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CONCEPT MAPPING TEACHING STRATEGY AND ACHIEVEMENT IN SCIENCE EDUCATION: AN OVERVIEW OF RELATED LITERATURE

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Abstract

Research has shown that many students lack the necessary knowledge and skills in science and technology to function in the modern world (American Association for the Advancement of Science at a time when there is increasing demand for scientifically literate individuals who can analyze and anticipate novel problems, rather than memorize disparate facts, and with the potential to change and adapt (AAAS, 1989; Ogawa, 1998). However, what is happening in schools is not promising. Students' performance and interest in science are declining (Markow & Lonning, 1998, Pendley et al. 1994, Lee and Fensham 1996) and laboratory work (Stensvold and Wilson 1992) and misconceptions (Nakhleh 1992, Herron 1996, Taber 1997, Sanger and Greenbowe 1999). In order to explain this, relevant research literature (Nakhleh 1992, Pendley et al. 1994) suggests several reasons: the lack of uniformity of concepts and the multitude of notation systems in use; highly fragmented and often very linear character of curricula in which insufficient attention is paid to concept definitions and their interrelationships and to relationships between concepts and phenomena; limited attention in science education to opportunities for synthesis in which students are explicitly taught the links between different concepts and how to visualize the methods; those opportunities would enhance

Keywords: Concept mapping, science education, learning strategy.

INTRODUCTION

Research has shown that many students lack the necessary knowledge and skills in science and technology to function in the modern world (American Association for the Advancement of Science at a time when there is increasing demand for scientifically literate individuals who can analyze and anticipate novel problems, rather than memorize disparate facts, and with the potential to change and adapt (AAAS, 1989; Ogawa, 1998). However, what is happening in schools is not promising. Students' performance and interest in science are declining (Markow & Lonning, 1998, Pendley et al. 1994, Lee and Fensham 1996) and laboratory work (Stensvold and Wilson 1992) and misconceptions (Nakhleh 1992, Herron 1996, Taber 1997, Sanger and Greenbowe 1999). In order to explain this, relevant research literature (Nakhleh 1992, Pendley et al. 1994) suggests several reasons: the lack of uniformity of concepts and the multitude of notation systems in use; highly fragmented and often very linear character of curricula in which insufficient attention is paid to concept definitions and their interrelationships and to relationships between concepts and phenomena; limited attention in science education to opportunities for synthesis in which students are explicitly taught the links between different concepts and how to visualize the methods; those opportunities would enhance

There is tremendous pressure on students to earn good grades because academic achievement is assumed to possess predictive value and used to bar the gate or to open between the primary, secondary schools and university, and also between the university and certain social professions (Sharma, 2005, p.69). Some of the prominent factors highlighted in the literature include a constant decline in the post-compulsory high school science enrollment (Smithers and Robinson 1988;Dekkers and DeLaeter 2001;Garg and Gupta 2003;Blalock et al. 2008); reluctance among the students to choose science courses, especially physical science courses in their final years of secondary education (Simpson and Oliver 1990;Garg and Gupta 2003;Trumper 2006); and a change in our value system as a result of which science related careers are not perceived attractive in terms of employment opportunities (Garg and Gupta 2003). To add to this, the constricted approach of understanding science by the general public has pared down the number of young people choosing to pursue the study of science and science as career choices (Durant et al. 1989;Durant and Bauer 1997;Miller et al. 1997;Bensaude-Vincent 2002;Stocklmayer and Bryant 2012).Secondary school and college students' knowledge of science is often characterized by lack of coherence and the majority of students engage in essentially rote learning (BouJaoude & Barakat, 2000, Brandt et al., 2001; Nakhleh, 1992) The problem is twofold: the abstract and highly conceptual nature of science seems to be particularly difficult for students as well as teaching methods and techniques do not seem to make the learning process sufficiently easy for students (Gabel, 1999; Schmid & Telaro, 1990). The prevailing teaching practices do not actively involve students in the learning process and seem to deprive them from taking charge of their learning (Francisco, Nicoll, & Trautmann, 1998). As the problem of improving the teaching/learning process preoccupies educators, concept mapping promises to be useful in enhancing meaningful learning.

