Gamification and BIM - The Didactic Guidance of Decentralised Interactions of a Real-life BIM Business Game for Higher Education

C. Heins[a]; G. Grunwald[b]; M. Helmus[c]

[a] Institute for Database-oriented Engineering, Jade University of Applied Sciences Oldenburg, Germany
[b] Chair for Design and Construction Management, Jade University of Applied Sciences Oldenburg, Germany
[c] Chair of Construction Management, University of Wuppertal, Germany
E-mail: christian.heins@jade-hs.de; gregor.grunwald@jade-hs.de

Abstract –

The Jade University of Applied Sciences organised the digital business game "PING PONG", a BIM Game, to teach students the networked and digital planning methodology BIM. Building Information Modelling (BIM) should be the planning standard for construction projects and thus a fixed component of university education. For this purpose, an innovative and motivating teaching format was developed with the course PING PONG, which brings about an increase in the quality of teaching and the success of studies. Based on the Erasmus+ project "BIM Game" [1][2], this article describes in detail how a realistic BIM business game can be designed to test the most common BIM key technologies in a scientific environment and to anchor the processes of collaborative working more firmly in the brain. Furthermore, the didactic means and a work portal that were used to evaluate the decentralised project work and to pace the game are presented to shorten the complex, interdisciplinary and time-consuming planning processes through simultaneous project work.

Keywords –

BIM Game; Building Information Modeling; BIM; HOAI; game design elements; business game; integrated planning; decision-oriented planning

1 Introduction

Playful learning is the most intuitive form of learning that people know. Even at a very young age, new skills are learned through play and adaptation [3] [4]. The Building Information Modeling (BIM) Game makes use of this natural play instinct and thus provides a higher motivation to deal with the topic of BIM. This is the initial idea and motivation of the European-funded research project “BIM Game” organized and developed in cooperation with various universities, colleges, training centres, and software companies from five European countries. Results were reported in the ISARC proceedings 2020 [1]. The BIM Game is developing further and is now incorporated into a regular lecturer at the Jade University of applied science, where the authors organized the digital planning game PING PONG. It was a three-day event to teach architecture students about BIM digital design methodology, but also to test new measures and tools to take the BIM game to a higher level.

2 The basic framework

The complex task of construction planning requires methodical knowledge, knowledge of general processes and structures as well as information about framework conditions such as laws, ordinances, guidelines, technical rules and specific information about the task. [5] The complexity of the planning and construction process has increased significantly in recent years, due to structural change in the construction industry and increasing competitive pressure. Factors such as increasing project sizes, more complex building geometry, hardly realisable time schedules and numerous requirements for the energy and resource efficiency of buildings lead to a growing number of actors involved in the project and thus different interests and process requirements. [6] This wide range of services cannot be offered completely by any one company, which is why construction projects are almost exclusively realised in cross-company cooperation. [7]

> *Decentralised planning becomes necessary as soon as a planning organisation divides the responsibility for planning tasks across its corporate hierarchy among several planners.* (cf. [8] [9])

With increasing complexity, topics such as the integration of the actors involved in the project or the creation of a consistent and compatible data environment are becoming increasingly important. Especially in the context of increasingly decentralised project cooperation, the aspect of cross-disciplinary and cross-application interaction and integration is becoming a central factor for the success of project-related cooperation and thus for the success of the project. Against this background, the question of integrated planning and the application of BIM has gained importance in recent years. [6]

Problem-solving in construction planning is predominantly done by methodologies without algorithms. Classical optimisation strategies cannot be applied due to mathematical non-scriptability and a lack of information [10]. In Germany, complexity is classically reduced by dividing construction planning tasks into the various service profiles according to the Fee Regulations for Architects and Engineers (HOAI). [11] The HOAI distinguishes between activities and results (cf. HOAI § 15 Para. 2). Listed are those activities which, in connection as a bundle of activities, produce a result as a prerequisite for decision-making **(decision-oriented planning)**. [5] The decision itself is not part of the service profile of a particular institution, since as a rule the decision-maker and the institutions preparing the decisions are not identical or should not be identical **(independent planning)**, i.e. the contractor will bring the respective result of a service phase into the decision-making process with the client. [5] The designation of the results of the individual service phases is the same for all service profiles of the specialist planners involved in the object planning so that the individual activities of all participants can be integrated into specific phases in each case **(integrated planning)**. [5] The activities described in the HOAI do not change as a result of new methodological approaches such as BIM, as the activity descriptions of the HOAI continue to be existential for construction planning. However, the service phases can mix or overlap or be carried out simultaneously instead of sequentially. The following figure (**Fig. 1**) shows this partially simultaneous arrangement in the familiar bar representation of a network plan.

