ISSN 1648-3898

PERCEPTIONS OF COLLABORATION, EQUITY AND VALUES IN SCIENCE AMONG FEMALE AND MALE COLLEGE STUDENTS

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Abstract. *Diversification of the science, technology, engineering and math (STEM) workforce requires a climate supportive of underrepresented groups. We studied undergraduate student attitudes to uncover perceptions that may be addressed through targeted pedagogies. We surveyed undergraduate students pursuing science and humanities programs to quantify their attitudes toward gender equity, the importance of values, the perceived contribution of competition and collaboration to science, and to examine their understanding of multidisciplinary collaborations in science. Women more strongly supported gender equity, were more likely to recognize women's contributions, and had a more positive view of female scientists' lives. Women perceived science as more collaborative, identified a broader range of disciplines, including social sciences and humanities, to include, and viewed collaboration as working directly with others rather than using published work. We relate our results to the need for gender-sensitive pedagogies and other changes in the college science curriculum.*

Key words: *science education, gender, undergraduate, values, multidisciplinary.*

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Introduction

The diversification of science, technology, engineering and mathematics (STEM) fields requires new skills, including an ability to work with diverse groups of people. Historically, in countries such as the U.S., STEM fields been dominated largely by white males. More recently, some fields (particularly the biomedical and social sciences) have seen increasing numbers of women. In the U.S., decreasing numbers of students are interested in STEM fields, and encouraging participation by women and minorities is a recruitment strategy. Accordingly, the last two decades have seen an increase in the number of educational programs to encourage participation by women and other underrepresented groups. For example, engineering education programs train people to work in diverse teams and to develop technologies for diverse users (Ihsen & Gebauer, 2009). Further, STEM research has become multidisciplinary and global in nature. For example, funding agencies, such as the U.S. National Science Foundation, require explanations of the "broader impacts" of research results (Mervis, 1997), more research articles are multi-authored (Speigel, Rosing & Price 1997), and increasingly, there are collaborations between natural and social scientists (Hurd, 1998).

However, researchers still struggle to identify effective strategies to promote diversity throughout the STEM workforce. For example, although there has been an increase in the number of women with doctorates in some STEM fields, a proportional increase in female faculty members has not occurred (Barber, 1995; Frehill, Javurek-Humig, & Jeser-Cannavale, 2006; Kulis, Sicotte, & Collins, 2002; National Academy of Sciences (NAS), 2007; Nelson & Rogers, 2005; Pell, 1996) and women are still not equally distributed across the STEM workforce (Rosser & Taylor, 2008). Women leave STEM disciplines because they experience limited support, pay inequity, an unsupportive work climate, persistent gender bias,

ISSN 1648–3898

and other negative structural/organizational experiences (NAS, 2007; Bently & Adamson 2003; Sonnert & Holton, 1996). Even women with high performance in math tend to choose less math intensive professions and, in some math intensive fields, having children impedes women's advancement (Ceci, Williams & Barnett, 2009).

In many countries, students' attitudes toward science appear to be becoming more negative, with girls' perceptions more negative than boys' (Gedrovics, Wäreborn, and Jeronen, 2006). This negative perception may be related gender differences in attitudes toward competition and collaboration. For example, grade school girls liked hands on activities and small group work (Little & León de la Barre, 2009) and learned in a more collaborative and less competitive manner than boys (reviewed in Brotman & Moore, 2008). Female students preferred science classes that stressed cooperation rather than competition (Kahle, 1996), and female engineering students responded more positively toward collaborative projects or problem based learning (PBL) systems than did male students (Du & Kolmos, 2009). Seymour and Hewitt (1997) found that loss of self-esteem resulting from a competitive atmosphere was a factor that encouraged both sexes to leave the sciences. They found that harsh grading systems in science classes precluded or discouraged collaborative learning strategies and women, despite their higher performance, tended to leave the sciences at higher rates than men. However, greater willingness to ask for help plus the tendency to work collaboratively helped female students buffer the competitive atmosphere.