Concept mapping is a teaching and learning strategy that establishes a bridge between how people learn knowledge and sensible learning. Concept mapping has been defined as a "meta-learning" (Wandersee 1990, p.927). The development of which can be traced to the well-known work of Ausube & Novak, 1978 ; Novak & Gowin (1984) . Meta cognition which is a strategy used in self-directed learning are mental processes that assist learners to reflect on their thinking by internalizing, understanding, and recalling the content to be learned (Borich 2004, p.297). They include invisible thinking skills such as self-interrogation, self-checking, self-monitoring and analyzing as well as memory aids for classifying and recalling content. Concept mapping promises to be useful in enhancing meaningful learning and students' conceptual understanding in Science and Physics (Novak and Gowin, 1984). Many science educators have recognized the importance of arranging instruction in order of assessment and Shavelson and Baxter (Shavelson et al., 1993) advised that such an arrangement is developed if concept mapping is settled within the curriculum. Thus, in the recent studies students were taught how to make concept maps as part of regular classroom instruction in a progressive manner using techniques similar to those suggested by White and Gunstone (1992. Concept maps are constructed by writing concepts and linking them by labeled lines. The labels are important because they require whoever is making the map to actively select convenient linking words. Similar to an outline or a flowchart, a concept map is a way of representing or organizing knowledge. a unique characteristic of Novak and Gowin's concept mapping strategies (1984) is the illustration of prepositional relationships among concepts with the use o f linking words (verbs, prepositions, and conjunctions) used to describe the relationship between two linked terms (Novak & Gowin, 1984) as summarized in Figure 1. The links need to make sense and to be real links between the two concepts; they need to show the two concepts in some meaningful way (Novak and Gowin, 1984). Constructivist based teaching involves students actively in constructing their own maps (Markow and Lonning, 1998).

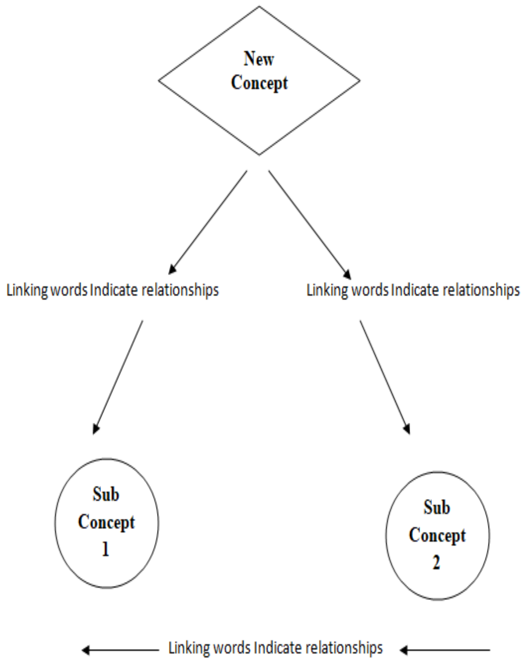

Figure 1. Features of a Concept Map

Concept maps help learners to make evident the key concepts or propositions to be learned and suggest connections between new and previous knowledge. Concept maps are flexible tools that can be used in a variety of educational settings (Stewart, Van-Kirk, & Rowell, 1979). For example, they can play a significant role in curriculum development, learning, and teaching (Novak, 1984). Concept maps are useful in science curriculum planning for separating significant from trivial content (Starr & Krajcik, 1990) and in focusing the attention of curriculum designers on teaching concepts and distinguishing the intended curriculum from instructional techniques that serve as vehicles for learning (Stewart et al., 1979). Furthermore, concept maps have been used as assessment tools to measure learning outcomes different from those revealed in commonly used psychometric instruments (Markham, Mintzes, & Jones, 1994). In an attempt to identify more conceptually based teaching and learning methods, research has investigated the use of concept maps in many content areas such as biology, physics, and chemistry.

