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Original Article

Factors Influencing Researcher Cooperation in Virtual Academic Communities Based on Principal Component Analysis

Jiangang Pang [1,2], Jan Capek [2]

Abstract

As a professional virtual community, the virtual academic community meets the new needs of scholars for academic cooperation in the network environment. It provides a more convenient way for scientific research cooperation. The purpose of this paper is to combine the factors influencing researcher cooperation in virtual academic communities and to verify and improve the index system of the factors influencing researcher cooperation in virtual academic communities with data support. Data for the research was obtained in an online questionnaire survey wjx.cn from forum muchong.com, which is the largest virtual academic community in China. Using principal component analysis method provides an in-depth data analysis of individual factors. The SPSS 20 was used to conduct a preliminary descriptive statistical analysis of the questionnaires. The results obtained show that community trust plays the most important role in the collaboration of researchers in virtual academic communities and that group interaction factors and individual factors also affect the cooperation of researchers in virtual academic communities. The conclusion suggests that the virtual academic communities need to establish and improve management norms and trust mechanisms, and also need to refine and improve the forum section and community incentives.

Keywords: Virtual Academic Community, Research Cooperation, Community Trust, Group Interaction Factors, Individual Factors, Principal Component Analysis.

1 Introduction

With the rapid development of information technology, the variety of virtual communities is increasing (Blanchard, 2008; Abfalter et al., 2012; McLoughlin et al., 2018; González-Anta et al., 2019). As a professional virtual community, the virtual academic community meets the new needs of scholars for academic cooperation in the network environment. It provides a more convenient way for scientific research cooperation (Wu et al., 2017; Peñarroja et al., 2019). In the virtual academic community, users are both knowledge providers and knowledge acquirers; the community's knowledge is transformed into readable explicit content on the platform. The process generates new knowledge or low-value knowledge to

[1] School of Economics and Management, Southwest University of Science and Technology, 59 Qinglong Ave Middle Section, Fucheng District, Mianyang, Sichuan, People's Republic of China
✉ pangjiangang@swust.edu.cn

[2] Institute of System Engineering and Informatics, Faculty of Economics and Administration, University of Pardubice, Studentská 95, 532 10 Pardubice, Czech Republic

upgrade and form high-value knowledge by user-shared knowledge assets (Li, 2015; Chiu et al., 2019). The behavior of researchers in the virtual academic community includes browsing, rewarding, posting and replying (Xu & Ye, 2011; Fadel & Durcikova, 2014; Hayes et al., 2017). According to the contribution threshold, only the posting and the effective reposting behavior reach a level of cooperation that can promote the efficient development of scientific research in the virtual academic community.

Cooperative behavior is driven by motivation for cooperation and directly affects the results of cooperation. Wasko and Faraj (2005), based on social capital theory, found that motivation such as personal reputation or helping others can directly affect virtual community users and encourage them to contribute their own knowledge. Hus et al. (2006) and Xu and Ye (2011), based on social cognitive theory, verified that trust, altruistic factors, identity characteristics, reciprocity and other factors have a significant impact on the knowledge sharing behavior of virtual academic community users. Chai and Kim (2010) show that incentives affect knowledge exchange and sharing behavior in blogs. Fadel and Durcikova (2014) point out that community equity is important for knowledge sharing. Crang and Mohamed (2016) show the development of various concerns and the changing media and practices involved. McLoughlin et al. (2018) suggest that virtual communities can offer an informal method of professional and inter-professional development and can decrease social and professional isolation, but the issues of privacy, trust, encouragement and technology are important for virtual communities. Chiu et al. (2017) point out that engagement and embeddedness influence the willingness to help others and the community. Embeddedness has a strong positive effect on engagement. While social support positively affects community identification and embeddedness, community identification does not have a significant effect on engagement.

Lai et al. (2018) believe that the willingness of individuals to share their knowledge in a virtual community has become an important factor in community success. The study proves that membership types play an important role as they moderate or restrain relationships based on certain knowledge sharing variables. Intrinsic and extrinsic motivations, social capital factors and knowledge sharing outcomes are crucial factors. González-Anta et al. (2019) examine a moderated mediation model and show that relationship and commitment was higher for communities of interest and virtual learning communities than for virtual communities of practice. Peñarroja et al. (2019) analysed the influence of facilitating conditions on the effectiveness of a virtual community of practice and found that the perceived usefulness and perceived ease of use moderated the effects of facilitating conditions on effectiveness through a sense of virtual community.

