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Flipping the Use of Science, Technology, and Society Issues as Triggering Students' Motivation and Chemical Literacy

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ABSTRACT

The aim of this paper was to investigate the effect of the use of science, technology, and society (STS) issues through flipped and traditional learning environments on students' motivation to learn chemistry as well as their chemical literacy (CL). Two freshman engineering classes totaling 89 students taught by the same instructor enrolled in a general chemistry course at a university were the sample of the study. The study had one intervention and one comparison group (CG); the groups were randomly assigned. The intervention group engaged in the STS issues through flipped learning environment while the CG engaged in the STS issues in a traditional setting. A motivation questionnaire was administered to the groups at the beginning and at the end of the treatment; in addition, CL items were administered at the end of semester. The treatment took one semester. Multivariate analysis of variance (MANOVA) was used to compare groups on pre-test scores; then, multivariate analysis of covariance was used to reveal the effect of treatments on motivation, its factors, and CL. The results indicated that utilizing STS issues through the flipped learning environment was superior to traditional STS instruction on increasing students' overall motivation score, intrinsic motivation, and relevance of chemistry. No significant difference was observed in CL scores. Further studies are suggested to investigate the impact of flipped STS interventions on higher-order thinking skills including socio-scientific reasoning.

KEY WORDS: science, technology, and society; flipped learning; motivation; chemical literacy; general chemistry

INTRODUCTION

There is a consensus on the need for deeper, more conceptually, rooted knowledge that students can relate to and apply to real-world problems in science-related fields, such as chemistry (Bulte et al., 2006; Cigdemoglu and Geban, 2015; Gilbert, 2006; Jenkins and Howard, 2019). However, traditional learning pedagogies do not seem to foster schematic applicable knowledge for the majority of students (Greeno et al., 1996). Yet, certain pedagogies are reported to overcome the challenges of using class time effectively (Estes et al., 2014; Strayer, 2012) and utilizing active learning strategies during the classroom (Gannod et al., 2008; Strayer, 2012; Kim et al., 2014). Therefore, pedagogies incorporating efficient use of class time and allowing acquisition of transferable science knowledge are required to overcome these commonly stated problems.

Conventional science instruction usually provides a type of knowledge that is called "inert knowledge" (Whitehead, 1929, as cited in Giamellaro, 2014) as it is decontextualized from the real world around us and fails to support scientific literacy. An instruction that engages students in content to help them to grasp contextualized interconnections among STEM fields and facilitate them being able to apply their knowledge outside of class may help students to go beyond that "inert knowledge." The use of science, technology, and society (STS) issues in instruction has potential to contextualize content so that

students are able to transfer their knowledge to other fields and develop science competencies that contribute to scientific literacy (Vaino et al., 2012; Bennett et al., 2007) and the nature of science (Celik and Bayrakçeken, 2006; Vázquez-Alonso et al., 2013). Both scientific literacy and nature of science are widely perceived to be the main goal of science education (OECD, 2009). The attainment of scientific literacy can be facilitated if the content and instruction of science courses are professionalized through supporting students' positive attitude and stimulation of motivation in science learning (OECD, 2009). For this reason, it is quite important to create learning environments contributing a gain in affective components.

According to Jenkins and Howard (2019), student-centered active learning pedagogies are widespread, but discipline-specific examples of implemented instructional approaches are needed to bridge the gap between pedagogical ideas and their enactment. The flip learning (FL) model has gained high demand since the model is perceived to address some challenges encountered in instruction, the model especially lets instructors allocate more time to student-centered learning environments (Eryilmaz and Cigdemoglu, 2019). Moreover, FL has many implications for improving students' cognitive and affective outcomes (Sookoo-Singh and Boisselle, 2018). Many works investigating effective aspects of FL have been published in higher education (Butt, 2014; Davies et al., 2013; Findlay-Thompson and Mombourquette, 2014; Mason

et al., 2013; Strayer, 2012). The majority of them revealed encouraging outcomes. For instance, participants in FL were more excited, engaged, and satisfied (Butt, 2014; Davies et al., 2013; Mason et al., 2013), more open to cooperative learning (Strayer, 2012) and had better grades (Mason et al., 2013). According to Findlay-Thompson and Mombourquette (2014), there was no change in the academic outcomes, despite participants' positive attitudes toward the learning strategy in an FL setting. Sookoo-Singh and Boisselle (2018) investigated students' motivation and achievement in chemistry and they found no achievement difference, but FL class had higher motivation scores.