Horton et al. (1993) conducted a meta-analysis study in which they found that there were many more studies using concept mapping in biology than in physical sciences and that, although results showed positive effects on attitude and achievement, these effects were more obvious in the biological than the physical sciences. In addition, Horton et al. found that concept maps were constructed mostly by students in class and that there were no differences between males and females, even though previous research (e.g. Novak & Musonda, 1991) suggested otherwise. Horton et al. (1993) came to a decision that concept mapping generally had positive effects on both students' achievement and attitude and concept mapping has been determined to help students' meaningful learning by helping them to see the links between scientific concepts (Fisher et al., 2000). For this purpose Novak and Gowin (1983) developed Concept maps based on Ausubel's 'Learning Theory'. Novak (1990), an educational researcher, fostered meaningful learning by developing concept maps as an instructional strategy and assessment tool for use in science education. Concept maps evolved from a 12-year longitudinal study of science concept learning in which Novak (1984) and his colleagues developed concept maps as a tool to represent and quantifiably measure learners' conceptual knowledge. In general, Novaks' technique is a hierarchical graphic organizer developed individually by students. It demonstrates their understanding of relationships among concepts and discriminates between rote and meaningful learning (Novak, 1990).

Similar to an outline or a flowchart, a concept map is a way of representing or organizing knowledge. However, a concept map goes beyond the typical outline because concept maps show interrelationships between concepts (Novak & Gowin, 1984).Concept maps illustrate hierarchical relationships except, they also illustrate interrelationships from one side o f the map to the other and from bottom to the top. In addition, a unique characteristic of Novak and Gowin's concept mapping strategies (1984) is the illustration of prepositional relationships among concepts with the use o f linking words (verbs, prepositions, and conjunctions) used to describe the relationship between two linked terms (Novak & Gowin, 1984). Novak (1984) has emphasized that the use of concept maps can be successful only by adopting a constructivist approach to education. In particular, constructivists hold that prior knowledge is used as a framework to learn new knowledge (Ausubel et al., 1978). Gaining access to students' unique views o f the world and then guiding the student to build upon these views seems to be the essence of the constructivist view o f learning. In Vygotskian terms, concept maps can be used to identify the dimensions of a student's zone o f proximal development (Vygotsky, 1978) in a particular domain. This suggests that concept mapping can enable the classroom over the past twenty years, teachers and curriculum designers have turned to graphic representation for showing relationships (Hyerle, 1995). Researchers have found that presenting graphic organizers helps students to see the relationship between main ideas and supporting details (Rooda, 1994). "Although we are now going beyond linear representations, we are just beginning to investigate how student centered designs for thinking facilitate learning" (Hyerle, 1995, p.89).

A study conducted by Ajaja (2011) determined the effects of concept mapping as a study skill on students' achievement in biology. The major findings of this study indicated a significant and consistent improvement in biology achievement as the period of experience with the use of the method increased. Also students who used concept mapping as a study skill retained biological knowledge longer than those who reviewed the concepts they were assigned to. All the students in the concept mapping classroom interviewed agreed that concept maps helped them not only in the determination of the relationships among the concepts but also shaped their understanding of the concepts and increased their critical thinking. The findings of Hall et al. (1992) and Kinchin (2000a, 2000b) are similar to this research finding. Kinchin (2000a) found a significant impact of concept mapping when used for instructing secondary school biology students. review of literature on concept map indicates that it is used in instruction and assessment (Novak and Gowin 1984; Jegede et al. 1990; Willerman and Mac Harg 199; Baron et al. 1992; Power and Wright 1992; Roth and Roychoudhury 1993; Trowbridge and Bybee 1996; Lomask et al. 1996; and Rice et al. 1998). Some other researchers have demonstrated its use in learning (MeCagg 1991; ChmeilesKI and Danseau 1998; Johnson and Raven 1998).This research was motivated in part by the growing incidence of failure in biology at the senior school certificate examination as a clear manifestation of poor learning strategy. Most researchers on concept mapping ascribe it to having the potential of making learners to remember information longer and to be able to use it more effectively because the information was moved into the long-term memory. In a situation like ours where the dominant method of teaching science in general and biology in particular is lecture method because of lack of equipped laboratories, it becomes necessary to look for alternative methods of instruction and study which will guarantee effective learning. Concept mapping look like one based on research findings on its usefulness. Concept mapping is based on Ausubel's (1968) theory of learning which emphasized the difference between meaningful and rote learning. Ausubel argued that meaningful learning builds one's cognitive structure by assimilating new concepts into one's existing conceptual structure. Novak (1998) confirmed Ausubel's stand when he stated that concept mapping is a major methodological tool of Ausubel's assimilation theory of meaningful learning. The literature on concept mapping provides a mixed bag of findings. Whereas in some situations significant differences were found, in others differences were not found in terms of its effectiveness. For example, Lambiotte, and Dansereau (1992) compared the effectiveness of different forms of lecture on recall of information. In one of the classes, concept maps outlines constructed by an expert was used as lecture aids. In the other class, the concept map aid was not provided. On comparison of the two groups on recall of material presented, the concept mapping condition did not show any significant difference over the other group. This however did not agree with the findings of Hall et al. (1992) who found a significant difference favoring concept mapping on recall of information in instructions using concept mapping in one subject domain.