Summarizing literature on the cooperation of researchers in the virtual academic community revealed that most of the research proposes factors and conducts empirical research based on social capital theory, social cognition theory, rational behavior theory, planning behavior theory, etc. The various factors have been divided into individual, interpersonal, community and other aspects based on experience, but the classifications lack the support of data. Based on the literature, this paper intends to verify and improve the index system of factors influencing researcher cooperation in virtual academic communities with data support. By collecting data through a questionnaire survey and using the principal component analysis (PCA) method, the paper provides an in-depth analysis of individual factors and a reference for the research of collaboration among researchers in the virtual academic community.

2 Methods and data collection

2.1 Principal Component Analysis

In our work, we use the principal component analysis method to analyze the main influencing factors. PCA is a statistical method of dimensionality reduction. It uses orthogonal transformation to transform possible linearly related variables into a set of linearly uncorrelated new variables, also known as principal components.

The covariance matrix of the original random variables is transformed into a diagonal matrix, and then the multidimensional variable system is reduced to a low-dimensional variable system with a high degree of precision, constructing an appropriate value function, and then transforms the low-dimensional system into a one-dimensional system.

The calculation steps of principal component analysis are as follows:

Step 1: Standardization of raw index data. Collected p-dimensional random variables $x = (X_{i1},X_{i2},...,X_{ip})^T$ i=1, 2,…, n, n＞p, constructed a sample matrix, normalized the sample array elements as follows Formula (1) and Formula (2), and calculated the normalized matrix Z.

$$z_{ij} = \frac{x_{ij} - \bar{x}_j}{s_j}, i = 1,2,\cdots n; j = 1,2,\cdots p \tag{1}$$

$$x_j = \frac{\sum_{i=1}^{n} x_{ij}}{n}, s_j^2 = \frac{\sum_{i=1}^{n} (x_{ij} - \bar{x}_j)^2}{n-1} \tag{2}$$

Step 2: According to Formula (3) and Formula (4), the correlation coefficient matrix R is obtained for the normalized matrix Z.

$$R = \left[r_{ij}\right]_p xp = \frac{Z^T Z}{n-1} \tag{3}$$

$$r_{ij} = \frac{\sum_{k=1}^{i} z_{kj} z_{kj}}{n-1}, i, j = 1,2\cdots, p \tag{4}$$

Step 3: Solving characteristic equation like formula (5), Getting characteristic roots, and determining the principal component. And determining the value of m according to formula (6), Then, for each λ_j, j=1, 2,…m, solving the system of equations $Rb = \lambda_j b$ yields a unit eigenvector b.

$$\left|R-\lambda I_p\right|=0 \tag{5}$$

$$\frac{\sum_{j=1}^{m}\lambda_j}{\sum_{j=1}^{p}\lambda_j}\geq 0.66 \tag{6}$$

Step 4: Solving principal components like formula (7) U_1 is the first principal component; U_2 is the second principal component… U_n is the nth principal component.

$$U_{ij}=z_i^T b_j,\ j=1,2,\cdots,m \tag{7}$$

2.2 Research subjects

This paper selected the users of the *muchong.com* forum, which is the largest virtual academic community in China. Most of the members of the forum *muchong.com* are college students, college teachers and researchers in various research institutions. These users have long-term and high-activity behavioral characteristics, and all have certain scientific research capabilities and experience.

2.3 Questionnaire design and data collection

The scale items in this paper are mainly derived from the scales in the existing literature. The questionnaire is divided into two parts: basic information and community research cooperation. The questionnaire design had three stages: literature examination, expert review and questionnaire modification; the questionnaire items are all medium-length questions and the questionnaire is accurate and efficient. The community research cooperation part of the questionnaire used the Likert5 subscale (1 = strongly disagree, 2 = disagree, 3 = indifferent/unsure, 4 = agree, 5 = strongly agree). The specific scale is shown in Table 1.