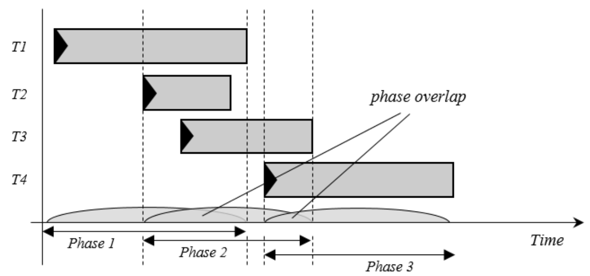

Fig. 1: Semi-simultaneous phase arrangement [7]

Simultaneous processing (*Simultaneous Engineering*) and the diverse networking and feedback of problem-solving cycles lead to a phase overlap in planning. In addition to positive effects on the quality of planning, this also opens up great potential for shortening planning periods. [7] The time-saving potential can be used, for example, to compress interdisciplinary subject areas that are traditionally only dealt with sequentially (one after the other) due to mutual dependencies.

These more complex subject areas, whose problems are to be solved primarily through iterative interactions with various subject experts go beyond the "normal" lecture content in the academic training of architects. However, a digital business game offers ideal conditions to train interdisciplinary and parallel collaboration on the project. For this playful way of learning, in addition to the usual assessment criteria for **results**, further assessment criteria e.g. **ideas**, **activities**, **decisions** and **interactions** need to be created to specifically guide and assess the students in a short time frame **(Fig. 2**).

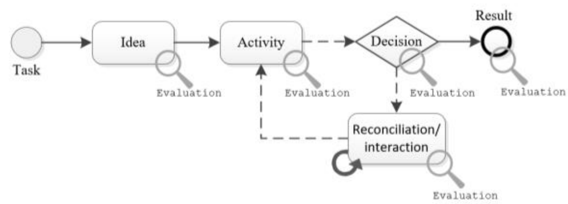

Fig. 2: Required evaluation criteria for digital business games in construction planning

3 PING PONG – a digital business game

The first decentralised and at the same time international business game was held at the Jade University of Applied Sciences over three days: 18 architecture students learned about the design and planning tools of the BIM methodology. Under almost real competition conditions four groups of up to five people planned a campus café for the university with the possibility of playing PING PONG; time limitation: 55 hours. In each group, responsibilities were divided and players took over different roles to learn and understand integrated planning processes. Cooperation within the group was decentralized, all students worked from home, planning took place directly on the 3D model. One of the motivating aspects of the game was the competition character of the event. Each group was in direct competition with the other groups, intermediate results from other groups were published partially to increase the pressure on the participants. The instructors came into play as coaches and trainers, helping the groups to overcome problems and difficulties, motivating and pushing them to new achievements. In the role of the client, the teachers invited the groups to have interim discussions and requested performance levels. Hereby aspects of independent planning could be trained.

The clock was ticking: Results had to be delivered precisely and, above all, on time. This was ensured by a *work portal* that controlled the entire game, structured process steps and requested efficient and decision-oriented planning. Time flew by, the conference rooms were open around the clock for discussions and meetings, and finally, after three exhausting working days full of activities, decisions and interactions exciting designs (like shown in **Fig. 3**) were presented and awarded.

The playful competitive atmosphere motivated all participants. It lowered the fear of using new technology, trained digital communication and provided insights into the benefits and performance of various digital planning tools.

Fig. 3: Final Design presented by: Melissa El Haddad, Anna-Lena Laube, Lisa-Marie Schlott, Christine Büch

3.1 Learning objectives

The primary learning objective of the PING PONG game is to understand and apply the digital planning methodology BIM. In a realistic simulation of a planning competition, this knowledge must be derived and evaluated on the students' design. In direct collaboration with group members and exchange with the client, the students plan and develop their ideas and use the appropriate digital tools.