Despite concerns about poor relevance of science and appealing attempts to improve the issue, there are pedagogies helping students to relate science knowledge to their fields and to support their scientific literacy so that their interest will be fulfilled. According to Osborne and Dillion (2008), students find chemistry concepts difficult to learn and consider such courses as adding little value to their lives and professions. Therefore, they do not find chemistry a popular subject area to study in the future. Such undesirable outcomes are generally attributed to conventional chemistry curricula, which lack in relating theoretical knowledge to students' real-life, hence, the inadequacy in improving their chemical literacy (CL). Gilbert (2006) categorized the problems of chemistry education in five categories: Overloadedness, isolated facts, lack of transfer, lack of relevance, and inadequate emphases. Such undesirable diagnosis of the conventional chemistry may overcome through active learning environments enriched with STS discussions. STS and context-based approaches are perceived to solve such reported problems of chemistry education and improve students interest and literacy (Bennett et al., 2007; Bulte et al., 2006; Holbrook and Rannikmae, 2007; Hofstein et al., 2010; Rannikmae et al., 2010).

Understanding relationships between science, technology, and society are essential for attaining basic scientific literacy (Vazquez-Alonso et al., 2013). Scientific literacy generally refers to "one's understanding of the concepts, principles, theories, and processes of science, and one's awareness of the complex relationships between science, technology, and society" (Abd-El-Khalick et al., 1998. pp. 417-418). Understanding science and technology has clear implications for productive citizenship in an information-driven economy (DiGironimo, 2011). The STS approach proposes to improve individuals' understanding of the relationship among these "S-T-S" issues. It is a metaknowledge that includes a wide array of multidisciplinary issues drawn (mainly) not only from epistemology, sociology, and history of science and technology but also from politics, ethics, psychology, etc. (Aikenhead et al., 1989, as cited in Vázquez-Alonso et al., 2014).

When STS issues are discussed in chemistry courses, we may expect the reported problems concerning: Overloadedness, isolated facts, lack of transfer, lack of relevance, and inadequate emphasis will be decreased. These student-centered activities

provide active engagement and enable students to transfer content knowledge to the real world around us. However, the problem is, instructors usually highlight that there is a lack of time for active strategies during the class hour. FL model may provide a solution for efficient use of class time for instructors at university. When FL model is integrated with STS issues, students may interact with authentic situations and problems for the development and application of scientific concepts and processes. Therefore, they will be provided to develop an insight into "real scientific projects, displaying fields where science is carried out and rehearsing important discussions on social issues related to scientific knowledge" (European Commission, 2004. p. 136). In addition, De Jong (2005) states that a critical remedy to heal current curriculum isolation is possible provided that the use of meaningful real-life contexts in the teaching and learning is employed so that it may be assumed that STS approaches will stimulate students' interest in chemistry and help them see how it relates to their lives (Bennett et al., 2003).

Theoretical Background

The frameworks proposing to improve students' science and chemistry literacy commonly include content knowledge, contexts that provide real-life application of content knowledge over which a discussion can be conducted to achieve higher-order thinking skills, and affective issues like interest or attitudes (for example, the program for international student assessment by the Organization for Economic Co-operation and Development [OECD, 2006]; Shwartz et al., 2005; Cigdemoglu et al., 2017). These frameworks overlap in providing real-life issues as a context on which content knowledge is employed and the frameworks assume that engaging in the STS or the context will increase students' interest. STS issues are also proposed to enhance students' nature of science understanding (Celik and Bayrakçeken, 2006; Vázquez-Alonso et al., 2013) hence their CL.

Based on the purpose of its use, the flipped learning model can serve both constructivist and/or behaviorist learning environments. When students are involved in assigned videos and texts outside the class hours individually, it may be considered as learning occurs through behaviorist assumptions. Later, when students engage in group discussions and make arguments with instructors, the learning environments turn to support social constructivist learning. STS issues also require students' active cognitive engagement since it recalls prior knowledge, necessitates transfer of content knowledge to new contexts, and provides a context that may support affective constructs such as motivation and interest. According to Bandura (1997), motivation and self-efficacy are related and students' self-efficacy has an impact on their academic performance. Cavas (2011) supports this idea from a Turkish context, stating relationship between motivation and academic achievement.

From a constructivist perspective, cooperative learning is a strong active learning method, and the method favors

students' achievement (Johnson et al., 2000). Using small group discussion has a significant impact on learning for undergraduate students (Springer et al., 1999). Moreover, Jensen et al. (2015) stated that active learning techniques are the most likely source of learning gain in flipped classroom implementations. The flipped learning model provides opportunities to instructors to advocate more time to student-led discussions since students are directed to already available course videos before the class hour. The concept of FL is usually integrated with cooperative and problem-based activities (Yelamarthi et al., 2015). Terenzini et al. (2001) compared a cooperatively taught class with a class taught in the traditional way, revealing that the former group had higher academic achievement, higher level reasoning, advanced critical thinking skills, better comprehension of concepts, a lower level of anxiety and stress, and a more positive and supportive relationships with peers, positive attitudes toward subject matter, and higher self-esteem.