Table1: *Table of influence factors. Source: Authors based on cited literature.*

Potential variable	**Observation variable**	**Sources**
Social cognitive theory	X1 self-efficacy	Fadel & Durcikova, 2014, p. 516; Chiu et al., 2017
	X2 results expected	Abfalter et al., 2012, p. 401; McLoughlin et al., 2018, p. 139
	X3 community trust	Fadel & Durcikova, 2014, p. 514; González-Anta et al., 2019, pp. 2-3
Social capital theory	X4 reciprocity specification	Laux et al., 2016, pp. 458-459
	X5 member trust	McLoughlin et al., 2018, p. 138; Lai et al., 2018
	X6 helping others	Wasko & Faraj, 2005, p. 37; Lai et al., 2018
Social exchange theory	X7 punishment mechanism	Abfalter et al., 2012, p. 402

Potential variable	Observation variable	Sources
	X8 incentive mechanism	Peñarroja et al., 2019, pp. 850-852
	X9 community traits	Wu et al., 2017, p. 36-37
Rational behavior theory	X10 knowledge sharing willingness	Hsu et al., 2006; Chiu et al., 2017; Lai et al., 2018
	X11 community atmosphere	Abfalter et al., 2012, p. 402
Planned behavior theory	X12 personal interest	Chiu et al.,2017
	X13 self-realization	Hsu et al., 2006; Chiu et al., 2017
	X14 egoism	Lai et al., 2018
Technology acceptance model	X15 psychological motivation	Laux et al., 2016, p. 458
	X16 informational motivation	Xu & Ye, 2011, p. 74; Laux et al., 2016, p. 461
	X17 community loyalty	González-Anta et al., 2019, p. 3
Organizational citizenship behavior theory	X18 altruism	Hsu et al., 2006; Xu & Ye, 2011, p. 73
Other (identity characteristics of Social capital theory)	X19 age	Wasko & Faraj, 2005, p. 37
	X20 user level	Mamonov et al., 2016
	X21 research experience	Chiu et al., 2017; Chiu et al., 2019
	X22 research field	Hsu et al., 2006
	X23 research organization	Mamonov et al., 2016
	X24 identity certification	Hsu et al., 2006; Peñarroja et al., 2019, p. 852

The survey was carried out using the online platform *wjx.cn*. The questionnaire was distributed and collected through the link of the online questionnaire. The issuance and collection of questionnaires are all used as forum currency. Each user can only fill out one. There are three channels: inviting virtual academic community members to fill out the questionnaire by posting; sending private messages to high-level or certified members of the community; publishing the questionnaire link in the official QQ group of the forum. The online questionnaire survey was conducted from March 2, 2018, to June 30, 2018. 531 questionnaires were distributed through the three channels, 515 questionnaires were collected, and the return rate was 96.9%. After a strict screening, 367 questionnaires were valid and the effective rate was 71.2%.

3 Solution and Results

3.1 Descriptive statistical analysis of samples

The SPSS 20 was used to conduct a preliminary descriptive statistical analysis of the valid questionnaires. The main statistical variables included age, gender, education, position and length of engagement in scientific research. See Table 2.

Table 2: *Distribution of sample characteristics. Source: Authors.*

Statistical variable	Item	Proportion (%)	Statistical variable	Item	Proportion (%)
Gender	Male	52	Length of engagement in scientific research	0–2 years	59.7
	Female	48		2–5 years	29.2
Education	Bachelor's degree	35.4		6–10 years	4.9
	Master's degree	55.3		11–15 years	4.4
	Doctorate	9		More than 15 years	1.9
	Postdoctoral	0.3			
Position	Professor/Researcher	0.8	Age	Under 20 years old	10.1
	Associate Professor / Associate Researcher	5.7		21–30 years old	71.7
	Lecturer	8.2		31–40 years old	14.4
	Teacher assistant	6.5		41–50 years old	2.2
	College student	78.7		Over 51 years old	1.6

Table 2 shows the male and female is basically balanced, the highest education is mainly concentrated in bachelor's and master's degrees, indicating that the subjects are highly educated and have certain scientific research ability. 78.7% of the respondents were college students, and the rest were instructors or teaching assistants. The length of engagement in scientific research was mostly within 5 years, and 11.2% of the members had more than 6 years. Research experience shows that the respondents had certain scientific research experience, and most of them were in the stage of learning development. The age most of them was from 20 to 30 years old, over 51 years old only account for 1.6%. This shows that most users in the virtual academic community are younger.

