Bebras Informatics Contest: Criteria for Good Tasks Revised

Jiří Vaníček

University of South Bohemia in České Budějovice, Czech Republic
vanicek@pf.jcu.cz

Abstract. The Bebras International Contest on Informatics and Computer Fluency has significantly grown in the number of participating countries and participants in recent years. Six years ago Dagienė and Futschek determined the criteria for good contest tasks, which are frequently used by the International Bebras Committee for selecting and improving tasks for national contest organizers. New experience and findings from several surveys allow us to reconsider these criteria from a new viewpoint and to assess which of these criteria are still actual, which need revisions and whether some new criteria are needed if the process of creation of informatics tasks for the contest is to be improved. The paper discusses the issues of motivation, interactivity, multiple-choice answers and content topics. The reviewed criteria and categories might be useful for authors of Bebras tasks as well as for creators of informatics curricula.

Keywords: teaching informatics, computer science education, informatics task, informatics contest.

1 Bebras Contest and School Curricula

The Bebras project [1] can undoubtedly be regarded as one of the most important milestones in the area of reintroduction of informatics content into schools across Europe over the past few years. In contrast to "official" ways such as definition of national curricula, taxonomy of learning objectives, outcomes and contents, the form of an informatics contest designated for average eager pupils interested in technology approaches the issue from the other pole: it looks for suitable topics and problems, suitable situations, didactical transformations of the original informatics topic.

Contest tasks focus on problem solving [2]. The process of their creation begins with authors from a number of participating countries, which is followed by an international workshop where tasks are selected and classified, improved and their wording is refined, after which contests are prepared by individual nations, tasks translated, finalized and used in the contest. This process is therefore a very good way to creation of a rich set of tasks that can also be used in school curricula in many countries.

The tasks represent small isolated problems and situations that can be integrated into the subject that is still very novel in schools in many of the participating countries. Thus the Bebras contest may play an important role in creation of school curricula from the "bottom", from basic elements, from individual questions, on which broader

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informatics concepts may be illuminated. School informatics is built on different types of tasks than tasks used in the Bebras contest; it uses practical and more extensive problems, projects, inquiries. The Bebras contest presents those types of tasks that are not based on practical activities on the computer to demonstrate the acquired skills. In this respect they are close to school mathematics, which also poses artificial problems that define the didactical situation. These problems can address concrete misconceptions of pupils, can focus on showing extreme situations in which understanding of a given concept is refined. The characteristics of informatics tasks in the contest are similar in some of these parameters.

School informatics, especially in the area of teaching algorithmization, has been using a whole range of software environments, microworlds and didactical programming languages. These learning environments provide the background for concrete practical tasks and more extensive pupils' programming projects. Mathematics educators also use ways of creating learning environments based on one task. Wollring mentions the relation "Task $\subset$ Task format $\subset$ Learning environment" and introduces 6 basic principles for designing learning environments: subject matter and meaning, articulation and social organization, differentiation, logistics, evaluation and links to other learning environments [3]. Learning environments that are close to children's everyday experience, e.g. Snake, Bus, Family, Stairs are used by Hejný in his scheme-oriented approach to mathematics education [4]. Bebras tasks can make a convenient starting point for creation of such learning environments that can be used in contest tasks and that will conveniently supplement environments already used when teaching algothmization. Creation of learning environments and research in problem posing may be one of the possible future trends in didactics of informatics.

2 Criteria for a Good Task

The history of the Bebras international contest on informatics and computer fluency (*http://bebras.org*) dates back to 2004 when Valentina Dagienė organized this contest for the first time in Lithuania [1]. The main goal of the contest was to motivate pupils to study informatics. The idea of "learning informatics through contest" has become popular in a number of countries. Last year the list of participating countries featured 29 countries from 4 continents. The Czech Republic joined the contest in 2008. Czech organizers' intention was to demonstrate to pupils as well as to their teachers how wide the field of informatics was [5]. This was in response to situation in informatics education in the Czech Republic, where compulsory ICT education is limited to information literacy, user-approaches to technology, to teaching how to consume technology.