Coursework that emphasizes equitable, collaborative, and multidisciplinary aspects could promote more positive attitudes and enhance learning for both female and male students. Non-competitive computer math games produced better learning outcomes for both sexes, in part because boys were not distracted by a focus on "winning and losing" (Wei & Hendrix, 2009). Overall, both male and female students engage more positively with science when the content is linked to issues relevant to the student; however, these interest areas can be gendered. Girls are more interested in health-related issues whereas boys show greater interest in economic and environmental issues (Teppo and Rannikmäe, 2003). In parts of Latvia, girls were more interested in topics related to the human body, specifically health and beauty and the soul, whereas boys were more strongly drawn to areas connected to technology (Gedrovics, 2006).

We investigated whether undergraduate students perceive science as a gender equitable, collaborative and multidisciplinary field. We were particularly interested in differences between male and female students' attitudes, as well as the effects of college science course experience. We concentrated on four areas: a) equity for women, b) the view of science as competitive, collaborative or both, c) whether scientific research is uninfluenced by personal or cultural values, and d) the degree to which science is multidisciplinary. Though views of what constitutes 'science' are culturally dependent, in the current study we focus on students in a U.S. Midwestern regional college with a homogeneous population. Our study population resides in a culture which associates science with stereotypically masculine traits, including competitiveness; narrow specialization; separation among the natural and physical sciences, the social sciences and the humanities; and a definition of objectivity which excludes personal and cultural factors. We hypothesized that since women are more likely to be "outsiders" to STEM fields in the U.S., their attitudes would be more likely to differ from these cultural norms. Further, we also expected students with less experience in natural and physical science fields (e.g. fewer courses) to share attitudes that differ from the scientific "mainstream". Thus, we predicted that women and students with fewer courses would be more likely to recognize the potential contributions of the social sciences and humanities to science collaborations. We expected these students to stress collaboration and the potential impacts of personal and cultural factors. We also expected that women would be more sensitive to gendered inequity since women are more likely to experience sexism.

Methodology of Research

We surveyed 311 students over two years at a 7000-student, regional, primarily undergraduate 4-year university in the Midwestern United States. The university population is primarily Caucasian with an approximately 60:40 female to male ratio. We believe that the results of our study can be generalized to undergraduate students at public universities with a similar population (e.g. rural, mostly Caucasian) fulfilling early science major (e.g. first or second year introductory courses) or general education requirements.

Near the end of spring semester 2008, we surveyed 91 students in an upper-level biology course (second year and above), and two women's studies courses (one upper level and one introductory). At this university, as in most U.S. institutions of its size, Women's Studies is an academic discipline with courses and degree programs with a focus primarily on the social sciences, arts and humanities. We selected Women's Studies courses because they are taken as general education credits by a wide range of students from disciplines across the university. In addition, we were also interested in whether students recognized the relevance of Women's Studies, and other diversity-oriented scholarship, to research in the natural and physical sciences. In this first year of survey data, sex and the number science courses completed could not be used as identifying variables for student responses to questions regarding multidisciplinary collaborations.

In the first week of the fall semester 2009, we surveyed 220 students in an introductory level biology course (required for natural and physical science majors) and three introductory women's studies courses. For the second year of the survey, we modified our methods and included a numeric code that enabled us to match short-answer and electronically graded responses by individual. This permitted analysis of short answer responses in combination with categorical data.

The survey included five questions for categorical data (sex, year in college, number natural and physical science courses and women's studies courses, and major). Four questions assessing attitudes toward women in science were taken from the equity subsection of the revised Women in Science Scale (WiSS; Owen et al., 2007). We designed Likert-scale questions on values and multidisciplinarity based on concepts presented in a publication on values and ethics in research (NAS et al., 1995). As an additional measure of student attitudes toward multidisciplinarity and competition/collaboration, all students were asked to answer the following two short-answer questions:

1. You are an expert human physiologist who is in charge of designing a multidisciplinary scientific study. You will invite a number of other experts to participate in this study. To make the study "multidisciplinary", from what other disciplines will you draw your additional experts?
2. Is science more "competitive" or "collaborative"? Give an example to support your answer.

Disciplines listed in response to the first question were counted and coded by discipline (Table 1). Responses to the second question were coded as competitive, collaborative or both. We coded examples as either direct or indirect collaborations. A direct collaboration mentioned scientists "working together", "putting their heads together", or "bringing (ideas) to the table". Examples of indirect collaboration did not describe scientists as working directly together. These responses typically included descriptions of scientists incorporating already published findings into research.