POSITIVE IMPACT OF CONCEPT MAPPING TEACHING STRATEGY ON LEARNING PROCESS

Cardemone (1975) made the first use of concept maps. He found that the preparation of a "master" concept map for the topic of 'ratio and proportion' helped him to plan instruction on this topic. Bogden (1977) also found that concept maps prepared by him in a Genetics course were found to be valuable in learning the course by a small minority of students. Studies which supports cognitive gain has its evolution since 1985 to 1987 when Novak himself taught Concept Mapping in classroom settings to upper elementary and secondary school children. His co-worker Moriera (1977) had also used concept maps with university students. Their first comprehensive study utilizing concept maps and vee diagram was conducted with junior high school students. The findings of this study were in line with the findings of researches conducted by Novak et al. The study led to the following conclusions: a. Classroom teachers motivated to use new metacognitive learning strategies can be successful in employing Concept Mapping vee diagramming tools with junior high school Science students.b. Skill in the use of these tools takes time, perhaps one or two years if used only in a single course. c. Conventional measures of students' ability/achievement are poor indicators of success with use of these strategies. d. Novel problem solving success is significantly correlated with success in Concept Mapping scores. e. Junior high school students have become adapted to primarily rote mode learning and it is not easy to move them to meaningful learning strategies. Briscoe C., Lamaster S.U. (1991)2 found positive effect on meaningful learning in biology. They selected few concepts from college biology and taught students through Concept Mapping and found that Concept Mapping enhances the meaningful learning. Barenholz H. and Tamir P (1992)3 selected twenty to thirty concepts as key concepts for a course in microbiology. They taught the students using Concept Mapping strategy. Paper, pencil response was used to take responses .Students show remarkably well in construction of concept maps Hall, Dansereau and Staggs (1992)1 assessed recall of information in the form of normal text or Concept Mapping. The researchers found a significant difference favoring Concept Mapping as a tool in biology concepts. Smith K M and Dwyer F M (1995)2 also favours to use Concept Mapping strategy to increase student achievement. Schmid R.F., Telaro G. (1996)3 use Concept Mapping as an instructional strategy for high school biology and found that Concept Mapping changes the scores of the students in the positive direction. They emphasize to use Concept Mapping for meaningful learning. Markow and Lonning (1998)4 tested the effect of Concept Mapping in college chemistry. The researcher found that the students had a strong positive attitude towards the use of Concept Mapping for a better understanding of chemistry concepts. Merrit , Ronald L., Jr. (1998)5 studied the effect of Concept Mapping on Precalculus students of Community college and found that their conceptual understanding of Inverse functions improved remarkably Santhanam, E., Leach, C., & Dawson, C. (1998)6 studied Concept Mapping on achievement in genetics in introductory classes of genetics in Australia and found positive results. The positive impact of the use of Concept Mapping on learning process was studied by Kinchin (2000a,2000b)4, Sjostrom M.P. (2000), Wilcox S.K. and Lanier (2000)5,Wood S. (2001)6, Harnosch D.L., Sato T., Zheng P., Yamaji S. and Connell M.(2002)1 Hibberd R. , Jones A. and Morris E. (2002)2 and Safayeni Frank, Derbentseva Natalia , Canas Alberto (2003)3 they found that Concept Maps are most beneficial in the learning process , they are able to reveal students' misconceptions in learning that are not captured by traditional method , means to promote and assess knowledge acquisition . Pankratius (1987; 1990)2 has used Concept Mapping in the high school Physics curriculum in an attempt to improve both instruction and learning. Kharatmal M., Nagarjuna G. (2005)3 studied the effect of concept mapping as knowledge organizer in the mathematics and found that for meaningful learning. Concept Mapping is an effective instructional tool.