3.2 Reliability Analysis and Validity Analysis

Reliability analysis is often used to verify the consistency, reliability and stability of measurement tools, and is generally used for testingf homogeneity within the data. In this paper, Cranach's α coefficient is used to estimate the internal consistency of multidimensional data and to test the reliability of the questionnaire. Usually, Cranach's α coefficient is greater than 0.7, meaning the reliability of the questionnaire is good and meets the requirements. The reliability of data was analyzed by SPSS 20, and the results are shown in Table 3.

This paper uses a correlation test to determine the validity of the questionnaire. The correlation test generally uses the Kaiser-Meyer-Olin (KMO) sample measure and the Bartlett sphere test to judge the correlation degree of each variable of the sample data. The KMO measure is used to test the correlation coefficient and partial correlation coefficient between variables. The Bartlett spheroid test is used to test whether the data is from a population following a normal distribution. The results of the KMO measure and Bartlett spheroid test for 24 factors are shown in Table 3.

Table 3: *Questionnaire reliability and validity analysis results. Source: Authors.*

Number of items	Cranach's α	KMO	Bartlett
24	0.924	0.898	0.000

Cranach's α coefficient and the KMO values of the overall scale are greater than 0.7, and the Bartlett values are all zero. Therefore, the questionnaire items are good, and the data validity of the questionnaire recovery is suitable for the next factor analysis.

3.3 Principal component extraction

In this stage we extracted key factors from the factors influencing researcher cooperation in virtual academic communities using principal component analysis. Taking the first multiple influencing factors with eigenvalue greater than 1 as the main component, 5 principal components were extracted, see Table 4.

Table 4: *Total variance. Source: Authors.*

Component	Initial eigenvalues			Extract square sum loading			Rotation square sum loading		
	Total	Variance %	Accumulation %	Total	Variance %	Accumulation %	Total	Variance %	Accumulation %
1	9.036	37.652	37.652	9.036	37.652	37.652	3.814	15.892	15.892
2	2.081	8.672	46.324	2.081	8.672	46.324	3.431	14.296	30.188
3	1.897	7.903	54.226	1.897	7.903	54.226	3.283	13.679	43.866
4	1.473	6.137	60.363	1.473	6.137	60.363	2.812	11.716	55.582
5	1.358	5.659	66.022	1.358	5.659	66.022	2.506	10.44	66.022

It can be seen from Table 4 that the variance contribution rates of the extracted five principal components are F1 = 37.652%, F2 = 8.672%, F3 = 7.903%, F4 = 6.137%, F5 = 5.659%. The cumulative variance contribution rate of the five principal components reached 66.022%, indicating that the measurable variables of 24 factors can explain more than 66% by five principal components. The contribution rate of F1 is over 37%, indicating that the results are reasonable and consistent with the purpose of this paper.

In processing the principal component factor analysis, the common factor variance test was used to explain the degree of interpretation. It is usually necessary to delete factor lesser than 0.5 to ensure the efficiency of the analysis results. In this paper, the extraction factors of the common factors are all within the range of 0.527–0.835. The results are shown in Table 5, indicating that the extracted common factors are better for index extraction.

Table 5: *Common factor variance. Source: Authors.*

Variable	Initial	Extract	Variable	Initial	Extract
X1	1.000	0.662	X13	1.000	0.666
X2	1.000	0.658	X14	1.000	0.637
X3	1.000	0.587	X15	1.000	0.667
X4	1.000	0.792	X16	1.000	0.747
X5	1.000	0.605	X17	1.000	0.647

Variable	Initial	Extract	Variable	Initial	Extract
X6	1.000	0.635	X18	1.000	0.678
X7	1.000	0.658	X19	1.000	0.624
X8	1.000	0.835	X20	1.000	0.600
X9	1.000	0.527	X21	1.000	0.760
X10	1.000	0.552	X22	1.000	0.575
X11	1.000	0.605	X23	1.000	0.589
X12	1.000	0.813	X24	1.000	0.727

3.4 Component load analysis

Five rotations were performed using the maximum variance method in the data analysis. The results are shown in Table 6.