In 2008, Dagienė and Futschek (in cooperation with Hein, Pohl, Cock, Sysło) published the paper *Bebras International Contest on Informatics and Computer Literacy: Criteria for Good Tasks*, in which they classify tasks into two content categories and formulate several key and recommended criteria for creation of informatics tasks. [6] These principles proved to be very useful for us as authors and organizers. They served as a good guide in coordination and selection of questions and their finalization in international workshops. The listed criteria considerably contributed to improvement of task quality and the process of their preparation.

Six years have passed since publication of the paper. This is a sufficient period of time for getting experience. It is now time to consider whether the listed categories and criteria are still topical or whether other useful criteria should be introduced. Our experience from work on the international team, our assessment of more than 300 tasks that have been used in the Czech national rounds of the contest within the past six years and several surveys among contestants and teachers - school coordinators serve as the starting point for discussion of some of the criteria.

3 What Should the Contest Be Testing?

Dagienė and Futschek mention that "users need also some thinking skills while applying technology" [6]. This could be referred to as computational thinking, whose definition for K-12 is currently much discussed on the grounds of CSTA and ISTE [7]. Computational thinking approach to informatics education at upper secondary schools is also discussed by Syslo [8], the same approach can be come across in the conception of Slovak national curriculum framework for primary schools [9] and in Computing program of study in the national curriculum framework in England 2014 [10].

Dagienė and Futschek claim the best way to develop thinking skills is to solve problems [6]. And it is true that this basic demand on a good informatics contest task has been met over the years. Gradually, tasks asking about important personalities and events of informatics history, tasks testing knowledge of facts or mastered knowledge of e.g. some algorithms have disappeared from task proposals. Authors of tasks also try to meet another demand that the contestants need no pre-knowledge when solving a task [2, 6]. They try to include all the needed information in the assignment. However, this leads sometimes to very lengthy assignments. Authors face the dilemma whether the additional information does not make the task less comprehensible and clear.

We tried to verify this experimentally in the Czech national round in 2013. The task used in this experiment was an interactive task about passage through labyrinth. We wanted to test whether reading a long text of the assignment may not be more difficult for the contestants than the possibility to discover the behavior of the system experimentally. Two versions of the same task were prepared. 14-15 year old contestants were assigned this task in the form of full verbal description of behavior of the system. 10-11 year old contestants were assigned the same task shortened to one quarter of the original length, only with basic instructions and a short task. When preparing the contest some teachers - pre-testers objected that the assignment for younger pupils was too brief. The same objections could be heard from older contestants who has taken the variant for younger contestants. However, younger pupils had no problems when solving the task in the competition. More than 90 % of the 6031 answers were correct, which clearly shows that the contestants were able to grasp the brief, incomplete assignment. This suggests that the possibility to discover rules on one's own may be more advantageous in certain questions than having to read them formulated.

It is most difficult to provide all the relevant information in a contest task as required by the criterion if the task is related to everyday work with computer, digital literacy or broader social context.

4 What Areas Should the Tasks Stem Out From?

Dagienė and Futschek introduce the following proposals of topics for the contest. They are six:

INF Information comprehension - representation (symbolic, numerical, visual), coding, encryption
ALG Algorithmic thinking including programming aspects
USE Using computer systems (e.g. search engines, email, spread sheets ets. - general principles, but no specific systems.
STRUC Structures, patterns and arrangements - combinatorics, discrete structures (graphs, etc.)
PUZ Puzzles - logical puzzles, games (mastermind, minesweeper, etc.)
SOC ICT and society, social, ethical, cultural, international, legal issues [6]

This is not the only existing proposal for categorization of contest tasks. E.g. Kalaš and Tomcsányiová propose categorization of informatics tasks into four categories: algorithmization, information comprehension, problem solving, digital literacy [11].

It is a question how well these topics cover the field of informatics and whether tasks can be distributed equally into the different topics, whether the proportion of tasks from each of the topics is about the same. To answer the question we analysed all proposals that were sent by authors for review in 2012 and 2013. The analysis of 424 proposals shows that:

- More than one half (216) of the tasks were classified by their authors as ALG type.
- 23 % of the tasks could not be classified into one topic category, their authors placed it into two (or more) topics simultaneously
- Some authors were not happy with the offered topics and used their own classification of the task type, e.g. *languages, combinatorics, graph, logic, sequence, constraints*.
- only 7 % of the tasks could be classified as USE (using ICT, digital literacy) and only 2 % as SOC (social and legal issues in use of ICT)
- other topics were represented as follows: INF 26 %, STRUC 19 %, PUZ 11 %.

