implemented beyond curriculum.

8.1 Selection of existing makerspaces

The results obtained from quantitative research in this paper are based on selecting existing makerspaces and are used in universities with implementation beyond curriculum. The selected makerspaces are an excellent illustration of the implementation practice, with a construct model worth checking, testing, using, and setting an example. After the pre-selection process of several makerspaces at various universities in Tianjin, China, by using different parameters, makerspaces selected were used as the material in the research in this paper. The main goal is to create a deep understanding of how makerspaces can integrate well beyond the university curriculum. It is essential to understand that many makers have found at other universities, who are likely to have construct models and views that differ from the makers of those in this paper.

8.2 Users in makerspaces

The focus of this paper is on exploring the construct model for makerspaces that exist beyond the university curriculum. In fact, users have an important role as subjects in supporting the process of using makerspaces. Along with these results, it is recommended for further research to focus on users or clients that they are not only the creators of makerspaces but there are many factors that influence the success of makerspaces themselves. In addition, motivation, ideas, time spent, and the impact of direct learning at the makerspaces are also important.

8.3 Comparison in makerspaces

Universities and makers selected in this study have various sizes, goals, funding, areas, and construct models. When choosing makerspaces, we considered the different ways and the processes universities organize them, but it does not complicate the comparability of makerspaces. Another critical point is the level of contrast between universities that affects the organization and the construct model used in making makerspaces. In addition to limiting the essential cases that emerged in this study, researchers decided to conduct research only in Tianjin, China. The problems that arise in the construction of the construct model are attempted to be elaborated by applying the interval of the discovery of this paper to the specific infrastructure of makerspaces. However, future research should focus on analyzing contrast differences and calculating social contrast between each university.

8.4 Benefits obtained from makers at the university

Based on the results obtained from the use of makerspaces, the positive benefits are examples of makerspaces in universities that have been examined. The results of statements from the makers are aimed at the interests of higher education. Henceforth, supporting research into the benefits of makerspaces is very important, and the authors of this paper highly recommend it. It is expected that this paper can also be made as one of the references. It is important to note that implementing makerspaces with classes directly and centered on specific projects can create ineffective results or fail to fulfil the expectations. Furthermore, makers of makerspaces must prioritize exploratory trade-offs between educators and students, because the impact on what students learn in makerspaces can be a cooperative source of energy for students.

9 Conclusion and implications

9.1 Conclusion

A specific makerspace may be rather different from many other contexts. This research described the development of theoretical framework and explanation of a construct model of influencing factors for makers in the universities applied beyond curriculum in Tianjin, China. Methods of questionnaire survey, descriptive statistics, correlation analysis, and multiple linear regression were used to explore the influencing factors of makerspace. The results are as follows: the innovation awareness of the maker subject is positively correlated with teamwork; the innovation awareness and teamwork are positively related to the effect feedback of the makerspace; Activating interest in maker activities is positively related to deep research, putting into practice, and precise creation; deep research has a positive correlation with putting into practice, and putting into practice has a direct correlation with precision creation. In the maker resources, Internet resources positively correlate with the sharing of university resources, and Internet resources and university resources positively correlate with enterprise resources. In this paper, a novel theoretical framework and construct model of makerspaces beyond curriculum offered enables us to analyze future practices and the resulting development of future-making.

9.2 Implications

Implementation of makerspaces in universities has increased very quickly, both in China and in other countries. Makerspaces foster dynamic innovations for the higher education ecosystem. Besides, makerspaces also offer assistance to create communities that aim to improve education and coordinate in student educational models. In makerspaces, students play a major role in innovation and creation in the real auspices of the university. Makerspaces themselves can be categorized as a machine or tool that can be used to help the development of students by giving them the workspace in the form of a gathering point with other students, where they can realize or channel their thoughts and aspirations.

Different models of makerspaces illustrate that makerspaces can be actualized in different ways, depending on various underlying factors. Ultimately, the purpose of making these makerspaces is to support curriculum learning and creation in each university. Larger makerspaces have a tremendous influence on their use because they can accommodate a larger population. Students can use makerspace as part of their classes, as substitutes for clubs of extracurricular activities, or as a place for entrepreneurial activities. In contrast, for small-scale makerspaces, the use is more focused, such as a specific interest group of makers. In either case, good makerspaces can motivate and support students through cross-curricular or interdisciplinary learning and supervision. Makerspaces will advance and actualize modern educational philosophy. They are essential in higher education because of their significant effects in shaping the maker environment.

The construct model is the basis for the success of makerspaces. It can be used to analyze and understand makerspaces that are within the scope of the university but beyond curriculum, and how to effectively implement makerspaces that may produce results as feedbacks to improve the university. Different understandings of a construct model in making makerspaces create nuances and distinctive shapes, which are of importance because they will be then actualized. Makerspace makers, namely students or the university itself, can directly see and feel its effects. Motivation and effectiveness in making makerspaces will increase drastically with the involvement of different parties and various maker resources provided.

Makerspaces also have essential values in the learning process of students. It better prepares students for competitions in the future by providing flexible instructions to advance their knowledge and skills. By various hands-on learning with all the tools for creativity at university makerspaces, students improve their learning beyond curriculum and develop their abilities in planning, organization, and implementation. Makerspaces also allow teachers and other partners to collaborate to reach results that may not be realized in classrooms centered on doing projects. Over time, those results can be used to investigate possible outcomes to achieve higher-order or other maker activities.

It is foreseeable that universities will fully realize the potential of the makerspace to redesign courses and transform the existing learning system.

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Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code availability n/a.

Declarations

Ethics approval n/a.

Consent to participate Written consent on voluntary and anonymous participation was obtained from all participants.

Conflict of interest The authors declare that they have no conflict of interest.

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