Table 6: *Factor load matrix after rotation. Source: Authors.*

Factor	Component					Factor	Component				
	1	2	3	4	5		1	2	3	4	5
X1	0.015	0.021	0.161	0.27	**0.75**	X13	0.091	0.35	0.216	**0.666**	0.213
X2	0.118	0.213	0.17	0.215	**0.724**	X14	0.338	0.272	0.126	**0.657**	0.03
X3	**0.58**	0.32	-0.05	0.367	0.105	X15	0.308	-0.1	0.1	0.093	**0.737**
X4	0.231	**0.842**	0.122	0.091	0.079	X16	0.219	-0.08	0.093	**0.817**	0.125
X5	**0.575**	0.096	0.075	0.488	0.145	X17	0.276	0.173	**0.688**	0.058	0.254
X6	0.207	0.41	0.131	**0.622**	0.141	X18	**0.753**	0.215	0.182	0.126	0.124
X7	0.314	**0.719**	0.157	0.12	0.054	X19	0.051	0.144	**0.726**	-0.04	0.267
X8	**0.797**	0.206	0.291	0.241	0.118	X20	-0.078	0.202	**0.717**	0.111	0.165
X9	0.233	0.206	0.17	-0.118	**0.622**	X21	0.287	0.18	**0.784**	0.165	0.056
X10	-0.021	**0.541**	0.311	0.281	0.289	X22	0.227	**0.561**	0.391	0.236	-0.006
X11	**0.708**	0.166	0.077	0.093	0.249	X23	0.285	0.025	**0.677**	0.219	-0.007
X12	0.219	**0.856**	0.127	0.104	0.069	X24	**0.752**	0.205	0.274	0.158	0.14

The rotation component matrix clearly shows the closeness of the 24 factors and the five principal components. Analyzing the distribution of the variables in the rotated factor load matrix, the following results can be drawn:

Firstly, X3, X5, X8, X11, X18, X24 have a higher load on the first principal component, indicating that the community's overall trust environment affects the willingness and behavior of the researchers in the virtual academic community. This research defines this component as the community trust component F1.

Secondly, X4, X7, X10, X12, X22 reflect the high load characteristics on the second principal component, indicating that continuous interaction of the members with different research areas, hobbies and reciprocal interactions influences the cooperation. The research defines the component as the group interaction factor F2.

Thirdly, X17, X19, X20, X21, X23 show high load on the third component, indicating that the basic characteristics of members in the virtual academic community have an impact on their scientific research cooperation. It can be seen that users' basic characteristics can generate a certain user cluster. The research defines the component as the individual basic feature component F3.

Fourthly, X6, X13, X14, X16 have high load on the fourth principal component, indicating that users' self-realization psychology, psychology of information needs and psychological factors have an effective impact on their scientific research cooperation. The research defines the component as individual psychological perception component F4.

Fifthly, X1, X2, X9, X15 have high load performance on the fifth principal component, indicating that users' estimation of self-capacity, expectations of the community's reputation gained by himself or herself, expectations of the results of collaboration and expectations of the quality of the community system have an impact on their cooperative behavior. The study defines this component as the individual expectations component F5.

The principal component meanings and specific variables are shown in Table 7.

Table 7: *Principal component meaning. Source: Authors.*

Principal component	High load variable	Principal component meaning
F1	X3 community trust X5 member trust X8 incentive mechanism X11 community atmosphere X18 altruism X24 identity certification	Community trust component
F2	X4 reciprocity specification X7 punishment mechanism X10 knowledge sharing willingness X12 personal interest X22 research field	Group interaction component
F3	X17 community loyalty X19 age X20 user level X21 research experience X23 research organization	Basic characteristics of individuals
F4	X6 helping others X13 self-realization X14 egoism X16 informational motivation	Individual psychological perception component
F5	X1 self-efficacy X2 results expected X9 community traits X15 psychological motivation	Individual expectations component

4 Discussion

Community trust plays the most important role in the collaboration of researchers in virtual academic community. User identity authentication, trust relationship and community trust mechanism are the core of community trust. Altruistic concept and incentive mechanism can establish trust and promote the overall trust atmosphere of the community. When members cooperate, they are more willing to exchange and share information, the community's good trust environment providing protection for the research cooperation activities of community members.

The cooperation of researchers in virtual academic communities is also affected by the group to which users belong. The differences in research fields and hobbies directly affect users, who then form different interaction groups. The reciprocity and knowledge sharing ensure the continuity of cooperation, while the punishment mechanism regulates cooperation behavior. As user interaction continues, different user groups are formed. The data shows that 63.2% of users believe that personal interests and research areas have a biased influence on their cooperative behavior.