The aim of defining topics is among others to guarantee that contests offer a variety in content and cover the whole spectrum of informatics tasks. Current distribution of tasks suggests that the topics are not well defined.

It seems purposeless to have a category that does not offer sufficient number of tasks. That is the case of the topic SOC, in which not a single task was accepted in

2013. It looks like this topic is too narrow. It would sound logical to incorporate this topic into the topic USE with which it shares its interconnectedness with everyday life unlike other topics which are much more theory-based.

The topic ALG on the other hand seems to be too wide and should be divided into subtopics. There are more possibilities for this subdivision:

- classification according to skills needed for task solution (e.g. algorithm design, error debugging and correction, search for output state, search for initial input state before algorithm implementation, exploration of algorithm universality, feasibility, selection of the most effective algorithm)
- classification according to extent of formalization (procedures in everyday life situations, algorithms using program structures, specialized algorithms for specific classes of situations, algorithms by design paradigms, algorithms known from theoretical informatics etc.)
- classification according to type of algorithm (sorting, searching algorithms …)

The fact that many authors used their own categories related to mathematical or logical fundaments of informatics suggest that an additional useful topic LOG (MAT) – constraints for making decisions, simple predicate logic, combinatorics, binary systems) should be introduced. The topic PUZ could then focus on problem solving, games and labyrinths, comprehension of rules, game strategies.

5 Digital Literacy in Tasks

The topic USE, which covers everyday use of ICT, digital literacy, user-centered approach, use of applications, is an integral part of compulsory curriculum in many countries. Blaho states that the field of ICT is often understood as mastering technology, as initial stage to informatics [9]. Schubert and Schwill regard ICT education as a framework of basic education in the area of informatics, communication and information technology [12]. If tasks connected to use of computer applications are included into contests like Bebras, the contest draws nearer to school curriculum and is more easily acceptable by schools and teachers as it meets the general public understanding of informatics as something connected to use of computers.

How do pupils perceive an informatics contest? A survey was carried out in December 2012 in the Czech national round of the Bebras contest. The questionnaire was answered by 13 %, i.e. 3500 contestants. Among other questions the respondents were given the opportunity to express their opinions on the contest. Apart from the expected classes of responses evaluating the contest (from “amazing” to “horrible”), comments on the respondent’s performance (“why didn’t I manage?”) and technical questions (“when will the lists of the best contestants be published?”), we could often come across opinions in which the contestants (especially from upper secondary schools) claimed the contest was not too much about informatics. Some of the participants’ comments follow:

- “More questions from informatics next time, please.”
- “This had nothing to do with Informatics!!!”

- "Why is this called a contest in informatics if only 2 (out of 15) tasks are about computers?"
- "The questions should focus on IT much more. These questions seemed to be from mathematics."
- "I wonder what the contest questions have to do with informatics. Maybe nothing at all?"
- "The fact that one answers on a computer doesn't make this an informatics contest." [13].

Some of the comments imply that pupils believe the contest is called an informatics contest as it is sat at a computer. These pupils see a distinction between informatics and computers. However, the comments also imply that either the informatics tasks are too artificial or distant from everyday life, or that pupils' conception they acquire at schools of what informatics is, of its basic concepts and types of problems it solves is wrong. It is also possible that pupils are not used to be solving difficult tasks on computers for whose solution they would have to apply reasoning, logic, make decision, and formalize their answers. These skills are never needed when merely running applications. Then they conclude that problems requiring thinking and reasoning are problems from the realm of mathematics or logic [14].

Tasks from the topic USE are problematic as they must be anchored in everyday life. Real-life situations connected to digital literacy often ask for experience, preknowledge or general knowledge and can rarely be solved merely by reasoning or computational thinking. This results in a clash of these tasks with one of the above mentioned criteria of Dagienė and Futschek [6], namely that no task can rely on preknowledge of details of specific IT systems. If this much needed criterion is used mechanically, many interesting questions may be rejected. In consequence authors might prefer not to propose tasks in this category for uncertainty and fear of their rejection. In this point of view it is easier and safer to prepare a theory-based task and thus avoid the risk of contact with everyday life situation. As the number of proposals in this topis is very low, the problem of application of this criterion is real.