Table 1. Disciplines scored for presence or absence in the response to short answer question.

Discipline	Included within the discipline
Arts	Photography, music, art
Culture	Gender, class, religion
Humanities	History, philosophy, religious studies, English, literature, writing, communication
Business	Economics, law
Math	Statistics
Science	All health sciences, medicine, exercise science, microbiology, biology, chemistry, physics, geosciences, etc.
Social sciences	Psychology, sociology, anthropology, education
Women's Studies	All courses with a Women's Studies designation
Total	Total number of disciplines listed out of these eight

ISSN 1648–3898

We used general linear models (GLM) with sex as the main effect to examine differences between females and males in mean scores for Likert-scale questions and the total number of disciplines. All participants were assigned a group designation based on their sex and number of natural and/or physical science courses completed (no science classes, one to two science classes and three or more science classes completed (abbreviated: F0, M0, F1, M1, F3, M3)). We used GLM with group as the main effect and specific contrast statements to examine differences among groups in mean scores for Likert-scale questions and number of disciplines. The following contrast statements were used: 1) females vs. males in each designation of science courses completed, excluding F0 and M0 because of an extremely small sample size for M0, (e.g., F1 vs M1, F3 vs M3, etc.), 2) participants with no science courses vs. those with one or more science classes completed (F0, M0 vs F1, M1, F3, M3), and 3) females that had not completed science courses vs. females with one or more science courses completed (F0 vs F1 and F3). To reduce experiment-wise error, only probability values based on these pre-planned contrasts were considered.

Responses from short-answer questions were scored as binary data indicating the presence or absence of an *a priori* determined response. For the question asking participants to list disciplines, we created a variable, "science only", which was scored 1 if a participant listed only science disciplines and 0 if the participant listed anything besides or in addition to a science discipline. The second question regarding views of science was scored as competitive, collaborative, or both. Examples were scored as either direct or indirect. Because an example could be only one or the other, and thus responses were non-independent, we analyzed scores for only the variable "direct". We used logistic regression to examine relationships between binary variables and sex and modeled the probability of the response variable equal to one.

Results of Research

Both male and female students supported equity for women in science. However, men's support was milder, and male students' responses were also more variable than women's. These differences were most pronounced between men and women who had taken more science classes. For example, nearly 100% of women strongly agreed that "women can make important scientific discoveries" ($n = 112$, mean score = 1.03, on a scale of 1-5 with five "strongly disagree"). Among students who had completed three or more science classes, there was a tendency for female students to agree more strongly that "women make important scientific discoveries" ($F_1 = 3.64$, $p = 0.06$). Similarly, women more strongly disagreed with the statement that "women should not have the same chances of advancement in science" ($F_1 = 4.17$, $p = 0.04$), and the difference was most pronounced among students who had taken three or more science classes ($F_1 = 4.88$, $p = 0.03$). Female students also more strongly disagreed that "a woman in science is likely to have an unhappy life" ($F_1 = 6.94$, $p = 0.01$). The same pattern was true for students who had completed one to two science classes; students with three or more science classes showed a non-significant trend in this direction ($F_1 = 4.86$, $p = 0.03$; $F_1 = 3.60$, $p = 0.06$, respectively).

Students recognized potential contributions of other disciplines to science. Both male and female students mildly agreed that scientists should be trained in the humanities (Table 2). Among students who had taken more science classes, males were more likely to disagree with the statement that "science rarely includes concepts from other disciplines"; the average female response was neutral (Table 2; $F_1 = 6.92$, $p = 0.01$). Among female students, the number of science classes taken affected their perceptions of specialization in science. Specifically, compared to females who had not taken science classes, females who had completed one or more science classes (F1 and F3) more strongly disagreed that "science requires narrow specialization and a single-minded focus" (Table 2; $F_1 = 5.32$, $p = 0.02$).

Women were more likely to include humanistic and social science disciplines when asked for a list of potential collaborators in a multidisciplinary scientific study; psychology and sociology were the most common disciplines included. More men listed only natural and physical science disciplines (Table 3), and the odds of a female listing only science disciplines was 38% that of males (Table 4). Thus, although males disagreed that science rarely includes concepts from other disciplines, they did not self identify disciplines outside of the physical and natural sciences when asked for potential collaborators in response to a short-answer question. None of the ten women who had no college science experience listed only science disciplines as potential collaborators.