3.2 Structure and boundary conditions

A total of 18 students from the architecture program took part in the course. Based on a self-assessment to be submitted in advance, they were divided into four teams of approximately equal strength. The boundary conditions were shaped by corona-related limitations: Participants worked from home. Various videoconference rooms were available during the game. In addition to a computer with webcam and microphone, the following software applications were part of the players' basic equipment:

1. Modelling and visualisation software
2. Web-based data management / cloud / CDE
3. Cost estimation software
4. Collision detection software
5. IFC Viewer
6. BCF application

The game was initiated by two introductory meetings that started three weeks before the workshop. This introduction was used to explain the process and organization of the game and to provide an overview of the software applications used in the game. For this purpose, video tutorials on how to use and install them were made available. The project description, competition overview, design manual, and modelling guidelines were also uploaded for review. Three days before the start of the game, the teachers conducted a software check of all players to ensure that all installations were completed successfully and that the technical requirements for participation were met. The total playing time was 55 hours. During this time, virtual meeting rooms within a Zoom conference were available to participants. The final submission of results was scheduled for the third day followed by presentations of the results and an award ceremony. A few days later the event was concluded with a final debriefing session in which the participants reflected on what they had learned.

4 Didactic means

The PING PONG course was characterized by a clear game structure, its rules and a process landscape that automatically demanded results. This gave the event transparency and orientation. The clear time constraints and the compact workshop format helped to create an intensive working atmosphere. At the same time, the event was directly related to practice, because the BIM Game was a true-to-life simulation of a restricted interdisciplinary planning competition, organized according to RPW 2013 [12], to show the students realistic conditions.

This was achieved within the game through a coordinated diversity of methods and tools. Different digital applications had to be used to solve the tasks. Conversations, group work, activating questions as well as client meetings (shown in **Fig. 4**) were different formats in which students had to use their knowledge, repeat and adapt it to the respective situation, thus cognitively consolidating information. In addition, the game structure included the possibility to improve already submitted performances afterwards. This repetition option served to reflect on one's performance and was used by all groups.

The participants received feedback through the regularly held client meetings. Here, the teachers were able to give feedback, check learning objectives, request additional services if necessary and make demands on the planners. Outside of the client meetings, the teachers were "coaches" and looked over the shoulders of the students. In this role, they gave help and tips, motivated and listened. This division led to a clear understanding of the roles in the cooperation with the students to distinguish the different forms of pedagogical support in terms of content and concepts.

The game was didactically condensed in very different ways. Above all, the format of a time-limited compact workshop led to the development of a very intensive working atmosphere. The competitive spirit of the participants was awakened and a team-building effect was created that motivated each individual - including the teachers - and thus produced excellent results.

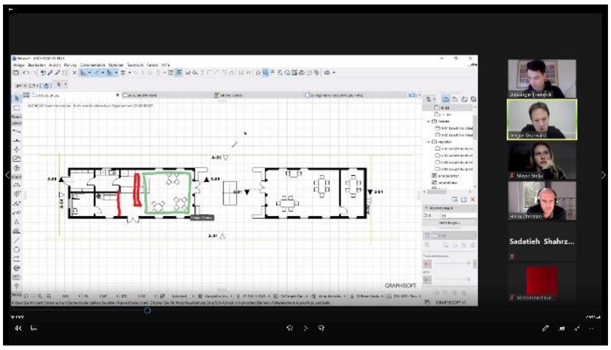

Fig. 4: Corrections to the model in the client meeting via screen sharing of the conference system

4.1 Didactic structure

The PING PONG game was developed through the application of Constructive Alignment. This learning goal-oriented didactics goes back to John Biggs [13]. Biggs suggests aligning learning objectives, assessment form and teaching and learning activities. In this respect, the learning objective was defined first (see 3.1 Learning Objectives).

In the following step, formats had to be found that could make learning progress visible. The idea was to integrate the examination in the form of a project presentation within a competition process. In this way, it was possible to measure the teaching and learning success and thus obtain feedback on the achievement of the objectives. The playfully structured presentation within an architectural competition made the participants forget the exam situation and achieved good results.

In the third step, the teaching and learning activities were placed in the game setting. Instructions for action, modelling guidelines, short tutorials, coaching talks, presentations, but also a mutual helping of the students, i.e. a variety of coordinated methods, were used for this.