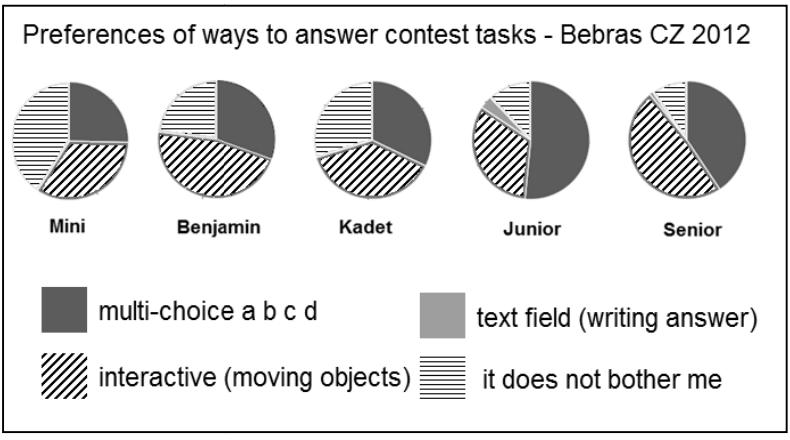

Fig. 1. Preference in types of answers for different age categories

Analogically tasks from the topic SOC related to legislation often face the situation when the expected (moral) practice of a person does not correspond lo legislation. Moreover, legislation may vary from one country to another and also within one country in some period of time. The reason for rejecting SOC tasks is often precariousness as the author's proposed correct answer may not be correct in other countries or may not be the only possible answer in different interpretations.

Especially because of tasks from the topic USE, which are perceived as crucially important in some of the participating countries and which not included in tests in sufficient numbers, the pre-knowledge criterion should be reformulated in such a way that tasks still do not require pre-knowledge of specific software applications but allow use of situations from work with software commonly used.

6 Interactivity of Tasks

Dagienė and Futschek also demand that tasks "*should* have interactive elements (simulations, solving activities, etc.)" [6]. We investigated how interactivity of a task contributes to its attractiveness.

In the questionnaire from 2012, the contestants also indicated their preferences in tasks (Fig. 1). Our analysis of their answers shows that fewer than one half of the contestants decidedly prefer interactive tasks. Interactive tasks are not even the most popular task type in all categories [13].

In the same 2012 questionnaire, repeated in 2013, we also asked about popularity and difficulty of the used tasks. The contestants were asked to choose from a list of tasks the one they found most interesting and the one they found easiest. With two exceptions, the most interesting task was one of the interactive tasks in all 10 categories. This shows that interactivity, if associated with a specific task, is evaluated differently than interactivity in general.

Then we compared the ratio of interactive and other tasks in the answers. This showed that, with the exception of the category Mini for primary schools, interactive tasks were seen as much more attractive and therefore also easier. However, this was not true universally; interactive tasks requiring work with keyboard (e.g. tasks simulating the tool Find/Replace) were much less interesting than graphic drag and drop tasks or tasks using mouse clicking. Thus we conclude that interactivity is attractive because of its graphic component and manipulation with the mouse.

The reason why interactive tasks were not so favourably accepted in the youngest category Mini might be that more than one half of all tasks in this category were interactive. This inflation of interactivity might have caused loss of their attractiveness.

One must stress that interactivity may substantially change character of the task. An experiment was carried in the national round in 2012 in which we prepared the same task both as an interactive and multiple choice task. While the multiple choice task was evaluated as average (the seventh most often selected as the most interesting task out of 15), its interactive variant was selected as the most interesting.

The possibility to manipulate or simulate in the computer environment may affect how pupils solve the task. They may be diverted from thinking to experimenting, to error and trial strategy in which they prefer cognitively less demanding methods. This might be one of the causes of popularity of interactive tasks. One must always consider carefully whether the demand that a task be interactive does not make the task much easier, of lower quality.

Attractiveness of interactive tasks may also result in a situation in which pupils pay more attention and spend more time solving interactive tasks than multiple choice tasks. This could then mean that interactive tasks are solved correctly by more contestants due to this extra attention. We wanted to verify this hypothesis through the database of 2013 national round. There were 34 454 contestants. We analysed 13 interactive and 57 non-interactive tasks. The outcome of this analysis does not verify the hypothesis. The contestants spent on average 2.8 times shorter time solving one interactive than non-interactive task.