Motivation is one of the key factors closely linked to science learning (Koballa and Glynn, 2007). Koballa and Glynn (2007) stated that motivational constructs are used to explain and figure out the patterns of students' thinking of science concepts, their emotions, and their actions regarding science. They also state that if science concepts are instructed effectively, there is the possibility to increase students' motivation to learn science. They mention the importance of hands-on activities, laboratory experiments, and inquiry-based lessons in improving motivation. According to Schunk (2000), some variables such as instruction, context, and personal parameters come to contact in learning; furthermore, the materials used and the contextual learning environments enriched with STS issues are related with meaningful learning and have an impact on motivating students toward learning.

Glynn et al. (2005) defined motivation as "an internal state that arouses, directs, and sustains human behavior" (p. 150). It can also be defined as any process that activates and maintains behaviors related to learning. From an educational perspective, when certain behaviors are displayed by students' own desire, interest, and curiosity, this is considered intrinsic motivation and it is inherent in students. Contrarily, when a behavior is intended to get a reward or to finish a task, it is regarded as extrinsic motivation and opposed to intrinsic motivation. In addition to intrinsic and extrinsic motivation, Pintrich and Schunk (2002) stated that motivation has other components such as goal orientation, self-efficacy, self-determination, and anxiety. According to Koballa and Glynn (2007), the constructs such as arousal, interest, curiosity, and anxiety have a significant role in the intrinsic motivation of students. In addition, such motivation is affected by how self-determined students are, how goal-directed their behavior is, how self-regulated they are, how their self-efficacy is, and how they find the concepts relevant to their lives.

One can pose the question "what motivates students to learn science." Self-determination theory (SDT) is one of the comprehensive and empirically supported motivation theory, and it proposes that conditions supporting students' experiences of autonomy, competence, and relatedness will foster their motivation. Deci and Ryan (2000) specifically stated that the relatedness is required to increase intrinsic motivation. Niemiec and Ryan (2009) pointed out that the way the teachers introduce tasks has an effect on their fulfillment of psychological needs for competence and autonomy; thus, these needs either enhance intrinsic motivation for meaningful learning or prevent the process. When science concepts are instructed effectively, that is, the constructs of motivation are supported; they have the possibility to improve students' motivation to learn science and make science more relevant for them. Related to fostering students' affective aspects, Osborne and Dillon (2008) suggested that with regard to education in Europe, "more attempts at innovative curricula and ways of organizing the teaching of science that address the issue of low student motivation are required" (p. 16). A similar inference on this notion is valid for the Turkish context, where students' general interest toward learning chemistry is not high.

Successfully promoting intrinsic motivation through making chemistry more relevant to students by the use of STS issues may increase cognitive engagement and as such result in achievement on the learning task together with affirming students' affective characteristics. This claim is valid if convenient learning strategies are integrated into chemistry curricula to support students' motivation. Having said this, determining the appropriate strategies to stimulate motivation and, then, implementing the strategy in actual classrooms are the endeavors of this study. Therefore, it presents an attempt to improve the learning environment with the flipped learning model and to investigate students' motivation and CL. The rationale for improving students' motivation to learn chemistry and making it more relevant is that chemistry is quite isolated from students' personal interests and current society and technology issues. The study hypotheses that students will be more motivated to learn chemistry and their CL will increase when STS issues are used in flipped learning model. The purpose is to investigate the effectiveness of STS-rich flipped learning model over conventional instruction on increasing students' motivation and CL. This research seeks answers to the following research questions:

- Is there a difference between students' motivation scores in flipped STS (f-STS) class and conventional STS (c-STS) class in freshman general chemistry course?
- Is there a difference between mean scores of factors of motivation in f-STS class and c-STS class in freshman general chemistry course?
- Is there a difference between students' CL scores in f-STS class and c-STS class in freshman general chemistry course?

METHODS

The Quasi-experimental Design
A quasi-experimental design was utilized for the study. To compare the effect of f-STS over c-STS students' motivation,

the treatments were randomly assigned to intact classes by tossing a coin. The collaborating instructor had two intact classes: One was the intervention (experimental) group and the other as comparison (control) group. As shown in Table 1, experimental and control groups took different treatments, but the same measurement tools (pre-test: Chemistry motivation questionnaire [CMQ] and post-tests: CMQ and CL) were administered.

Sample

A number of freshman engineering students were conveniently selected as the sample for this study. An instructor volunteered to participate by teaching an intervention group (IG) and comparison group (CG). In detail, the subjects consisted of 89 freshman engineering students. Of these, 48 were male and 41 were female. Forty-four of the participants (23 males and 21 females) were in the IG and 45 of them (25 males and 20 females) were in the CG. The age range of the students was between 17 and 25 years. The researcher conveniently selected the university and the classes for this research. Therefore, the findings are limited to this sample. Before the implementation, ethical permissions were obtained from the researcher's institutional review board. Students were informed about the study, confidentially is assured, they were free to quit from the study whenever they want.