There was no difference between the sexes or among the groups in total number of different disciplines mentioned in the short-answer question response ($F = 0.35$, $p = 0.55$; $F = 1.76$, $p = 0.12$, respectively). In our 2009 results, 131 students provided lists of disciplines; 73% of those listed only one or two disciplines. Out of the eight disciplines scored, the mean number listed was only 1.27 and the mode was 2.0.

Student responses to the question of whether science is collaborative or competitive also differed based on gender and college science course experience. Overall, women saw science as more collaborative, whereas male students were more likely to describe it as competitive (Tables 3 and 4). The odds of a female describing science as collaborative were 2.97 times that of male students (Table 4). Women who had not completed any college science courses were most likely to describe science as collaborative (Table 3). Students with 1-2 science courses tended to describe science as either competitive or collaborative but not both (Table 3). There was a trend for females and males (excluding the four males who had no previous science courses) to describe science as both collaborative and competitive as they completed more science courses (Table 3).

In addition to identifying science as collaborative, more women used direct examples of collaboration (Table 3), and women were 2.1 times more likely than men to use direct examples (Table 4). These examples typically included the words "working together" or "at the same table". For both females and males, there was a trend of increasing numbers of students using direct collaboration examples as they completed more science courses (Table 4; excluding the four males who had no previous science courses). These numbers should be interpreted with caution because only 32% of females and 18% of males provided examples in their response to the question.

Students mildly agreed that while social and personal beliefs can affect science, values could be separated from science. There were no significant differences between the sexes or between students with and without experience in science classes on the questions pertaining to values in science (Table 2).

Table 2. Means and results from statistical tests for survey questions, total scores and binary data by group and sex.

Category	Question text or explanation of variable	Test results	Means by group and sex							
			F0 (17)	F1 (97)	F3 (112)	M0 (4)	M1 (30)	M3 (50)	Female (226)	Male (84)
Equity	***Women should not have the same chances for advancement in science careers as men do.**	F > M; F3 > M3 (disagreement)	4.59	4.80	**4.81**	5.00	4.63	**4.46**	4.79	4.56
	*Women can make important scientific discoveries.	M3 > F3 (disagreement)	1.06	1.08	**1.03**	1.00	1.13	**1.12**	1.05	1.12
	Women have the same opportunities in science as men do.	ns	2.35	2.19	2.17	2.25	1.83	1.98	2.19	1.94
	***A woman in science is likely to have an unhappy life.**	F > M; F1 > M1; F3 > M3 (disagreement)	4.71	**4.70**	**4.72**	5.00	**4.33**	**4.47**	**4.71**	**4.45**

ISSN 1648–3898

Category	Question text or explanation of variable	Test results	Means by group and sex							
			F0 (17)	F1 (97)	F3 (112)	M0 (4)	M1 (30)	M3 (50)	Female (226)	Male (84)
Values and multi-disciplinarity	It is important that scientists have training in fields such as history, literature and/or philosophy.	ns	1.94	2.07	2.02	2.25	1.76	2.16	2.04	2.02
	Values can be separated from science.	ns	2.53	2.52	2.52	1.75	2.60	2.41	2.52	2.45
	Social and personal beliefs can shape scientific judgment	ns	2.29	2.20	2.29	1.75	1.90	2.08	2.25	2.00
	***Science requires narrow specialization and a single-minded focus.**	F1, F3 > F0 (disagreement)	**3.47**	**4.01**	**4.18**	4.50	4.00	4.37	4.06	4.24
	***Scientific studies rarely include concepts from disciplines outside of science.**	M3 > F3 (disagreement)	4.07	3.79	**3.68**	3.00	3.50	**4.10**	3.75	3.83

Bold printed numbers and results other than ns indicate statistical significance at the P ≤ 0.05. Responses were coded as: 1 = strongly agree, 2 = mildly agree, 3 = neutral, 4 = mildly disagree, and 5 = strongly disagree. Ns indicates an effect that was not statistically significant. F0 and M0 are females and males respectively that had not completed any college science classes, F1 and M1 had completed 1-2 college science classes and F3 and M3 completed three or more college science classes. Numbers in parentheses are sample sizes.