CONCEPT MAPPING TEACHING STRATEGY AND PERFORMANCES IN SCIENCE EDUCATION

Briscoe C., Lamaster S.U. (1991)2 found positive effect on meaningful learning in biology. They selected few concepts from college biology and taught students through Concept Mapping and found that Concept Mapping enhances the meaningful learning. Barenholz H. and Tamir P (1992)3 selected twenty to thirty concepts as key concepts for a course in microbiology. They taught the students using Concept Mapping strategy. Paper, pencil response was used to take responses .Students show remarkably well in construction of concept maps. Hall, Dansereau and Staggs (1992)1 assessed recall of information in the form of normal text or Concept Mapping. The researchers found a significant difference favoring Concept Mapping as a tool in biology concepts. Novak D.Joseph and Dismas Musonda (1992)2 conducted a twelve-year longitudinal study of Science concept learning. The experimental group, comprising 191 students, was imparted instruction using audio tutorial Science lessons based on Concept Mapping. The purpose of this study was to examine the use of Concept Mapping as a strategy to facilitate meaningful learning based on a theoretical structure. The effect of this instructional strategy was assessed in terms of comparative group means on cognitive learning. Companies were made on method, prior knowledge and gender. Attitudinal changes were also examined. The study utilized pre - test/post-test true experimental design. Analysis of the outcome also included the interaction of students' cognitive performance level and their abilities to use Concept Mapping strategies. The study involved 429 Science students of IX grade in two selected junior High schools. The experimental findings reveal that Concept Mapping group did slightly well on the content post test than the conventional group. Lambiotte J. and Danseau D. (1992)3 compared Concept Mapping and lecture Method on secondary school students. They found that students with more well established schemas for the circulatory system when given knowledge through Concept Mapping treatment, Concept Mapping found more effective than lecture method. Willerman Marvin and Macharg Richard A. (1992)1 studied the concept mapping as a Model. The objective of this study was to determine if concept mapping used as a Model it could improve Science achievements of eighth grade students. The Experiment: The experimental group (n+40) was presented with concept mapping, as a model at the beginning of a Science unit. The control group (n=2) was not presented with the concept mapping. The instrument used to measure academic achievement was a teacher made test. The objective type questions were at all levels of Bloom's Taxonomy except synthesis and evaluation. Results: One tailed t-test was used to compare the experimental and control group scores. The results indicate that the use of Concept Mapping produces a significant increment in academic gain for students in eighth grade. Horton P.B., Mc Conney A., Gallo, Woods, Hamlie (1993)2 studied the effectiveness of concept mapping as an instructional tool and found Concept Mapping enhances the achievement of students in the subject of science. Lamar James Bagget (1993)3 studied the effectiveness of Concept Mapping as advanced organizers. The subject in the study was 111 students from six intact Biology classes in a southern Mississippi community school. One control group and two concept mapping experimental groups were used in the study. A pre-test posttest experimental design was used. Multiple linear regression analysis was employed to test the hypothesis at 0.05 level of significance. The results showed that the two experimental groups outperformed the control group in attaining concepts of Biology (Photosynthesis). Jaffery Austin Jay (1994)1 conducted research to study the effectiveness of Concept Mapping in a college level Biology course. The research designs allowed for a comparison between experimental and control groups in regard to achievement and found it in the positive direction. A majority of experimental group participants agreed that the Concept Mapping strategy aided them in identifying connections between concepts, provided them with a way to gain an integrated view of the subject matter, and made them active rather than passive learners. Many experimental group participants constructed concept maps collaboratively and, in turn, suggested that collaborative Concept Mapping should be infused within the Cell Biology course in the future. Markham and Mintzes (1994)2 highlighted the difference in traditional scores and Concept Mapping scores as signifying that Concept Mapping is helpful in meaningful learning in the science subject. They carried their study on elementary school students examining the extent to which differences exist in the concept maps of advanced college biology majors (n=25) and beginning non majors (n=25) in the domain of mammals. Results indicate that the Concept Mapping is more effective. Esiobu, Soyibo (1995)1 studied the effect of Concept Mapping on cognitive achievement in ecology and genetics. They found that students studied with Concept Mapping learning mode achieved more in the ecology and genetics rather than other mode of learning. Schmid R.F., Telaro G. (1996)3 use Concept Mapping as an instructional strategy for high school biology and found that Concept Mapping changes the scores of the students in the positive direction. They emphasize to use Concept Mapping for meaningful learning. Santhanam, E., Leach, C., & Dawson, C. (1998)6 studied Concept Mapping on achievement in genetics in introductory classes of genetics in Australia and found positive results.