Instruments
CMQ

The science motivation questionnaire developed by Glynn and Koballa (2006) was modified into the CMQ to gather data about students' motivation to learn chemistry. Ranging from 1 to 5 (5-point Likert type scale from 1 [never] to 5 [always]), the questionnaire included 30 items. The factors of the questionnaire are as follows: Intrinsically motivated to chemistry learning (Int. items: 1, 16, 22, 27, and 30), extrinsically motivated to chemistry learning (Ext. items: 3, 7, 10, 15, and 17), relevance of learning chemistry to personal goals (Rel. items: 2, 11, 19, 23, and 25), self-determination for learning chemistry (Sdet. items: 5, 8, 9, 20, and 26), self-efficacy in learning chemistry (Seff. items: 12, 21, 24, 28, and 29), and anxiety about chemistry assessment (Anx. items: 4, 6, 13, 14, and 18). The questionnaire was administered to the students in its original language.

To test the factor structure of the CMQ proposed by Glynn and Koballa (2006), confirmatory factor analysis (CFA) was conducted with responses of 171 students who were similar to participants of the study as pilot scores. The reliability

of the scores must be at least 0.70 to perform CFA (Pallant, 2007). The Cronbach's alpha coefficient of reliability was 0.88. In addition, the reliability coefficients of the factors were found as 0.79 for Int., 0.41 for Ext., 0.70 for Rel., 0.65 for Sdet., 0.70 for Seff., and 0.77 for Anx. The descriptive of the CMQ and related dependent variables was controlled for assumptions of CFA, skewness, kurtosis, linearity, and outliers were all checked and none of which were violated. The CMQ score was latent variable and it predicts six constructs: Int., Ext., Rel., Sdet., Seff., and Anx. The International Business Machines Statistical Package for the Social Sciences (SPSS) Amos 22.0 program was used for CFA, items 20, 7, 3, 15, and 30 have low standardized regression weights, so they were removed from the questionnaire one by one up to obtaining appropriate goodness of fit values (CMIN/DF = 2.318, p = 0.000, GFI = 0.884, AGFI = 0.911, CFI = 0.922, NFI = 0.814, RMSEA = 0.086). In addition, this factor had quite low reliability coefficient at the beginning, and then, when the modifications were done its reliability increased to 0.72. In the final version, there were 25 items in the CMQ, with a max score of 125 and min of 25.

CL items

As described by the framework of Cigdemoglu and Geban (2015) and Cigdemoglu et al. (2017), the CL items included some certain dimensions; content knowledge, higher-order thinking, and interest. Each CL item was contextual and scored as cumulative of these dimensions. The weight of content knowledge and higher-order thinking was equal (40% for each), and interest dimension had relatively less weight (20%). Totally, there were 10 CL items, each from different chapters. The maximum score that could be obtained from the test was 100 (each question's maximum score was 10), the minimum score was 0. Expert opinions were taken from chemistry professors for validity of the items. Kuder–Richardson 20 reliability coefficient of the scores was acceptable and above 6. Item difficulties were also calculated, the alternatives of the questions that required higher-order thinking were difficult than knowledge-based items. The items were administered to both groups after the implementation. A sample item is shown in Figure 1.

Treatments

The instructor used the same STS issue for both the intervention and CG; therefore, each group covered the same STS discussion. In each chapter, an STS was introduced through a real-life context for attracting the students' attention. The learning environment encouraged students to feel they needed to know how the scientific knowledge was applied in STS issues. The main differences among the implementations are described below. The implementation took one semester covering 10 different general chemistry chapters. The researchers tried to minimize threats to internal validity of the study, i.e., maturation, testing, and history effect were all equal to each group. The courses were also observed for treatment verification.

Table 1: Research design of the study

Groups	Pre-test	Treatments	Post-tests
IG	CMQ	f-STS	CMQ, CL
CG	CMQ	c-STS	CMQ, CL

CMQ: Chemistry motivation questionnaire, IG: Intervention group, CG: Comparison group, f-STS: Flipped science, technology, and society, c-STS: Conventional science, technology, and society, CL: Chemical literacy