7 Assignment and Motivation in Tasks

Dagiene and Futschek also mention that the story of the task plays a crucial role in contestnats' motivation [6]. Posing questions and tasks for the Beaver contest is often approached as "dressing a CS task into an ICT attire". In the pool of proposals from previous years, one can discern several approaches to posing tasks:

- finding some classical informatics task and giving it an attire of a simple story, most often using the fairytale character of a Beaver-moderator, who introduces the problem
- taking a task which is primarily about computer science and searching for an everyday life situation or a situation which somebody could imagine as real-world that corresponds to the original task problem
- starting from application of informatics in another discipline (mathematics, physics, biology) and constructing a story with a real-world situation which illustrates use of some informatics concept or principle used for its solution
- observing the world around you (or your teaching) and letting it inspire you to formulation of a task (usually from the topic USE).
- starting from a practical task drilling the skill to use some application and posing a multiple choice question. Changing the task from the instructional or practical (do this, create this) to situational (a situation is described and a question is added).

The character of Beaver (beaver goes to school, beaver drives a car) is very frequent in the pool of proposals. This personification of beaver brings paradoxical situations. In some tasks e.g. the beaver eats meat or bridges are constructed for this water animal to get from one river bank to another. Tasks introduced through beaver "stories" sometimes do not sound very real, or their solution does not sound practical. Contestants' especially upper secondary school contestants') comments on tasks such as "beaver did, beaver went, …" were full of irony. Older contestants found tasks with people working on computer in place of beavers much more acceptable. However,

some contestants in categories for pupils younger than 13 claimed they liked the beaver and demanded that "more tasks with the beaver" be included. Therefore the authors of proposals should always bear in mind that the effect of motivating contestants by this fairytale character changes with age.

When making proposals, authors also have to face the risks that their tasks may favour pupils who have had the opportunity to memorize the solving procedure. There are some tasks that make use of a typical procedure characteristic for the particular type of task and a mere application of the procedure leads to the correct solution. This discriminates contestants who have not come across this type of task at school and have not had the chance to memorize its solution. For example any square grid path problem can be solved very easily if the contestant is familiar with the basic principle that the number of possible paths to a given junction equals to the sum of possible paths for all neighbouring previous junctions. If the contestant does not know this principle it is very hard to discover it in the 3 minute time limit. Any task based on a typical informatics problem described in literature bears the risk that some of the contestants will be familiar with its solving method.

Somewhat problematic is in our opinion the demand on political correctness of tasks, i.e. the criterion that "Good tasks contain no gender, racial or religion stereotypes." [6]. Not underestimating the import of this proclamation, our experience from totalitarian communist times makes us very cautious when putting this criterion for contest tasks into practice. If e.g. a task in which a boy from Germany gives a piece of ham to a boy from the Czech Republic is rejected because it could offend somebody's religious beliefs, it may be seen as limiting authors' freedom. We could then also ask whether the danger of the impact gender stereotype could have on success rate of girls in solving a task would not result in rejection of a task in which girls string beads.

Responsibility for creation of a set of contest tasks for national rounds is in the hands of national authorities and it should be their role to review the pool of proposals sensitively and make decisions about the tasks' political correctness in the context of their own national culture, and only after if not acceptable in their cultural context reject them or modify them. We think that such reviewing process on international level is dangerous.

8 Quality of Wrong Choices

Quality of the task assignment is one of the criteria of good tasks to which much attention is paid by Dagienė and Futschek: this involves wording of the question, correct answer and its justification. Rules for good assignment include e.g. the rule not to use negation in questions as the contestant often overlook it or have problems with its logic. Our experience of the process of task development from an international workshop and from analysis of a pool of proposals suggests that it is equally as important to pay attention to formulation of the incorrect answers in multiple-choice tasks as their quality may considerably influence task difficulty. The contestant chooses from four choices and if some of these can be eliminated without actually understanding the task, the chance that they will guess the right answer grows.