Concept mapping has been related to both meaningful learning and higher achievement scores in science. Concept mapping has been recommended for coursework in physics (Moreira, 1985), chemistry (Novak, 1984), biology (Jegede et al. 1990; Jayathilaken, 1991;; Marion et al. 2010 Stewart, Van Kirk & Rowell, 1979), and ecology (Heinze-Fry, 1984). Although concept mapping is recommended by many writers, there have been relatively few research studies which evaluate the use o f concept mapping at elementary and middle grade levels (Willerman & Mac Harg, 1991). This study examined the effects o f concept mapping on the science achievement o f secondary level students.

The positive impact of the use of Concept Mapping on learning process was studied and the result revealed that concept mapping strategies are most beneficial learning strategy in the learning process. (Kinchin, 2000a,2000b; Sjostrom, 2000; Wilcox & Lanier 2000; Wood, 2001; Harnosch & Sato , Zheng P., Yamaji S. and Connell M. 2002; Hibberd R. , Jones A. and Morris E. (2002); Safayeni Frank, Derbentseva Natalia , Canas Alberto 2003 . They are able to justify students doubts and misconceptions in learning acquired by traditional method, means to promote and access knowledge acquisition(Zanting et al. 2003; Sigmar et al. 2006) studies on concept mapping in terms of learning, instruction and knowledge management. They emphasized on use of concept mapping strategy enhances students cognitive processing.

There are number of studies found which emphasized impact of concept mapping strategy has a positive impact on learning achievement (Sharma et al.(2013), Novak. Gowin and Johansen(1983), Willerman., Macharg(1992)Bartels(2000),Manoj(2004),Elhelou(2006),Chiou(2008),Awofala(2011),Alhaddabi(2011),Cheema and Mirza(2003),Francisco et al.(2002), Udeani and Okafor(2012), Nwoke(2015), Kumar(2004), Marutirao. Patankar(2016),Sheu(2008),Pankratius(1990), Emmanuel(2013) and studies which proves concept mapping has no impact on science learning achievement (Lehman, Carter, and Kahle (1985) Lakshmi, G. (1997) Marlow and Lonning (1998),Kkarakuyu(2010),Chawla (2013), Akuzinwanna(2012),Ojo and Egbon(2013), Boujaoude and Attich(2008), Chawla(2013), Rao and Manjula(2004), Abdi(2015), Ghorai and Guha (2018),Appoji and Shailaja( ), Donald and Wanda(2009), Sherries and Kahle(1984), Hsu et al. (2004), Omole and Yusuf(2016), Sudha (1990), Akyildic and Mehmet(2006), Ogonnaya et al.(2016) , Sakiyo and Waziri(2015), Ezeudu(2013) Karakuyu, Y. (2010) Omole, M.I.M., & Yusuf, H.O. (2016) Hsu et al. (2004) Appoji, S., Shailaja,H.M 2017). Advantages o f the concept mapping strategy are numerous (Edmondson, 1995; Mason, 1992; Jegede et al. 1990; Pankratius, 1990; Schmid & Telaro, 1990; Ault, 1985; Novak & Gowin, 1984). Concept maps help the teacher design better lesson plans by increasing cognitive learning, enhancing retention, and producing a higher order of learning logical thinking, analysis, and application. In the process of mapping concepts, a student's concepts and ideas are revealed and thus, misconceptions may be corrected.A variety of qualitative and quantitative research studies have demonstrated the value of using concept mapping in the science classroom (Novak, 1990; Willerman & MacHarg,1991; Penello, 1993). Concept maps have been successfully constructed by students from kindergarten to college and have been determined to be effective for the recognition of organizational patterns, problem solving, and retaining scientific information (Moreira, 1977; Penello, 1993).Concept mapping has been developed as a method of tapping into a learner's mental structure and providing the learner and teacher with ways to see what the learner already knows.

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