Table 3. Comparison of proportions of students responding to short-answer questions requiring a list of disciplines in a multidisciplinary study and a description of science as competitive or collaborative.

Included in response	Test results	F0	F1	F3	M0	M1	M3	Female	Male
		(10)	(76)	(70)	(4)	(29)	(30)	(156)	(63)
***Science disciplines only**	M > F	0.00	0.06	0.04	0.25	0.10	0.10	**0.04**	**0.11**
***Competition**	M > F	0.10	0.24	0.21	0.50	0.41	0.30	**0.22**	**0.37**
***Collaborative**	F > M	0.70	0.45	0.39	0.00	0.17	0.27	**0.44**	**0.21**
Both competitive and collaborative	ns	0.10	0.17	0.31	0.50	0.21	0.33	0.23	0.29
***Direct collaboration**	F > M	0.20	0.29	0.34	0.25	0.10	0.23	**0.30**	**0.17**
Total number of disciplines listed	ns	1.00	1.08	1.49	2.00	0.83	1.33	1.26	1.14

Bold print indicates statistical significance at the P ≤ 0.05. F0 and M0 are females and males respectively that had not completed any college science classes, F1 and M1 completed 1-2 college science classes and F3 and M3 completed three or more college science classes. Numbers in parentheses are sample sizes.

Table 4. Logistic regression results for binary response variables and sex.

Response variable	Estimate	Error	Chi-Square	p value	Point Estimate	95% Wald Confidence Limits	
Science only	-0.95	0.48	3.96	**0.05**	0.39	0.15	0.99
Competition	-0.72	0.33	4.94	**0.03**	0.49	0.26	0.92
Collaboration	1.09	0.35	9.65	**<0.01**	2.97	1.50	5.91
Both	-0.29	0.34	0.73	0.39	0.75	0.39	1.45
Direct collaboration	0.74	0.37	3.93	**0.05**	2.10	1.01	4.38

d.f. = 1, effect is sex, coded as female = 1 and male = 0; modeled for the response variable =1. Response variables with P-values in bold print are statistically significantly explained by the model.

Discussion

Equity

Although both female and male students opposed inequity, women's responses indicated stronger opposition to gender inequity in science. For example, women indicated stronger support than men for advancement opportunities for women scientists, women more strongly agreed that women could make important scientific discoveries, and women more strongly disagreed that a woman in science is likely to be unhappy. We argue that these differences, though slight, reveal important differences between male and female college students that can impact the perception and attainment of gender equity in the sciences. These differences indicate a slight hesitation on the part of male students to support equity for women in the sciences. Valian (1999 & 2005) argues that women have not achieved full equity in academic fields in the U.S. because of persistent gender schemas where women are expected to behave in certain ways that disadvantage them in academic careers. This leads Valian to conclude that discrimination persists because of the accumulation of small disadvantages, rather than the existence of blatant sexism. For example, senior male engineering professionals underrate the importance of stereotypically feminine traits, such as valuing diversity, communication skills and balancing work and life pressures (Male, Bush & Murray, 2009).

One reason that women may not persist in the sciences could be the negative impacts of a lack of full support for equity by their male peers–even slight differences or lukewarm, rather than enthusiastic support, can impede women's progress. It is especially significant that the differences between male and female students' attitudes toward women in science became more pronounced as students completed more science courses in their undergraduate program. This is crucial for women because STEM careers or academic programs may become less appealing over time because their male peers become less supportive overall. Small instances of discrimination and gender bias, such as the one we detected amongst college students, accumulate to disadvantage women and impede their progress in scientific careers (NAS, 2007).

Competitive vs. Collaborative View of Science

As we predicted, female student's perspectives on the nature of scientific research differed from cultural norms that emphasize the competitive aspects of science. Women saw science as a more collaborative process. Women were also more likely to see collaboration itself as a direct process involving people "working together" or "at the same table", whereas men tended to define collaboration in terms of scientists using the work of others. However, overall, it appears that as students take more science courses they begin to see science as having both collaborative and competitive elements and to understand collaboration as a direct process.

Our findings are significant because one reason women might leave the sciences, or be less attracted to scientific disciplines to begin with, is the perception that science is a solely competitive field.