The preliminary introduction to the game was an important tool for initiating the game. To reflect on what was learned, a debriefing was held one week after the end of the game, according to Hattie rank 1 for successful learning [14].

4.2 Learning processes

Sustained learning only takes place when several channels are simultaneously absorbed during information intake, if active information intake is repeated at a later time and if students feel exposed to a moderate stress situation in a safe environment.

The work portal described below is based on the following findings:

- Support of verbal and written knowledge exchange with students
- Repetition effect: Voluntary repetition in the active absorption of information
- Establishment of a moderate stress situation in a safe environment

"If you want to explain something to someone else, you have to understand it yourself beforehand, e.g. you have read or heard it. Anyone who tries something out or applies it already associates the entire sequence of events with the actual information, which is why the result is more firmly anchored in the brain than if they had merely observed the same result with someone else." [15]

"The more often managers can practice dealing with stress in a safe environment, the more confidently they will later apply what they have learned in their professional lives." [16]

5 Work portal

The Business Process Management System (BPMS) Bizagi steered the business game phases, from modelling to executing and evaluating processes. Key elements provided within this BPMS are a process engine where the process models are executed and a web-based work portal for user's interaction providing means to manage a worklist, taking and completing tasks, among other functionalities. [17]

5.1 General concept

For the integration of the work portal into the runtime system of a `.NET` framework, the "Bizagi Suite" offers three packages (*Modeler*, *Studio* and *Automation*). The Bizagi-*Modeler* supports the modelling of processes based on “Business Process Modeling Notation 2.0” (BPMN2.0) to visually document, simulate and optimise business processes. Bizagi-*Studio* includes low-code software for automating business processes and Bizagi-*Automation* transfers business logic to a digital (working) platform on which technical and human activities are executed and orchestrated. Furthermore, the Bizagi-*Automation* package implements the business processes on different information technology (IT) systems, such as desktop computers or mobile systems. For a better understanding, the differences between BPM and BPMN2.0 are briefly explained below.

5.1.1 BPM

"Business Process Management (BPM) is a systematic approach to capture, design, execute, document, measure, monitor and control both automated and non-automated processes to sustainably achieve objectives aligned with business strategy. BPM involves the deliberate and increasingly IT-enabled determination, improvement, innovation and maintenance of end-to-end processes." [18] Here, "end-to-end process" always stands for the holistic process view, i.e. from the start to the end of a work sequence. [19]

5.1.2 BPMN2.0

If the overarching view is reduced to pure process modelling, the meaning of the acronym BPM changes to "Business Process Modeling". In addition to process logic, this involves the technically correct representation of "lived" work sequences. "Business Process Model and Notation" (BPMN) is a standard for visually representing process logic. BPMN is used to communicate a variety of information to a variety of audiences. Through multiple diagrams, BPMN covers different types of modelling and thus enables the modelling of end-to-end processes. [20] Originally, BPMN was developed only to be read by humans. With BPMN 2.0, mapping to the execution language WSBPEL (Web Services Business Process Execution Language) was established to make the existing process semantics also machine-readable. [20]. BPMN 2.0 thus offers a standardised process language that can be read and interpreted by humans and machines. [19] (Further information of the BPMN2.0 process semantics see [21] [22].)

5.2 Implementation into the game

Bziagi's process engine ran the BPMN2.0 process model locally. The work portal was accessible via `HTTP` (Hypertext Transfer Protocol) and guided the participants (shown as groups in **Fig. 5**) and the contest organizers (shown as the client in **Fig. 5**) transparently and sequentially through the game, which is structured as follows:

- Phase-0: Project initiation
  (Target working time (twt): 1 hour).
- Phase-1: Concept
  (twt: 5 hours, through simultaneous processing)
- Phase-2: Design
  (twt: 5 hours, through simultaneous processing)
- Phase-3: Evaluation
  (twt: parallel to the further course of the game)
- Phase-4: Feedback
  (twt: 1 hour)
- Phase-5: Presentation
  (twt: max. 5 hours)