Figure 1: A sample chemical literacy item, from electrochemistry chapter

f-STS in the IG

A teaching flowchart (Figure 2) indicates the flow of lessons for the IG. In all lessons, students were encouraged to engage in discussions, concepts were explored together, and decision-making was attained at the end. The same flowchart was followed throughout all lessons of IG. As an example, the chapter of electrochemistry is shown. Before the lesson, students watched a short video concerning the issue of "how does a hydrogen fuel cell car work?" They then took a quiz through a learning management system about the video. The quiz grade was not used as an assessment; it was used rather to control whether students watched the video or not. During the class, the instructor asked about the hydrogen fuel cell car and the chemistry behind it. Students' prior knowledge and ideas about the issue were evoked with discussions to create a need to know base to learn content knowledge of electrochemistry. The instruction covered all conceptual details such as fuel cells, half reactions, voltaic cells, free energy, and batteries. Whenever possible, the instructor referred the conceptual details of electrochemistry to the hydrogen fuel cells while teaching the content. The IG spent almost 15 min with the STS about the chapter before the class hour, and the last 15 min of the course hour was devoted to discussion on STS issue. In this phase, instructor directed students to make effective decisions concerning the STS considerations about the efficiency of hydrogen fuel cell cars.

c-STS in CG

A sample course flowchart in Figure 3 indicates how the instruction was carried out in the CG.

The lessons usually started with teacher-driven questions for engaging students in electrochemistry concepts followed by expository teaching supported by daily life examples. The basic framework for CG was set as teacher centered. The teacher generally asked questions to engage students and then briefly introduced concepts as done in their routine classes. At the end of each unit, the last 30 min was advocated to the same STS issue covered in IG. A handout explaining how hydrogen fuel cell cars work was explained. To avoid inequality among the groups, the same STS was used and a similar amount of time was spent for the STS engagement. Although the STS was diffused in content of electrochemistry in the IG, it was only provided as an example of application of the concepts in the CG.

Analysis of the Data

Students' responses to CMQ were entered into SPSS 22 as pre- and post-test. Total scores of students for each pre- and post-test and total scores of each factor were calculated. CL item scores were also entered into SPSS as post-scores. The type of the treatment was the independent variable of the study; the dependent variables were overall CMQ scores and CL scores. In addition, Int, Ext, Rel, Sdet, Seff, and Anx were also taken as dependent variables of the study. The descriptive and inferential statistics of the analysis are provided in the next section. First, MANOVA was used to check if statistical difference across pre-CMQ and pre-CMQs factors' (Int, Ext, Rel, Sdet, Seff, and Anx) existed before the treatments. Based on observing difference in pre-Seff scores; then, the multivariate analysis of covariance (MANCOVA) was used for the analysis of CL and post-CMQ scores. The percentage of missing values in the whole data was <5%, and the missing values were replaced by the mean scores. The negative items were reversed before all the computations. To make factors' scores comparable, their total scores were divided by the number of items in each factor.

RESULTS

The results are organized in the order of providing statistics for pre-test scores, post-test scores, and the main analysis for the research questions.
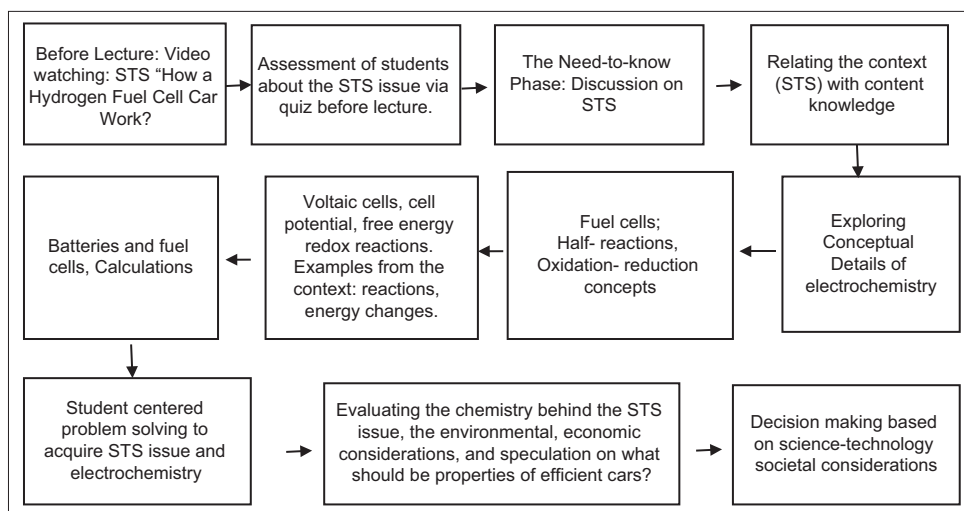