The cooperative behavior of researchers in the virtual academic community is also affected by three types of individual factors. Basic characteristics such as user age, account level, and scientific research experience form a certain social distance, which affects users' cooperative behavior in the virtual academic community. The psychological needs of users, such as self-realization, the perception of their own reputation, the perceived benefits of helping others, and the perception of the benefits of information acquisition can drive community members to cooperate. Users' expectations of their own capabilities, expectations of cooperation results, and expectations of community quality characteristics can influence their cooperative behavior. If the behavior can bring rich material, psychological and emotional feedback to the individual, they have a greater willingness to implement such action.

After the extraction of the factors affecting the cooperation of researchers in *muchong.com* forum, the community trust component accounted for 37.6%, the individual factor accounted for 19.6%, and the group interaction component was only 8.7%. Among the individual factors, the basic characteristics, psychological perception, and expectation accounted for 7.9%, 6.1%, and 5.6%, respectively, the impacts were equivalent to the group interaction components. It can be seen that community trust is the most important, and the degree of influence at individual level is second. At the same time, the proportion of the three types of individual factors is equal to the group interaction component. The basic characteristics, psychological perceptions, and expectations of individuals have an important impact on the research cooperation behavior of virtual academic communities. The cooperation of the virtual academic community is mainly influenced by the overall trust environment. If the community has a good overall trust environment, members actively seek cooperation to meet the needs. The cooperative group and the division of the community sector provide convenience for group interaction. By subdividing the individual influence factors, it was found that multi-dimensional individual factors have an impact on the cooperative behavior of researchers. Therefore, in order to ensure the development of the virtual academic community, community cooperation must be analyzed from the community, user groups, and individual cooperation. At the same time, the basic unit of the community and the basic unit of cooperation – the individual members of the community – should be discussed in detail.

5 Conclusion

By summarizing the literature on the cooperation of researchers in the virtual academic community, this paper identified factors influencing the cooperation of researchers in the virtual academic community. It selected the uses from the *muchong.com* forum as survey subjects and used the principal component analysis method to analyze the data from the collected questionnaires. The study found that community trust is the most important factor affecting cooperation in scientific research. The basic characteristics of individuals, individual psychological perception, individual expectations and the importance of group interaction are equivalent. The individual factors should be refined into three dimensions: individual basic characteristics, individual psychological perception, and individual expectations. The reason for the low efficiency of scientific research cooperation in the academic community is the lack of personalized service analysis based on the individual characteristics of community members. At present, most virtual academic communities promote the cooperation of members through the establishment of incentive mechanisms. Another virtual community enhanced the active enthusiasm of members through the cultivation of membership and loyalty but ignoring the individual traits of members.

It is important to establish and improve the management norms and trust mechanisms of the virtual academic community. The trust of members in the community becomes a necessary prerequisite for scientific research cooperation. The establishment of community management norms and trust mechanisms is a necessary guarantee for members' trust. Imperfect trust mechanisms and management practices reduce the willingness of members to cooperate and the efficiency of cooperation. By improving community management norms and trust mechanisms, community managers can improve the overall trust atmosphere and trust level of the community and promote the cooperative behavior and cooperation efficiency of members.

The construction and refinement of the virtual academic community are very important. Community managers need to refine and improve the forum section according to different aspects such as user login purpose and research field, provide gathering places for scientific research groups with different purposes, and to form a unique community culture atmosphere making cooperation in the virtual academic community more efficient.

The virtual academic community should improve and perfect the community incentives. Although the forum management system is relatively complete, the scale benefits are still lacking. Community managers should improve the incentive mechanism according to the reputation incentives and economic incentives, give the cooperation contributors a certain incentive to promote users' second cooperation, and attract more users to join the community for scientific research cooperation.

This research, however, is subject to several limitations. There are two major limitations that could be addressed in future research. First, our study focused only on the users of *muchong.com* forum. Although *muchong.com* is the largest virtual academic community in China, the scope of research is still limited, more international virtual academic communities need to be included. Second, the data collection was not comprehensive. In the 367 questionnaires we analysed, the majority of respondents were students, which might be problematic for the topic itself as well as for the right and uniform interpretation of questions. The analysis would be more interesting if it was done on a larger sample of data and if the data was obtained from multiple sources.

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ORCID

Jiangang Pang https://orcid.org/0000-0002-4482-6096

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