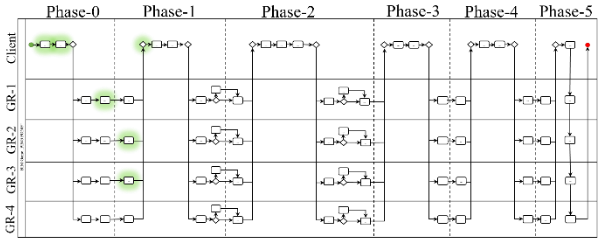

Fig. 5: The technical BPMN2.0 process model on which the work portal is based and the processing progress visible to all groups (green markings)

After completing phases 1 and 2, the results of all groups were displayed in the work portal. The competitors could then decide to either go to a well-deserved end of work, start working directly on the following phase or improve their results (cf. **Fig. 6**). Improving the results inevitably led to an increased workload (outside the target working hours) or reduction of the target working hours of the subsequent phase. All groups chose improvement (a voluntary repetition of previous performance), through an increased workload.

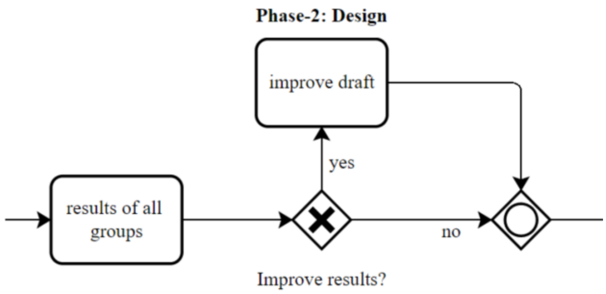

Fig. 6: Extract from the technical process model; competitors' decision to voluntarily improve results

Overall, all groups had to complete the same tasks in the same target work time. Task distribution and result retrieval were done automatically and successively through the work portal. Only those who had uploaded all the required results could close the current activity and start a new one. There was no "back button" so that only the final results to be assessed had to be uploaded. As soon as an activity was completed, the results were saved in the work portal and the competition progress was displayed to all competitors in real-time (cf.

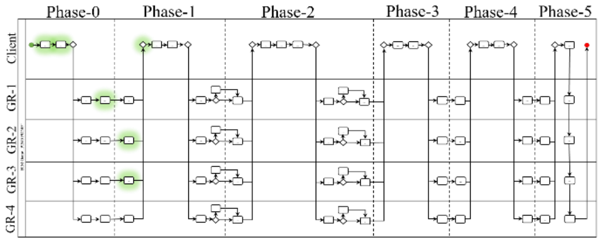

Fig. 5 the green markings).

Thus, participants were guided through the game, driven to precise performance formulation and on-time submission. However, due to a large number of tasks and mandatory deadlines, students were forced to reduce target achievement criteria, either in design quality, detailing of construction, cost calculations, or sustainability information. There was not enough time to meet all criteria. This led to an unusual stress situation for the students and they had to practice dealing with this dilemma by setting priorities and also accepting cutbacks in the project.

5.3 Framework conditions and targets

There were clear targets for the architectural design, called in and checked by the work portal: regarding the costs, an upper limit of a maximum of 500.000 EURO was set, for the planning of the design a deadline of 3 days. In addition to the modelling guidelines, the design manual and the spatial pilot, the quality objectives in terms of functionality, sustainability and design qualities of the building were defined by an exposé distributed at the beginning of the game with the following weighting:

- Functionality (factor 5)
- Design quality (factor 3)
- Economic sustainability
  - Costs according to DIN276 [23] (factor 4)
  - Collision-free planning (factor 1)
- Ecological sustainability
  - Energy efficiency (factor 2)
  - Proportion of renewable raw materials (factor 2)

The BIM process focused on the creation, handling and overlay of IFC (Industry Foundation Classes) models as well as model-based clash detection and documentation via BCF (BIM Collaboration Format). The logic of the functional BIM process is shown in **Fig. 7**. The points in it are briefly explained below:

1. Employer's Information Requirements (EIR)
2. BIM execution planning (BEP)
3. Create IFC models
   3.1. Architecture
   3.2. Structural engineering
4. Overlay IFC models (coordination model)
5. Collision Detection
6. Documentation of collisions via BCF

Iterative planning processes and under consideration of different interests, the design was developed in such a way that as many of the required goals as possible were achieved. Regular discussions with clients were steered by the work portal, enforcing client participation and thus forcing decision-oriented planning. With the quality objectives, the game was given clear evaluation benchmarks that both provided orientation in the decision-making process during the entire game and regulated the comparative evaluation of the results at the end.