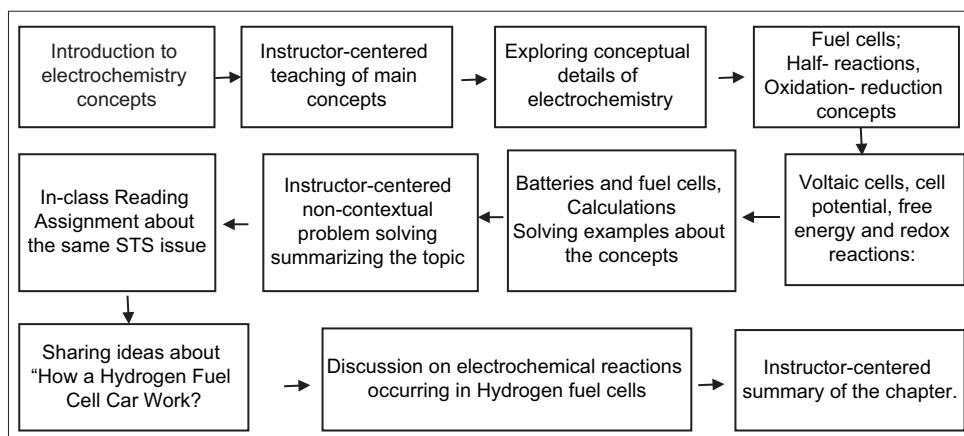**Figure 2:** A sample lesson flow in intervention group

Figure 3: A utilized teaching flowchart for comparison group

Statistical Analysis of Pre-CMQ and Pre-CMQs Factors: Int, Ext, Rel, Sdet, Seff, and Anx

To explore whether a significant mean difference between IG and CG exists in terms of pre-CMQ and pre-CMQs factors' (Int, Ext, Rel, Sdet, Seff, and Anx) before the treatment, MANOVA was used.

Before the main MANOVA analysis, the assumptions: the sample size, normality, and outliers, linearity, multicollinearity-singularity, and homogeneity of variance-covariance matrices were all checked. The results indicated that IG and CG have not statistical significant mean difference based on pre-CMQ (p = 0.208), pre-Int (p = 0.280), pre-Ext (p = 0.443), pre-Rel (p = 0.977), pre-Sdet (p = 0.541), and pre-Anx (p = 0.436). However, there was a statistically significant mean difference between pre-Seff scores (p = 0.017) of IG and CG. As shown in Table 1, CG group had higher mean, such result implied that pre-Seff score needs to be used as a covariate for the analysis. Table 2 shows the descriptive statistics for pre-CMQ and each factor of the CMQ across IG and CG.

Statistical Analysis of CL, Post-CMQ, Post-CMQs Factors: Int, Ext, Rel, Sdet, Seff, and Anx

After the treatment, post-scores are collected. MANCOVA was computed to reveal the effect of treatment on post-CMQ and its factors.

Table 3 shows the descriptive statistics regarding this analysis. It shows that IG students had higher mean score of CL, post-CMQ, post-Int, post-Ext, post-Rel, post-Sdet, and post-Anx, whether these differences were significant or not had been investigated by MANCOVA. The assumptions of MANCOVA: The sample size, normality and outliers, linearity, multicollinearity and singularity, and homogeneity of variance/covariance matrices assumptions were checked, no violation was observed. The results are given in Table 4.

The results given in Table 4 indicated that IG and CG do not have statistically significant mean difference based on collective scores (F (7, 80) = 1.623, p = 0.141; Wilks' Lambda = 0.876). To control the differences across separate dependent

variables, follow-up ANCOVA was performed. Table 5 shows the details regarding each dependent variable.

When the results for dependent variables were considered separately, post-CMQ, post-Int, and post-Rel had statistically significant difference across IG and CG. As shown in Table 5, the treatment had statistically significant positive effect on post-CMQ scores (F (1, 86) = 6.971, ρ = 0.010), post-Int (F (1, 86) = 3.960, ρ = 0.050), and post-Rel (F (1, 86) = 6.129, ρ = 0.015). The IG students' overall motivation, intrinsic motivation to learn chemistry, and relevance of learning chemistry to personal goals had been positively affected by the flip STS instruction. Comparing the mean scores of IG and CG from Table 3, it can be implied that students of IG found learning chemistry relevant to their personal goals with the help of STS diffused instruction through FL. The other dependent variables Cl, Ext, Sdet, Seff, and Anx

Table 3: Descriptive statistics of CL, post-CMQ, and its factors for groups

Dependent variables	N		Mean		Standard deviation	
	CG	IG	CG	IG	CG	IG
CL	45	44	65.81	66.67	7.9567	7.6779
Post-CMQ	45	44	80.30	81.87	11.317	11.872
Post-Int	45	44	3.239	3.403	0.7009	0.6971
Post-Ext	45	44	3.144	3.270	1.0204	0.8780
Post-Rel	45	44	3,078	3.432	0.7935	0.7799
Post-Sdet	45	44	3.478	3.494	0.8508	0.6296
Post-Seff	45	44	3.569	3.282	0.7639	0.7948
Post-Anx	45	44	2.782	2.836	0.6464	0.9829