ISSN 1648–3898

In our results, women with no science courses were most likely to see science as collaborative rather than competitive. Thus it could be that as women progress in science they begin to see it as more competitive and it becomes less attractive to those women who value collaborative relationships. This trend could be exacerbated by gender bias on the part of male colleagues. Attitudes of male peers are critical to positive experiences in collaborative groups for women; although Du and Kolmos (2009) identify group work as a positive means to recruit women to engineering, working in teams with male students can be negative if the women feel that their male peers doubt their technical competence. Additionally, because scientific research is becoming a more collaborative, multidisciplinary endeavor, pedagogies that emphasize these collaborative aspects for male students are important to train them to be effective scientists. Any changes in science pedagogy to specifically reinforce the collaborative nature of science will therefore benefit all students.

Multidisciplinary Contributions

We found some evidence to support our prediction that women would be more likely to recognize science as multidisciplinary, in that they were more likely than men to include social science and humanities disciplines in a hypothetical collaborative project. Males perceived multidisciplinary collaborations to consist of health, natural and physical science disciplines. Overall, it appears that males are more narrowly focused on science disciplines and less likely to be widely inclusive when considering multidisciplinary collaborations in science. However, there appears to be an effect of the number of science courses taken on male and female responses to this question. Among students with three or more science classes men were more likely than women to agree that scientific studies include concepts from non-science disciplines. This question is somewhat limited in that we are not sure how the students are defining a non-science discipline. However, this could reflect a difference in views of science among women with more and fewer science classes. Females who had taken college science courses disagreed more strongly than females with no college science experience that science requires narrow-minded focus and specialization. Thus, women with fewer science classes saw science as being more specialized.

Tobias (1990) found that students chose not to enroll in a science major because they wanted a more "well-rounded liberal education". If our results are interpreted as indicating a difference between women in and outside of science, women less interested in science may view science as field that is too specialized to allow for true multi-disciplinary collaboration. Thus, women more likely to identify social science and humanities disciplines as potential collaborators to scientific research might be self-selecting out of science early on because they believe that science is too specialized to welcome this approach. Our results underline the significance of using multidisciplinary case studies and examples as a strategy for encouraging female persistence in the STEM fields, as well as promoting an appreciation for multidisciplinary contributions among male students. These pedagogies are already in practice but they may be more effective if the importance of multidisciplinarity in the sciences is explicitly taught as part of their content focus.

Values in Scientific Research

Overall, students tended to mildly agree that while social and personal beliefs can affect science, values could be separated from science. We hypothesized that students with less experience in science classes would disagree more with the statement about values being separable from science. We assumed that they would have a broader view of knowledge construction than science students who we expected to be more invested in strict definitions of objectivity. However, this was not the case, as we did not see any effect of number of science classes on the responses to the values questions. Ultimately, the goal would be to have students recognize that it is difficult to separate values from science and whether values should, or can be separated may be case-specific (NAS, 1995). However, students do not appear to recognize these nuances. Helping students develop this awareness is important because a value neutral view of science has been identified as a barrier to interdisciplinary collaboration (Lélé

& Norgaard, 2005).

Conclusions

Given our results we have the following recommendations for teaching science to undergraduate students. Overall, we recommend stressing the collaborative nature of science, or at least, portraying science in the context of a discipline that values both the collaborative and competitive. All students would benefit from a wider perspective on the nature of science that includes the responsibility of the scientist to examine potential bias in the process. Furthermore, specific acknowledgement of the potential contributions of the social sciences and the humanities toward addressing the issue of values in science would help students recognize the utility of these disciplines as well as enhancing their ability to think about values and ethics. Finally, introducing both male and female students to issues of gender equity would enhance the positive climate in science. Our results are significant because they indicate the persistence of gender differences in how male and female students perceive of science, and specifically think about equity for women in science. In concert with the existing research in this area, these results indicate that these slight differences could provide one explanation for the lack of persistence of women in many STEM fields.

Acknowledgements

We thank the instructors and all of the students who voluntarily participated in the surveys. We thank L. Blunsom, A. Morrow, and M. Malott for insights and preliminary work on the project, and J. Carver, M. Latimer and anonymous reviewers for helpful critique.

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Received 01 January 2010; accepted 26 April 2010

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