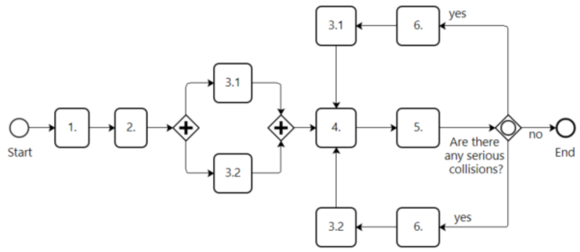

Fig. 7: The functional BIM process logic of the business game

5.4 Evaluation

The assessment of the competition performance was divided into two parts. Firstly by assessing the group results as *soft facts* and secondly by assessing the *hard facts* taking the content of the uploaded files in the work portal into account.

Evaluation criteria for the *soft facts*:

The IFC models were presented as the final group result by the respective competitors. The evaluation was made subjectively by the clients, based on the functional and design quality of the building as follows:

- Functionality:
  Fulfilment of the spatial programme, utilisation concept/utilisation offer, spatial formation, orientability and traffic organisation in the interior, accessibility from the outside, structuring of open space quality.
- Design quality:
  Quality of the urban planning and building design concept, building quality, design of the building structure and the individual areas, quality of the open space.

Evaluation criteria for the *hard facts*:

- BCF files as a result for economic sustainability and as evidence for the model-based interactions as well as the decisions during group processing

- Building costs as a result of economic sustainability and as evidence of cost activities
- A/V-value as a result of the evaluation of energetics and as evidence of Computer-Aided Design (CAD) activities
- Sustainability index as a result for the evaluation of the share of renewable raw materials of the building shell and the proof of CAD activities
- IFC models of the architecture and the structure as a concept idea in phase 1

6 Conclusion

As Building Information Modeling is set to become the design standard for construction projects, academic training must teach digital design methodology. However, it is important not to limit training to the simple application of the individual tools, but to understand that the introduction of the methodology creates new work methods and processes that need to be mapped. The business game PING PONG described aims to test the most common key BIM technologies in a scientific environment so that users can experience the most common digital technologies individually. By solving technical problems independently, the procedures of the model-based coordination process can be anchored more firmly in the brain. This refers especially to the cooperative, interdisciplinary and parallel way of planning, decision-oriented and integrated. These new challenges must be experienced and tried out rather than described in theoretical treatises. Because experience shows that the advantages of BIM can simple be read, but not simply applied. That is why the business game PING PONG is an excellent way to gain initial experience playfully, in protected laboratory conditions. The student evaluation confirms this assumption: 100% of the evaluators think that the practical relevance of the course has become clear, and it is also unanimously certified that the theoretical content was better understood through the exercises. 83.3% think that they have learned something new.

7 Suggestion on further research

With the second business game "JADE WORK", the BIM game was held for the second time and was opened to students of the Department of Civil Engineering and external participants. By including students from other faculties and players from the private sector, the real-life conditions of the game could be intensified. The high level of interdisciplinarity in the groups led to new, detailed impulses through additional expertise, while the external participants in turn benefited from the digital competence of the students. It should be noted that the BIM Game is an experimental field that can be continuously supplemented and enriched with further aspects. Be it through the integration of life cycle assessment (LCA) to take greater account of sustainability aspects in the design, or the remuneration of services through the billing of fees to focus more strongly on aspects of construction management. The chosen innovations are strongly subject to the respective thematic focus of the game and are of course also dependent on the game duration. This business game could, for example, be conducted internationally in one day due to the different time zones. The great success of the business game motivates to develop it further, to continue the event and to make it a permanent part of the teaching. Extending this to a whole semester is also one of the plans of the authors.

Fig. 8: Draft Group 1: Stella Meyer, Gizem Toraman, Sharzad Sadatieh, Frederick Denzinger, Kurda Karim Mohammed

Fig. 9a: Draft Group 4 - Youssef Diyar, Lara Kretschmann, Cosima Plett, Gülhat Kaska; Fig. 9b: Draft Group 2 - Eva Wittich, Navrattan Singh, Tami Hamel, Pauline Buske; Fig. 9c: Draft Group 1 (s.a.)

Further information on the project can be found on https://forschungsnotizen.ihjo.de/bim-im-planspiel-lernen/.

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