CMQ: Chemistry motivation questionnaire

Table 4: MANCOVA results based on CL, post-CMQ, and post-CMQs factors

Source	Wilks' Lambda	F	Sig. (ρ)
Treatment	0.876	1.623	0.141

CMQ: Chemistry motivation questionnaire, MANCOVA: Multivariate analysis of covariance

Table 2: Descriptive statistics of pre-test scores for Int, Ext, Rel, Sdet, Seff, Anx, and CMQ

Dependent variables	N		Mean		Standard deviation	
	CG	IG	CG	IG	CG	IG
Pre-CMQ	45	44	80.11	76.89	11.67	12.31
Pre-Int	45	44	3.202	3.037	0.7522	0.6758
Pre-Ext	45	44	2.832	2.995	0.9919	1.009
Pre-Rel	45	44	2.985	2.981	0.6916	0.6963
Pre-Sdet	45	44	3.626	3.539	0.7141	0.6236
Pre-Seff	45	44	3.549	3.183	0.6607	0.7535
Pre-Anx	45	44	2.894	2.826	0.6375	1.001

CMQ: Chemistry motivation questionnaire

Table 5: Follow-up univariate analysis for pairwise comparison

Dependent variable	Treatment				
	df1	F	Sig. (ρ)	Eta squared	Observed power
CL	1	2.587	0.111	0.029	0.356
Post-CMQ	1	6.971	0.010	0.075	0.742
Post-Int	1	3.960	0.050	0.044	0.503
Post-Ext	1	0.430	0.514	0.005	0.099
Post-Rel	1	6.129	0.015	0.067	0.687
Post-Sdet	1	0.602	0.440	0.007	0.120
Post-Seff	1	0.002	0.965	0.000	0.050
Post-Anx	1	2.255	0.137	0.026	0.318

CMQ: Chemistry motivation questionnaire

Table 6: Follow-up univariate analysis over gain scores

| Dependent variable | Treatment | | | |
	df1	F	Sig. (ρ)	Eta squared	Power
Gain-CMQ	1	7.322	0.008	0.078	0.763
Gain-Int	1	6.656	0.012	0.071	0.723
Gain-Ext	1	0.040	0.842	0.000	0.055
Gain-Rel	1	4.536	0.036	0.050	0.558
Gain-Sdet	1	0.541	0.464	0.006	0.113
Gain-Seff	1	0.447	0.505	0.005	0.101
Gain-Anx	1	1.142	0.288	0.013	0.185

CMQ: Chemistry motivation questionnaire

did not have statistically significant differences across the groups.

Statistical Analysis Over the Gain Scores of CMQ and its Factors

In addition to the analysis of post-test scores, we also calculated the gain scores for each of the dependent variables by subtracting pre-test scores from post-test scores. The results supported the findings obtained from post-test scores. Table 6 shows related values.

Both post-score and gain score results supported the hypothesis that students would be more motivated to learn chemistry intrinsically and find learning concepts relevant to their lives using flip facilitated STS instruction in a freshmen general chemistry course. In their research, Vaino et al. (2012) revealed similar results indicating the positive effect of everyday issues on improving students' intrinsic motivation. Nentwig et al. (2009) described the "ability to extract relevant information from a variety of source" (p. 1) as an important aspect of scientific literacy, although STS instruction is expected to promote CL, in this case, there was no difference. One possible reason for this result might be that both groups learnt about the STS related to the content. Based on all these results, f-STS class and c-STS class in freshman general chemistry course had statistically different motivation scores. Based on the factors of motivation, f-STS was more powerful in supporting intrinsic motivation and relevance of chemistry. Finally, the interventions did not differ on CL for this research.

DISCUSSION AND CONCLUSIONS

This study revealed that flip STS intervention supported students' motivation to learn chemistry more than c-STS instruction. This intervention also increased intrinsic motivation to learn chemistry and relatedness of chemistry to students' personal goals. The use of STS issues as teaching modules possibly made students to be more interested in mastering the task and task-related strategies (Pintrich and Schunk, 2002). Flipping the STS issue before the course hour might increase students' familiarity with the issue, and this acquaintance might help them to transfer the content knowledge to the STS issue and thus improve their motivation. The teaching approach used in conventional group was heavily driven connection between

STS issue and content of the chapter. Following a similar type of instruction throughout the semester influenced students' perceptions of finding chemistry relevant to their lives.

f-STS learning modules started over a video showing details about STS issue, later students tested their understating of STS through a quiz. During the class, the instructor linked all conceptual details to the previously watched STS topic. The instructor created a learning environment, in which students experienced the STS in their everyday lives and felt more inclined to learn about it. The instructor established a need to know based on integrating STS and content. In the control group, the STS issue was just provided as an example to the application of concepts. Students did not able to watch the video. In the f-STS intervention, students discussed with their peers, explored the chemistry behind the issue with the instructor, and then the instructor extended the STS-related concepts to a platform, in which decision-making with reasoning was required. Vaino et al. (2012) described such learning environments as nourishing students' psychological needs for the constructs of motivation such as autonomy, competence, and relatedness. Besides, the modules promoted the internalization process by realization of the value and applications of chemistry in a way that students' personal lives were affected. Sookoo-Singh and Boisselle (2018) also investigated students' motivation in chemistry using flip learning model, they found that the FL class had higher motivation scores. Flipping the chemistry course may also support students' motivation too.