This can happen if

1. the set of choice answers is badly constructed
2. it pays off to go through all the choice answers and test them in the assignment rather than solve the problem
3. a common mistake missing among offered answers warns the contestant
4. there are weak choices just to make up the needed number of choices

Ad 1. Some sets of choice answers are constructed by deriving wrong variants from the correct answer by minor modifications. The contestant, if experienced in taking tests, sees that one of the offered answers shares characteristics with each of the other variants, realizes it is the source variant and marks it as the correct one without actually understanding the issue.

Let us illustrate the point:

Question: What will be the output of this programme?
(we do not need to show the programme here)

a) Result: c=20
b) Result: c=36
c) Result: c=40
d) Result: c=20+c

Without having to read the task assignment we can infer that the right answer is a). The numerical result of the calculation is the same as in answer d) and we can expect answers b), c) to be consequences of a mistake in the calculation. Answer d) involves a mistake of a different type. Although it is not worthless if the pupil finds the right answer by such logical reasoning, it has nothing to do with his/her knowledge of informatics, only with his/her knowledge of sitting tests.

Ad 2. If the author of a task wants the contestant to solve the task by thinking, the choice answers should be in such a form that it does not pay off to test the choice answers in the assignment. In ideal case reading of the assignment guides the contestant to knowledge that directly points at the right answer whereas testing all variants is very time demanding with a considerable risk of making a mistake.

The following set of choice answers Dice (the assignment is not important) is an example of a set whose author avoided mistakes from 1 and 2:

a) draw_2A, draw_2, turn_90, draw_2
b) draw_2, turn_90, draw_2, draw_2A
c) draw_2A, turn_90, draw_2, draw_1
d) draw_2, draw_2A, turn_90, draw_2

This set of choices does not allow us to guess the correct answer without understanding the assignment and having the required knowledge. And it would be too time demanding to test all the choices in the task assignment.

Ad 3. Especially in case that a task easily leads to various erroneous results (e.g. calculation using an algorithm), it is crucial to ensure that the set of choice answers includes the most likely mistakes. If the contestant makes a mistake and gets a result that is not among the choice answers, he/she is alerted to the fact that his/her solution

is wrong. Thus the contest is less regular as some contestants being wrong get a hint in this form while others do not. Apart from selecting choice answers carefully, authors should also modify the task in such a way that their solvers do not make too many different mistakes leading to too many different results.

Ad 4. If a contestant does not know the correct answer, he/she is likely to be trying to guess it. Then existence of one or more obviously nonsensical answers that can be eliminated at once without any knowledge of the topic considerably increases the contestant's chance to guess the correct answer. E.g. in case of questions requiring a yes/no answer authors should ask about two phenomena simultaneously so that the number of possible answers is extended (e.g. yes,yes/yes,no/no,yes/no,no).

The following is our proposal of a criterion for good multiple-choice task:

- the problem in the task should offer a reasonable number of possible answers (neither too few, neither too many)
- the incorrect answers should represent all the typical mistakes the contestant may make while solving the task
- the correct answer should not stand out (by its length, choice of words etc.)
- every task should have a set of choice answers comparable in quality

9 Conclusion

Criteria for a good task for international informatics competition proved to be very useful as they guide authors of proposals to posing more usable tasks.

- Based on our findings we recommend that task topics be reorganized in such a way that they become more useful in defining the content of national contests and that they are representative of the field of informatics. We recommend that the topic SOC be integrated in the topic USE and the topic ALG be split into additional criteria. We recommend that the topic LOG (MAT) be added.
- The contest becomes more comprehensible if contestants come across tasks that they perceive as work with computer. That is why also tasks from everyday work with computers should be included and the criterion demanding elimination of preknowledge should be reconsidered as it may sometimes be counterproductive when applied in the topic USE. This might be subject to discussion.
- We propose that the criterion of suitable answers in multiple choice tasks be added; attention must be paid to selection of the wrong variants as they affect quality of the whole task.
- Interactivity of tasks makes the contest more attractive if interactivity means manipulation with mouse. On the one hand interactivity makes the contest more appealing, on the other hand it may affect the character and difficulty of the task, which must always be taken into account.
- If tasks stem out from real life situations, it will be appreaciated by older contestants. Younger will enjoy motivation through the fairytale character of Beaver.

In conclusion we would like to stress the most important aspect of the contest: the created solid and growing community of authors and researchers can significantly contribute to future coordinated process of inclusion of informatics content into school curricula in many countries.

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