In line with the reported literature stating the effect of STS instruction on motivation (Vaino et al., 2012; Vázquez-Alonso et al., 2013), we can also claim that the flip supported STS treatment intrinsically motivated students to learn chemistry and required students' active participation. The discussions about societal aspects of STS consisting of high-tech technologies, such as nanotechnologies, synthetic biology, neuroscience and issues related equity and ethics about the STS issues, and political consideration about them, may have increased students' curiosity and interest as well; thus, IG was inherently motivated to learn chemistry. Similarly, King et al. (2008) revealed that students reported real-world connections of concepts and contexts increased their engagement since these tasks were interesting and productive for them.

Throughout the semester, these participating students had the chance of engaging in real-world STS topics. Watching the videos and creating disequilibrium with students cognitive processing, teacher-driven strategies including questioning and discussion, elaborating the issue for concept construction, the design enabled the students to connect the outcomes they obtained from these chemistry issues to other chemistry concepts and STS contexts. The use of such learning environments creates stimulation of students' personal mental activities to enable progression of teaching successfully (Parchmann et al., 2006).

When it comes to CL, both f-STS instruction and c-STS instruction had similar impact on students' CL scores.

Introducing the same STS to each group might be one reason for this outcome. Moreover, the CL scores consist of content knowledge (40%), higher-order thinking skills (40%), and interest (20%), a cumulative score was used for comparison. The flipped part of the course for the IG did not totally focus on pure content knowledge; it was rather about the related STS context. Students in that group might not have been fully engaged in the content knowledge part of an STS before the class hour, as a result, this might have been the cause for no difference in the CL scores. Although based on the results other dependent variables concerning motivational constructs were more influenced by flip STS, this was not enough to detect a difference in CL since the percentage of interest (an affective factor) in CL was relatively low (20%) in a total CL score. Further studies may take each aspect of CL separately to compare the effectiveness of instructions, especially higher-order thinking skills and socio-scientific decision-making. Findlay-Thompson and Mombourquette (2014) also reported no change in the academic outcomes in flip learning environment, despite participants' positive attitudes.

The pre-post design compared the gain of the groups and results were evaluated as the contribution of the design to affective issues of f-STS class. The conclusions drawn from the study are limited and narrowed to this sample since a random assignment of students and university was not possible. In addition, using a pre-constructed questionnaire for measuring students' motivation to learn chemistry for general may be evaluated as a limitation since the implementation covered only 10 chapters of general chemistry. Notwithstanding such a limitation, we may assume that it is good to report that the design positively affected students' intrinsic motivation and their perceptions of finding chemistry topics relevant to their lives. Some other educational approaches within the STS framework such as context-based approach may have similar effects on students' affective issues too. Further studies may enlarge this study by developing more lessons on different concepts for increasing students' motivation to learn chemistry and enlarge their sample size. Further studies may also add content knowledge to the flipped part of course design; this might affect students' academic achievement or CL too.

Based on our findings, such f-STS design is a promising way involving science and technology discussions to help students to close the gap between school chemistry, to increase their intrinsic motivation, and to make chemistry more relevant to students' personal goals. No study integrated STS and flipped learning model to explore experimentally its impact of constructs of motivation (Int, Ext, Rel, Sdet, Seff, and Anx) and CL. Improving intrinsic motivation and relatedness of chemistry to students' lives is a significant outcome for this study. Similarly, Vaino et al. (2012) revealed that context-based modules designed according to SDT improved students' intrinsic motivation. However, their instrument, topic, grade level, and even the instruction itself were different from the current study.

To sum up, fostering students about the STS are crucial if students are expected to function effectively in today's highly industrialized labor force as well as in their social life. Scientific advancements and technological improvements influence the daily lives of citizens in many aspects, students, as democratic citizens should comprehend the interdependence of science and technology. A comprehensive understanding of these STS issues might assist students to evaluate critically and analyze independently the decisions made in regard to science and technology. Gain in intrinsic motivation to learn chemistry and make chemistry more relevant to students' lives is evidence to suggest that flipping STS designs can be incorporated into teaching-learning environments for making chemistry more relevant and motivating.

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